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Self-control of learning multiple motor skills

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SELF-CONTROL OF LEARNING MULTIPLE MOTOR SKILLS

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
in
The Department of Kinesiology

by
Wilbur Fong Wah Wu
B.S., University of California Los Angeles, 1999
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In pursuit of the “American Dream” my parents have sacrificed so that I can follow whichever path I choose in life. I am sure there are sacrifices that I do not know about but for the ones I do know about I would like to say thank you from the bottom of my heart. For the sacrifices I don’t know about I only hope that I have implicitly learned what it takes to be the self-sacrificing parents you have been to me; this is just as much your accomplishment as it is mine. I would also like to thank my brother for being a role model and my sister for putting up with a second father figure. I love you all very much.

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ABSTRACT

Learning is commonly referred to as a “two-way street” between the learner and instructor. Until recently, learning has been studied using a “one-way” approach in which numerous studies have explored learning in situations where the experimenter or instructor shapes the practice environment. A number motor learning studies have shown the effectiveness of the learners’ abilities to control various aspects within their learning environment. Studies on augmented feedback (Chiviacowsky & Wulf, 2002; Janelle, Kim, & Singer, 1995), observational learning (Wulf, Raupach, & Pfeiffer, 2005), and physical assistance devices (Wulf & Toole, 1999) have found that learning is enhanced when individuals are able to control the schedule of feedback and the schedule of model observations, and when to use physical assistance devices.

Three experiments explored the generalizability of self-controlled learning on practice schedules when learning multiple tasks. Experiment 1 explored the learning differences between a group that was given the option to choose which task to practice within the practice session and a group that was given a predetermined schedule of practice. The results revealed no significant differences. Experiment 2 further explored the effect of self-control on practice schedules: the purpose was not only to investigate the learning benefits of self-control over a predetermined practice schedule, but also how participants choose within their learning environment. Results revealed that the self-control group outperformed a yoked group on a delayed transfer test. In addition, self-control participants chose to switch tasks after “good trials” and created schedules that gradually increased the amount of contextual interference as practice progressed. Finally, Experiment 3 sought to determine if the learning benefit of self-control was caused by
self-regulatory processes or attributable to choice within the practice environment. This was done by comparing a group that chose their practice schedule before practice began to a self-control group that chose which task to practice during the practice session. The results revealed that the group that chose tasks during practice outperformed the group that chose their practice schedule before the practice began. Experiment 3 demonstrated that self-regulation was the underlying mechanism for the enhanced learning benefits seen in previous studies of self-control.
CHAPTER 1.

GENERAL INTRODUCTION

Skill acquisition researchers have explored learning mainly in situations in which the experimenter or instructor shapes the practice environment. Using this approach, they have investigated how structuring practice properly can enhance the learning of motor skills. For instance, how practice variability, practice distribution, modeling, and augmented feedback affect the learning of a motor skill. A common characteristic arises in these varying learning paradigms: the experimenter not only dictates how a skill should be performed but also controls the order, amount, and distribution of the practice environment.

The learning process is commonly referred to as a “two-way street” between the learner and instructor. While most skill acquisition research has focused primarily on understanding skill learning, with the investigator controlling the entire practice session, an understanding of the learner’s impact on practice has not been addressed to the same degree. According to Solmon (2003), in order to create more effective learning environments, the role of the learner and his or her influence on the process of learning must be considered. This viewpoint has been recognized within the physical education domain and has spurned a change in traditional teaching frameworks, which assume the teacher is the direct cause of learning, to a modified framework that incorporates learners as active participants that control their learning environment (Solmon, 2003). While the role of the student as an active participant within the learning process has been a topic of concern in physical education, skill acquisition research is mostly comprised of experimentally-controlled learning environments that lack the active involvement of the
learner. The result may be a “one-way street” of learning and a “one-way” understanding of how humans acquire motor skills.

Evidence for the benefits of involving students in the structuring of their learning process was first demonstrated in educational research. According to Schunk and Zimmerman (1994), self-regulated learning is “the degree to which learners are metacognitively, motivationally, and behaviorally active” participants in their learning process. In short, this means that allowing students to participate in the design of the learning process and the structuring of the learning environment can motivate learners and induce them to think about their learning strategies. According to Zimmerman (2000), self-regulation occurs in a cyclic pattern consisting of interactions between strategy formation, strategy execution, and strategy analysis (via feedback).

Recently, a number of skill acquisition studies have shown the effectiveness of the learners’ abilities to control various aspects within their learning environment. For example, studies on augmented feedback (Chiviacowsky & Wulf, 2002; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Janelle, Kim, & Singer, 1995), observational learning (Wulf, Raupach, & Pfeiffer, 2005), and physical assistance devices (Wulf & Toole, 1999) have found that learning is enhanced when individuals are able to control the schedule of feedback and the schedule of model observations, and when to use physical assistance devices. Skill acquisition investigators have termed learners’ ability to control aspects of their learning environment “self-controlled learning.” Researchers have suggested that when participants undergo self-controlled learning, the processes that drive the learning benefits are due to self-regulatory processes which constitute a system
of goal pursuit, strategy formation to obtain the goals, and evaluation of those strategies based on feedback.

Thus far, the benefits of self-controlled learning have been demonstrated with augmented feedback, observational learning, and physical assistance device paradigms, all of which required participants to learn only one task. The following three experiments attempted to explore the generalizability of self-controlled learning on practice schedules when individuals learn multiple tasks and therefore improving upon the applicability of previous studies. The purpose of Experiment 1 was to explore the learning differences between a group that was given the option to choose which task to practice within the practice session (self-control) and a group that was given a predetermined schedule of practice. Experiment 2 further explored the effect of self-control on practice schedules: the purpose was not only to investigate the learning benefits of self-control over a predetermined practice schedule, but also how participants choose within their learning environment. Examining how participants choose may shed more light on whether self-regulatory processes are responsible for the learning benefit provided by self-controlled learning. Finally, Experiment 3 sought to determine if the learning benefit of self-control was caused by self-regulatory processes or attributable to choice within the practice environment. According to Schunk and Zimmerman (1998), self-regulatory processes require cyclic interactions between strategy formation, strategy execution, and strategy analysis via feedback. If these cyclic interactions are not present and an equal learning benefit is demonstrated, then self-regulatory processes cannot be responsible for self-controlled learning as many researchers have suggested.
CHAPTER 2.

EXPERIMENT 1: THE EXPLORATION OF A SELF-CONTROLLED PRACTICE SCHEDULE USING A GOLF PUTTING TASK

INTRODUCTION

In previous motor skill learning studies that have investigated self-control, the participants were required to learn one criterion movement pattern; there were no additional variations of the movement pattern. Few studies have involved participants that self-control multiple tasks within a learning environment. One study that investigated the self-control of acquiring multiple skills was by Titzer, Shea, and Romack (1993). They compared a self-control practice condition to random and blocked practice schedules. Participants performed a barrier knockdown task: they knocked down barriers with a ball, learning three prescribed movement patterns. A self-control group generated their own practice schedule. The second group used a random practice schedule (e.g., acb cab cba) and the third group practiced under a blocked schedule (e.g., aaa bbb ccc). Results showed that the blocked and self-control groups exhibited significantly faster reaction times than the random group during practice. On an immediate retention test, the self-control group again demonstrated a significantly faster reaction time than the blocked group and significantly faster movement times than the random and blocked groups. On a retention test 24 hours later, the self-control and random groups made fewer errors than the blocked group. The self-control group later reported that they chose schedules that contained blocked practice, serial schedules (similar to random practice, but the learner knows which skill will be practiced for the upcoming trials), and random schedules. While the study showed that the self-control group performed as well as the blocked group during practice and as well as the random group during retention, the
study was unable to identify whether the learning effect of the self-control group was due
to the learner’s ability to choose tasks within the practice schedule or to the mixed
practice schedules.

Another study that incorporated learning different tasks in a self-control paradigm
was performed by Bund & Wiemeyer (2004). They asked participants to control
parameters of a table tennis forehand stroke. Specifically, participants controlled the
direction and length of the ball trajectory, as delivered by a machine. Results indicated
that the self-control groups performed significantly better on forms scores of the forehand
stroke than yoked groups. While the investigators incorporated the learning of different
tasks, they did not specifically examine whether learners are able to self-control multiple
tasks. Instead, their purpose was to study learners’ preferences and self-efficacy ratings
on preferred (schedule of video instruction) and non-preferred (variability of practice)
practice conditions.

Because the Titzer et al. (1993) study could not clearly attribute an enhanced
learning effect for the self-control group and the Bund and Wiemeyer (2004) study did
not directly investigate learning multiple tasks while allowing learners to self-control, the
present experiment was designed to explore whether learners can self-control their
practice schedule when having to learn multiple tasks. In contrast to the Titzer et al.
(1993) study, this experiment incorporated a yoked condition to determine if self-
controlled schedules are better for learning than a schedule predetermined by the
experimenter. The yoked practice schedules were considered predetermined by the
experimenter because yoke participants were not informed that their schedules were
generated by self-control participants; yoke participants were provided practice schedule
before the practice session and were told by the experimenter to follow the predetermined order of tasks. For this experiment, the movement pattern to be learned was a golf-putting stroke and the parameter modifications were the varying distances to the target. It was hypothesized that the self-control group would perform better than a yoked group in both an immediate and delayed transfer test.

METHOD

Participants

Thirty right-handed male and female undergraduates participated in the experiment for course credit. All subjects were unaware of the purpose of the study and were novice to the skill of golf-putting. All participants provided informed consent.

Apparatus and Task

The apparatus consisted of a putting surface, a standard golf putter, and a standard golf ball. The putting surface was constructed from a rectangular piece of carpet so that the ball would roll at a rate of seven on the Stimpmeter (a common method used in golf to measure the speed of a putting surface by releasing a golf ball from a small inclined ramp onto a flat surface and measuring the distance rolled). The putting surface was marked with white chalk to identify three start locations and one target (Figure 2.1).

Figure 2.1 The putting surface contained a circular target with 6 concentric rings surrounding it. If the ball rested outside the last ring, a score of 7 was given. The putting surface also contained three distances: 3, 4.5, and 6 feet. Distance to the target and target size varied based upon the Index of Difficulty. The ID’s were 6, 9, and 12.
The start locations were 0.914, 1.37, and 1.83 meters from the target, which resulted in a Fitts’ index of difficulty of 6, 9, and 12 respectively (Schmidt & Lee, 1999). Six concentric rings surrounded the circular target to provide measures of error. The circular target had a diameter of 4 regulation size golf balls. Each ring outside the target had a width of 2 regulation size golf balls.

The participants’ task was to putt a golf ball to the circular target from each of three start locations; the goal was to make the golf ball come to rest within the circular target. Participants were scored based on where the golf ball rested on the golf mat. If at least half of the ball rested within the target, participants received zero points, a perfect score. Each ring outside the circle added one point to their score. The first ring outside the circle was scored as one point and the last ring was scored as six points; any putt that landed outside the last ring received seven points. Putts that landed on top of a line were assigned the lower score. For example, if the ball rested on the line bordering the five and six point area, the participant would receive five points. Scores were determined by the participants to prevent experimenter bias.

**Design and Procedure**

Upon arrival to the testing facility, participants completed a consent form. Participants were then randomly assigned to two groups: the self-control group and the yoked group. General directions of the experiment were read to the subjects. Directions on putting form instructed participants to hold the club in the fingers, with the right hand below the left, and to place the ball in the center of the stance. Before the practice session, participants were given a 6-trial serial pretest in which they putted from each start point twice. The 6-trial pretest ensured that both groups started the practice session
with performance scores that were not statistically different from one another. In
addition, the pretest was included so that it could be compared to the 5-minute serial
transfer test to evaluate whether participants in both groups improved their performance
from the beginning to the end of practice. Participants in the self-control group were
given the option to choose the order in which they practiced each distance. Specifically,
they were allowed to select the putting location before each trial was executed.
Participants in the yoked group had identical practice schedules to the self-control group;
the only difference was that the self-control group chose the putting location before each
trial while the yoked group did not. In effect, the yoked group’s schedules were
predetermined by the participants of the self-control group. Both groups were told they
would be tested on the three putting locations they practiced. Participants performed one
day of acquisition, consisting of 90 trials. To assess learning, two 12–trial serial transfer
tests were administered 5 minutes and 24 hours after the practice session.

RESULTS

The dependent variable of interest was the score received for each putt. The score
was based on the six concentric rings that surrounded the target. The scores from the
pretest, 5-minute, and 24-hour serial transfer tests were summed for the analysis because
the target scores were considered to be ordinal data. The pretest was analyzed for both
groups using a one-way analysis of variance (ANOVA) to ensure that both groups were
not statistically different from one another in putting performance. In order to evaluate
improvement in performance from the beginning of practice to the end of practice, a one-
way ANOVA was performed for the pretest and the first six trials of the 5-minute serial
transfer test. Analysis of improvement was conducted in this manner because the number
of trials practiced for each putting location varied from one self-control participant to another. This was due to each self-control participant choosing practice schedules that did not contain the same number of practice trials for each putting location. The 5-minute and 24-hour serial transfer tests were included to see if performance was stable over time. A 2 x 2 ANOVA (group x test) with repeated measures on test was used to compare both groups’ performance during the 5-minute and 24-hour serial transfer tests to evaluate the stability of performance over time.

**Pretest**

Analysis of the pretest revealed that both the self-control (M = 22.2, SD = 5.31) and yoked (M = 24.2, SD = 6.37) groups had average sum scores that were not significantly different from the other (Figure 2.2). Specifically, a one-way ANOVA of the pretest did not reveal a significant main effect for group F (1, 29) = 0.725, p > .05.

![Figure 2.2](image)

*Figure 2.2* The graph of the pretest revealed that there was no significant difference between both groups. Comparison of the pretest and 5-minute serial transfer test revealed a significant difference on test between both groups.
Practice

Both groups reduced their sum scores in putting performance due to practice. A significant difference was found between the pretest and 5-minute transfer, $(1, 29) = 25.89, p < .05$ (Figure 2.2).

Figure 2.3 shows that the self-control group chose to spend more trials on the two distances that were the most difficult according to Fitts’ Index of Difficulty. Participants chose to practice the shorter or easiest distance least frequently, 27% of the total trials, and the farthest distances most frequently. Specifically, they chose to allocate the majority of practice trials to the middle distance, 38%, and the farthest distance slightly less, 35% of the total trials.

![Figure 2.3](image)

**Figure 2.3** The graph depicts the distribution of start points selected by the self-control group.

Transfer

5-Minute Serial Transfer

The self-control ($M = 26.8$, $SD = 10.1$) and yoked ($M = 28.8$, $SD = 7.7$) groups had similar putting performance for the 5-minute serial transfer test (Figure 2.4).
Moreover, the analysis of the sum scores did not reveal a significant difference between both groups in putting performances, $F(1, 28) = 1.02, p > .05$. In addition, no interaction was found for group and test.

![Graph showing average sum score of 12 trials for 5-minute and 24-hour serial transfer]

**Figure 2.4** The graphs of the 5-minute and 24-hour serial transfer reveal no significant difference between the two groups.

### 24-Hour Serial Transfer

The self-control ($M = 28.7$, $SD = 6.7$) and yoked ($M = 31.3$, $SD = 8.5$) groups did not differ in their putting performance for the 24-hour serial transfer test (Figure 2.4).

Moreover, the analysis revealed that the self-control participants did not have significantly lower sum scores than the yoked participants, $F(1, 28) = 1.02, p > .05$. The group x test interaction was not significant.

### DISCUSSION

Past studies (Wrisberg & Pein, 2002; Wulf & Toole, 1999; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Janelle, Kim, & Singer, 1995) have indicated that when individuals are given control over an aspect of their learning process, it can be
beneficial for learning. While those studies illustrated the benefit of self-control, they only required participants to learn one criterion movement. The purpose of this experiment was to investigate whether or not learners can enhance their learning when given the ability to choose, among multiple tasks, which task to practice before the trial was actually executed. It was hypothesized that the self-control group would perform better on an immediate and delayed transfer test because they would be able to distribute their practice schedule based on their individual perception of the demands or difficulty of the tasks.

Analysis of the transfer test results showed no significant differences between the self-control and yoked conditions. A possible cause for the lack of statistical difference between the self-control and yoked conditions may have been the way the putts were scored (concentric rings with a specified area were used to measure error). There may have been too few rings drawn around the target and the area between each ring may have been too large, in effect masking larger differences that may have occurred.

With respect to how participants in the self-control condition chose which task to practice, participants chose to practice the shortest or easiest distance, according to Fitts’ Index of Difficulty, least frequently. The self-control participants chose to practice the two farther distances most frequently. It was predicted that learners would practice the farthest distance most frequently because it would have been the most difficult of the three tasks. The results revealed that the middle distance was practiced the most and the shortest, or easiest, distance was practiced the least. While these results do not perfectly match the prediction, it does show that the learners distributed the tasks within the practice schedule according to the difficulty of the task. Specifically, they chose to
practice the shortest distance the least and spend more of their practice time on the tasks they considered more difficult.

The process of self-regulation refers to the pursuit of goals through strategy formation, execution of strategies, and evaluation of those strategies. From this study, there seems to be some evidence that the learners are creating a strategy associated with the relative difficulty of the task, thus influencing the overall practice schedule. Specifically, self-control participants either directly or indirectly adjusted their practice schedules based on task difficulty. Participants may have directly chosen to practice the easier task the least, assuming that the more difficult tasks would take more time to learn; thus, they adjusted their practice schedules to allocate more trials to the more difficult tasks. Since the shortest distance yields the easiest task, participants adjusted their schedules to allot more time on the tasks that were more difficult and would take longer to learn.

Participants may have indirectly adjusted their practice schedules due to their personal assessment of their performance. Specifically, participants may have not scheduled their practice solely on the basis of task difficulty but on their performance of each task. The shortest distance may have been chosen for practice the least because it took less time to learn than the other tasks. As self-control participants progressed through the practice session, they may have been adjusting their practice schedule according to successful trials. Once they felt they had mastered one level of difficulty, they began to practice the next difficult task.

Self-control of multiple tasks during practice warrants further investigation. While Experiment 1 did not find a generalizable effect of self-control on practice
schedules, the self-control group demonstrated performance scores in the predicted direction of the hypothesis: self-controlled learners seem to receive learning benefits due to their ability to choose or construct their practice schedules. Future studies should include error measures that are more sensitive than the concentric rings used in the present study. In addition, if self-control is found to be generalizable to practice schedules, future studies should involve further analysis of the practice phase. Specifically, the process of self-regulation should be more closely examined by asking participants why they change tasks in order to understand the underlying reasons for how they choose to schedule their practice trials. Investigation into how participants choose may reveal whether or not learners execute the self-regulatory processes of forming strategies, evaluating strategies, and selecting the appropriate strategies to attain the specified goals.
CHAPTER 3.

EXPERIMENT 2: SELF-CONTROLLED PRACTICE SCHEDULES FOR LEARNING MULTIPLE MOVEMENT PATTERNS

INTRODUCTION

The incorporation of self-regulatory processes within motor skill learning research, known as self-controlled learning, has provided evidence to open a new avenue of research within the field. For some time, within motor learning research, investigators have been the sole architects of the practice environment. Specifically, investigators have manipulated various practice variables within the learning environment to see how they affect the learning process. Such an approach has produced a “one way” understanding of how humans learn motor skills. In an initial attempt to study self-control in motor learning, Janelle, Kim, and Singer (1995) allowed learners to control the amount of augmented feedback received during practice as they learned a ball-throwing task. Researchers found that learners who requested feedback when they wanted learned the throwing task better than participants who were given a predetermined schedule of feedback. Since their initial study, additional studies have found an enhanced learning effect when learners are given the opportunity to choose within their practice environment. These studies have covered a broad range of motor learning paradigms that include observational learning (Wrisberg & Pein, 2002; Wulf, Raupach, & Pfeiffer, 2003), augmented feedback (Chiviacowsky & Wulf, 2005; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Janelle, Kim, & Singer, 1995), use of physical assistance devices (Wulf & Toole, 1999), dyad practice (Wulf, Claus, Shea, & Whitacre; 2001), and practice schedules (Bund & Wiemer, 2004; Titzer, Shea, & Romack, 1993).
Despite the increasing number of self-control studies, few have addressed the effect of self-control on practice schedules when learners are required to learn multiple tasks. The initial attempt was made by Titzer, Shea, and Romack (1993). Using a barrier knockdown task, they showed that the self-control condition was at least as effective as a random practice condition. What the investigators failed to include in the study was a yoked condition in which an additional group of participants would have the same practice schedule as the self-control condition but no choice within their practice session. More recently, Bund and Wiemeyer (2004) asked participants to control the length and direction of table tennis balls using a forehand stroke. The self-control groups performed significantly better on form scores than the yoked groups, but there was no statistical difference between the groups with respect to accuracy scores. While the researchers allowed participants to control the amount of variability during practice, the study did not investigate how participants chose tasks during their practice session. That is, did self-control participants choose practice schedules that contained a small or large amount of repetition? Moreover, when participants chose to switch task, did they decide to switch on the basis of performance scores?

Experiment 1 of this proposal provided an exploratory investigation into the effects of self-control on practice schedules when individuals learn multiple tasks. While the results did not statistically support the benefits of self-controlled learning, they corresponded with the direction of the proposed hypothesis. Experiment 2 aimed to further explore the generalizability of self-controlled practice schedules when individuals learn multiple tasks. To accomplish this, participants were asked to learn a three keystroke pattern. In order to create three different experimental tasks, the relative
timing structure for the keystroke pattern was altered. A three key-stroke pattern was employed to decrease the amount of movement instruction given to participants. In order to provide a more sensitive error measure than the six concentric rings used in experiment 1, relative timing error (RTE), absolute error (AE), total variability (E), absolute constant error (|CE|), and variable error (VE) were measured.

In addition to exploring the generalizability of self-control, experiment 2 examined how participants chose tasks during practice. Investigation into how self-control participants choose may shed light on self-regulatory processes that some suggest occur within the practice phase. For this experiment, it was hypothesized that participants in the self-control group would perform better on both an immediate and delayed transfer test.

METHOD

Participants

Thirty right-handed male and female undergraduate students participated in the experiment. All participants provided informed consent. In addition, all participants had no prior experience with the experimental task nor were they aware the specific goals of the study.

Materials

A computer, computer keyboard, and color monitor were used for the study. The computer was situated on a table, and participants sat comfortably in a chair with the experimental equipment in front of them. The computer utilized a Microsoft XP operating system to execute a Lab View program that was created specifically for this
experiment. Participants used the number key pad of a computer key board to perform each task.

After the practice phase was completed, all participants were asked to complete a questionnaire (see Appendix 4). A summary of the results is provided in Table 3.1. The questionnaire asked participants how they chose to practice and whether or not they employed as many movement or mental strategies they wanted. The questionnaire was adapted from Chviakowsky and Wulf (2002).

**Table 3.1 Summary of Responses from Post Practice Questionnaire**

<table>
<thead>
<tr>
<th>Employed as many movement strategies as they wanted.</th>
<th>Self-Control</th>
<th>Yoke Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes:</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>No:</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>When you decided to practice a different task</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>after good trials:</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>after bad trials:</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>randomly:</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Other:</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Told to change task when not ready.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes:</td>
<td>n/a</td>
<td>11</td>
</tr>
<tr>
<td>No:</td>
<td>n/a</td>
<td>2</td>
</tr>
</tbody>
</table>

**Task**

The task for this experiment was to sequentially depress a three-key sequence of numbers 2, 4, and 6, according to three relative time sequences. All participants used the index finger of their right hand only. The goal was to learn to depress the number sequence according to the three relative time structures and be as accurate as possible in duplicating each relative time structure. The relative movement times were 900 and 700
ms (56% and 44% of the total movement time), 500 and 1100 ms (31% and 69% of the total movement time), and 1400 and 200 ms (88% and 12% of total movement time).

The relative movement times were chosen so that the proportions of the total movement time were dissimilar from one another. The total movement time of 1600 ms was selected because Chiviakowsky and Wulf (2002) and Simon and Bjork (2001) used similar total movement times in which they employed key stroke tasks. Participants were asked to produce the time sequences during the pretest, practice phase, 5-minute serial transfer, and 24-hour serial transfer tests.

**Design and Procedure**

Participants were assigned to two conditions, self-control and yoked, in the following manner: the first participant that arrived was assigned to the self-control group, and the second participant was assigned to the yoked group. This process of assignment repeated until 15 participants were included in each group. Participants in the yoked group had identical practice schedules to the self-control group; the only difference was that the self-control group chose each task before every trial while the yoked group did not. The yoked practice schedules were considered predetermined by the experimenter because yoke participants were not informed that their schedules were generated by self-control participants; yoke participants were provided practice schedule before the practice session and were told by the experimenter to follow the predetermined order of the schedule. Experiment instructions were read to the participants and a demonstration was given by an experimenter to illustrate the experimental task. Participants in the self-control condition were shown the three time sequences, along with the number sequence, on an instruction sheet and were informed that during the acquisition phase they could
“choose whichever relative time sequence” they wanted before each trial was performed. Both groups were told “they would be tested on all three relative time sequences.” The only difference between the practice schedules of the self-control and yoked groups was that the self-control group was allowed to choose before each trial whereas the yoked group received a predetermined practice schedule. Participants were shown their relative time performance after every trial.

All participants performed a 6-trial serial pretest, 90 trial acquisition phase, 5-minute serial transfer test, and 24-hour serial transfer test. The 6-trial pretest was performed to ensure that both groups were not statistically different from one another in keystroke performance at the beginning of practice session. In addition, the pretest was included so that it could be compared to the 5-minute serial transfer test to evaluate whether participants in both groups improved their performance from the beginning to the end of practice. Analysis of improvement was conducted in this manner because the number of trials practiced for each task varied from one self-control participant to another. This was due to each self-control participant choosing practice schedules that did not contain the same number of practice trials for each task. The 5-minute and 24-hour serial transfer tests were included to see if performance was stable over time.

Data Analysis

The dependent variables of interest were relative timing error (RTE), absolute error (AE), total variability (E), absolute constant error (|CE|), and variable error (VE). RTE was a variable of interest because it provided an accuracy measure of the relative timing performance. In other words, RTE measured the absolute difference between the proportions of the response segments performed by each participant and the goal...
proportions for each segment. Overall measures of performance accuracy were
determined using measures of AE and E. Total variability, or E, is similar to AE in that
they both measure overall performance accuracy, but E accounts for both response bias
and response variability with respect to the overall movement time. AE measures the
average absolute deviation between a participant’s response and the goal movement time.
Unlike RTE, AE and E measure the difference between time required to complete the
total response and the total goal movement time. Response bias was measured using
|CE|. |CE| was a dependent variable of interest because it measures the average error in
performance or the bias in performance with respect to the target. Moreover, |CE| was
used because it accounts for the canceling effect of positive and negative values that may
hide the true magnitude of bias. For response variability, VE was used to measure the
inconsistency of responses or variability of the participants’ performances about the mean
value.

The relative timing error (RTE), which provides a measure of relative timing
accuracy, was calculated by summing the absolute value of the proportion of the segment
achieved by the participant subtracted by the goal proportion time. This was done for
each movement segment where:

Total MT = Total Movement Time

MT1 = Movement Time 1

MT2 = Movement Time 2

and

RTE (for task 1) = | (MT1/Total MT) *100) – 56 | + | (MT2/Total MT*100) – 44 |

RTE (for task 2) = | (MT1/Total MT) *100) – 31| + | (MT2/Total MT*100) – 69|
RTE (for task 3) = \left| \left( \frac{MT1}{Total\ MT} \right) \times 100 \right| - 88 + \left| \left( \frac{MT2}{Total\ MT} \right) \times 100 \right| - 12

The absolute error (AE) was calculated by the following method:

\[ AE = |MT1 - GT1| + |MT2 - GT2| \]

where MT1 = Movement time 1
MT2 = Movement time 2
GT1 = Goal Movement Time 1
GT2 = Goal Movement Time 2

The total variability, another measure of overall success, was determined as follows:

\[ E = CE^2 + VE^2 \]

The constant error (CE) was calculated by taking the average signed errors over two trials and variable error (VE) was calculated by taking the standard deviation of the CE measure. Absolute constant error was calculated by taking the absolute value of the CE measure.

At the end of practice, a questionnaire was provided (see Table 2.1) to assess when self-control participants chose to switch tasks and begin practicing another task. The questionnaire was provided to evaluate the characteristics that are associated with switching tasks during practice. Specifically, did self-control participants choose to switch tasks after good trials as demonstrated by Chiviacowsky and Wulf (2002)? A one-way ANOVA was performed to determine if the self-control group switched tasks after successful trials compared to the yoked group. Absolute error scores were taken from the trial that preceded a task switch.
RESULTS

Task

A 2 x 3 x 3 ANOVA (group x task x test) with repeated measures on the last factor of the RTE scores did not reveal a significant main effect for task $F(2, 234) = 0.15, p > .05$. In addition, there was no interaction of condition x task x test, $F(2, 234) = 0.367, p > .05$. This indicates that participants in both groups did not differ in their performance between tasks despite the condition they were assigned or test they performed. In this case, analyses of the dependent variables combined the three tasks within the analyses.

Pretest

The pretest was analyzed for both groups using a one-way analysis of variance (ANOVA) to ensure that both groups were not statistically different from one another in key-stroke performance. In order to evaluate improvement in performance from the beginning of practice to the end of practice, a 2 x 2 ANOVA (group x test) with repeated measures on test was performed for the pretest and 5-minute transfer test.

Relative Timing Error

Analysis of the RTE scores revealed no significant difference between the self-control ($M = 53.1, SD = 77.2$) and yoked ($M = 62.4, SD = 113.6$) groups, $F(1, 29) = 0.42, p > .05$. Moreover, both groups did not significantly differ on performance with respect to the goal proportion for each segment of the key pattern sequence.
Figure 3.1 A graph of the mean RTE scores for the serial pretest, 5-minute, and 24-hour serial transfer test shows that the self-control group learned the relative timing sequence better than the yoked group as demonstrated on the 5-minute and 24-hour serial transfer tests.

**Absolute Error**

The pretest scores using the absolute error measure, or measure of overall accuracy, revealed that both the self-control (M = 848.4, SD =123) and yoked (M =884.9, SD = 127.3) groups exhibited AE scores that were not significantly different from one another, F (1, 29) = .043, p > .05 (Figure 3.2).

**Total Variability**

Both the self-control (M = 793.4, SD =215.7) and yoked (M = 924.6, SD =215.7) groups had E scores that revealed no significant difference, F (1, 29) = 0.19, p > .05. This indicated that both groups were not significantly different from one another during the pretest with respect to the cumulative amounts of bias from the target and response variability (Figure 3.3).
Figure 3.2 The mean AE score for the serial pretest, 5-minute, and 24-hour serial transfer test for the self-control and self-control-before groups.

Figure 3.3 The mean E score for the serial pretest, 5-minute, and 24-hour serial transfer test for the self-control and self-control-before groups.

**Absolute Constant Error**

The measures of absolute constant error, or bias from the goal proportions, indicated that the self-control (M = 711.7, SD = 192) group did not significantly differ from the yoke (M = 626, SD = 192) group, F (1, 29) = 0.10, p > .05 (Figure 3.4).
Figure 3.4 The mean |CE| score for the serial pretest, 5-minute, and 24-hour serial transfer test for the self-control and self-control-before groups.

Variable Error

VE scores revealed no significant difference between both the self-control group (M = 373.5, SD =108) and the yoked (M = 497, SD =108) group, F (1, 29) = 0.65, p >.05. Both groups were not significantly different in their response variability during the pretest (Figure 3.5).

Practice

In order to evaluate the participants’ improvement in performance due to practice the pretest and the 5-minute transfer test were compared using a 2 x 2 ANOVA (group x test) for both groups. A significant improvement in performance when comparing the pretest to the 5-minute transfer test would indicate that the participants improved their key-stroke performance due to practice. A separate analysis was done for each of error measures.
Figure 3.5 A graph of the mean VE scores for the serial pretest, 5-minute, and 24-hour serial transfer test reveal no differences between the groups.

Relative Timing Error

Both groups reduced their relative timing errors when the pretest and the 5-minute serial transfer test were compared (see Figure 3.1). The analysis indicated a significant main effect for test, $F(1, 28) =12.2, p < 0.05$. There was no significant main effect for group, $F(1, 28) = 3.8, p = 0.05$, nor was there a significant interaction, $F(1, 28) = 0.576, p > 0.05$. This indicated that both groups significantly improved their relative timing accuracy due to the practice session.

Absolute Error

With respect to overall accuracy as determined by absolute error, both groups significantly reduced their absolute error between the pretest and both transfer tests (see Figure 3.2). Analysis of the AE measures revealed a significant main effect for both test factor, $F(1, 28) = 7.69, p < 0.05$, and the group factor, $F(1, 28) = 5.71, p < 0.05$. There was no significant interaction observed, $F(1, 28) = 1.58, p > 0.05$. This indicated that
both groups significantly reduced their overall error due to the practice session and the self-control group exhibited less error on the 5-minute transfer than the yoke group.

**Total Variability**

The self-control and yoked groups were not able to reduce the amount of total variability from the beginning of practice to 24 hours after the practice session ended (see Figure 3.3). Specifically, analysis of the total variability scores did not reveal a significant main effect for test, $F(1, 28) = 0.211, p > 0.05$, or a significant main effect for group, $F(1, 28) = 0.142, p > 0.05$. In addition, there was not significant interaction, $F(1, 28) = 0.359, p > 0.05$.

**Absolute Constant Error**

The absolute constant error measures indicated that participants from both the self-control and yoked groups reduced the amount of response bias with respect to the goal movement times (see Figure 3.4). Analysis of $|CE|$ did not reveal a significant main effect for test, $F(1, 28) = 0.987, p > 0.05$. The analysis also did not indicate a significant main effect for group, $F(1, 28) = 2.00, p > 0.05$, nor was their an interaction, $F(1, 28) = 1.16, p > 0.05$.

**Variable Error**

In addition to response bias, the self-control and yoked groups also decreased the amount of response variability from the beginning of practice to 24 hours after practice (see Figure 3.5). Analysis of VE revealed a significant main effect for test, $F(1, 28) = 8.43, p < 0.05$. The analysis did not reveal a significant main effect for group, $F(1, 28) = 1.23, p > 0.05$, or a significant interaction, $F(1, 28) = 0.765, p > 0.05$. 
Task Switching Characteristics

A simple linear regression was performed on the self-control condition using the 24-hour serial transfer performance as the dependent variable and the number of times participants chose to switch from practicing one task to practicing another task as the independent variable. This was done for two purposes. The first was to explore the types of practice schedules the self-control participants chose for their practice session. A practice schedule with many task switches would indicate that self-control participants chose a schedule that resembled a random or serial style of practice, whereas a practice schedule with few switches would indicate that self-control participants chose a schedule that resembled a blocked style of practice. The second purpose was to investigate the relationship between the number of task switches and performance on the 24-hour serial transfer test. That is, does the practice schedule influence the 24-hour transfer performance (a test that measures the stability of performance after a period of time)?

Table 3.2 shows the number of times each self-control participant chose to switch tasks during the practice session and the corresponding AE score attained for the 24-hour transfer test. AE scores were used for this analysis because they may best represent the information self-control participants used as the basis for switching tasks. Specifically, participants compared their keystroke performance for each segment to the difference of the goal times required for each segment. In effect, they based their performance on an absolute error measure.
Table 3.2 The Number of Task Switches by Self-Control Participants during Practice and the Corresponding Mean AE Score for the 24-Hour Transfer Test

<table>
<thead>
<tr>
<th>Participant #</th>
<th>Number of switches</th>
<th>Mean AE score for 24-hour transfer test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>679</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>343</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>270</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>548</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>623</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>338</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>378</td>
</tr>
<tr>
<td>8</td>
<td>17</td>
<td>396</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
<td>159</td>
</tr>
<tr>
<td>10</td>
<td>38</td>
<td>201</td>
</tr>
<tr>
<td>11</td>
<td>41</td>
<td>292</td>
</tr>
<tr>
<td>12</td>
<td>42</td>
<td>307</td>
</tr>
<tr>
<td>13</td>
<td>71</td>
<td>440</td>
</tr>
<tr>
<td>14</td>
<td>75</td>
<td>185</td>
</tr>
<tr>
<td>15</td>
<td>75</td>
<td>150</td>
</tr>
</tbody>
</table>

When viewing the number of task switches made during the practice session for each self-control participant, the results indicate that the number of task switches made during practice varied with each participant. Some self-control participants decided to repeat practicing a task many times before switching to a new task. In contrast, other participants decided to switch tasks relatively frequently during practice. The data revealed that with the exception of three participants, AE scores were similar across the number of task switches. A simple linear regression analysis with number of switches as the main factor and AE score for the 24-hour transfer test as the dependent variable for the self-control group revealed a linear relationship between the number of switches and the AE score received during the 24-hour transfer test, \( y = -2.898 \times \text{(number of switches)} + 436.377, p = .05 \) (see Figure 3.6).
Figure 3.6 The figure shows the key-stroke performance during the 24-hour transfer phase for the self-control group. It indicates that other than three participants of the self-control group, the number of switches made during practice did not affect key-stroke performance during the 24-hour serial transfer test.

In order to identify whether self-control participants did in fact switch after good trials, the means of both the yoked and self-control groups were obtained for the keystroke performance of the trial that preceded a task switch. The mean for the self-control participants revealed that they chose to switch tasks after relatively good trials. Specifically, they chose to switch tasks when the preceding trial, before a switch, had an average AE score of 381. This is a relatively good score, compared to their pretest scores (AE = 847) and their 24-hour transfer test scores (AE = 354). The yoked group switched tasks, predetermined by the schedule, when the preceding trial had a greater average AE
score (AE = 589). Analysis revealed a significant difference between both groups F (1, 28) = 48.2, p < .05.

The manner in which self-control participants chose tasks within the practice session favored a type of blocked practice rather than a random style of practice. Specifically, two participants chose a strictly blocked style of practice while no participants chose a strictly random or serial style of practice. Most participants chose mixed styles of practice that incorporated blocked, random, and serial practice. Moreover, most of the self-control participants chose a practice schedule that began with a blocked style of practice. After an initial period of practicing in a block manner, or mini blocks, participants then adapted their practice schedule to a style that had a greater amount of contextual interference (see Figure 3.7). Specifically, participants would reduce the amount of repetitions of a task, creating smaller mini blocks, or change their practice schedule to a random or serial practice style.

Transfer

In order to assess the adaptability and stability of what was learned during practice the 5-minute and 24-hour transfer was analyzed using a 2 x 2 ANOVA (group x test) with repeated measures. A separate 2 x 2 ANOVA was performed for each error measure.

Relative Timing

The self-control group had significantly lower relative timing error than the yoked group (see Figure 3.1). The analysis revealed a significant main effect for group, F (1, 28) = 6.63, p < .05. The main effect for test was not significant, F (1, 28) = 0.027, p >
.05, but there was a significant interaction found for group and test, $F (1, 28) = 6.42, p < .05$.

![Figure 3.7](image)

**Figure 3.7** The figure depicts how the self-control participants chose to practice the three tasks. The three colors of red, green, and yellow represent the three key stroke tasks participants were asked to learn. The practice schedules represent the manner in which self-control subjects increased the amount of contextual interference as the practice session progressed from beginning to end. The smallest colored squares represent one trial.

**Absolute Error**

The self-control had significantly lower absolute error scores than the yoked group (see Figure 3.2). The analysis revealed a significant main effect for group, $F (1, 28) = 10.4, p < .05$, and a significant main effect for test, $F (1, 28) = 56.4, p < .05$. There was no significant group x test interaction observed, $F (1, 28) = 6.63, p > .05$. 

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Total Variability

With respect to total variability, both groups did not differ significantly from one another (see Figure 3.3). There was no significant main effect for group, \( F(1, 28) = 3.2, p > .05 \), nor was there a significant main effect for test, \( F(1, 28) = 0.007, p > .05 \). However, there was a significant interaction observed, \( F(1, 28) = 11.8, p < .05 \). Simple effects tests revealed that the self-control group had less total variability than the yoked group on the 5-minute transfer test, \( F(1, 28) = 4.55, p < .05 \), but there was no statistical difference between the two groups on the 24-hour transfer test, \( F(1, 28) = 1.83, p > .05 \).

Absolute Constant Error

The analysis of response bias with respect to the target, \(|CE|\), did not reveal any differences between the two groups (see Figure 3.4). There was a significant main effect for group, \( F(1, 28) = 3.00, p > 0.05 \). The main effect for test was not significant, \( F(1, 28) = 0.036, p > 0.05 \), but there was a significant group x test interaction, \( F(1, 28) = 11.5, p > 0.05 \). Simple effects tests revealed that the self-control group exhibited less absolute constant error than the yoked group on the 5-minute transfer test, \( F(1, 28) = 4.37, p < .05 \), but there was no statistical difference between the two groups on the 24-hour transfer test, \( F(1, 28) = 1.57, p > .05 \).

Variable Error

Analysis of response variability did not reveal a main effect for group, \( F(1, 28) = 1.14, p > 0.05 \), nor was there a main effect for test, \( F(1, 28) = 3.02, p > 0.05 \). In addition, there was no interaction found for group x test, \( F(1, 28) = 0.65, p > 0.05 \). The analysis indicated that both groups were not significantly different in the variability of keystroke performance (see Figure 3.5).
Questionnaire

Table 3.1 reconstructs the questionnaire and the corresponding results. Upon completion of the practice phase, a majority of the participants from both the self-control and yoked groups reported that they had ample opportunity to explore movement and mental strategies, 93% and 73% respectively. One participant in the self-control group did not answer the questionnaire while two participants in the yoked group chose not to answer the questionnaire. The yoked group reported that their predetermined schedule instructed them to practice another task when they did not want to switch tasks. When participants from both groups were asked when they would have liked to switch tasks they reported that they would have switched to a new task after “good trials.”

DISCUSSION

In Experiment 1, significant learning differences were not found between the self-control and yoked groups as assessed by 5-minute and 24-hour serial transfer tests. While there were no significant differences found for Experiment 1, the results were in the direction of the hypothesis, which stated that learners who choose which task to perform during practice would outperform a yoked group with a predetermined practice schedule on an immediate and delayed transfer test. The purpose of Experiment 2 was to further explore the generalizability of self-controlled practice schedules when individuals learn multiple tasks. If the benefit of self-control generalized to practice schedules, an additional purpose was to determine the characteristics of self-selected practice schedules. In Experiment 2, it was hypothesized that participants in the self-control group would perform better on both an immediate and delayed transfer test. The results confirmed the hypothesis. Specifically, the self-control group outperformed a yoked
group on both transfer tests when asked to learn three relative timing patterns, indicating that the self-control condition is better for learning than a predetermined schedule of practice. In addition, a majority of self-control participants chose practice schedules that contained low amounts of contextual interference at the beginning of practice and progressed to higher amounts of contextual interference at the end of practice.

The RTE measures, which measured the proficiency of participants acquiring the relative timing patterns of the keystroke sequences, revealed that the self-control group learned the three relative timing patterns better than the yoked group and sustained the learning enhancement well after the practice session was completed (24 hours after practice). The measures of overall accuracy, as assessed by AE, showed that the self-control group outperformed the yoked group in acquiring the overall movement time for the three keystroke patterns. When looking specifically at the measure of E, the self-control group performed the key stroke task with less error on the 5-minute transfer test than the yoked group. The difference between the self-control group and yoked group on the 5-minute transfer was driven mainly by the measure of bias or |CE|. The self-control group committed fewer directional errors with respect to the target than the yoked group. The VE measure did not reveal significant differences between the groups, indicating that both the self-control and yoked group exhibited the same amount of response or keystroke variability.

The difference between the error measure findings of both groups may be explained by the answers the participants provided in the questionnaire (see Table 3.1). When the yoked group was asked if there was a point in practice in which they wanted to continue to practice a task but was told by the schedule to switch, a majority of the yoked
participants said they were unable to continue practicing the current task. This indicates that a predetermined schedule could be inhibiting the ability of yoked participants to choose, institute, evaluate, and refine strategies. That is, participants of the yoked group may have been trying to confirm a strategy or may have needed additional trials to refine the correct strategy, but could not because the predetermined practice schedule required them to switch to tasks. This finding, along with the measures of RTE for the pretest and transfer tests, suggests that the yoked group was unable to find or confirm the appropriate strategy to enable them to successfully achieve the relative timing pattern for the three tasks. While yoked participants were practicing, the predetermined shift in task of the practice schedule may have inhibited the yoked participants from finding or refining the appropriate strategy. In contrast, the self-control group had the opportunity to practice as many trials with a particular task as they desired. Unlike the yoked participants, their RTE scores may have been lower than the yoked group because they chose the appropriate amount of trials to select and refine the appropriate strategy. Yoked participants may have very well chosen the correct strategy but may have not had the appropriate amount of trials to refine it. The questionnaire results indicate that participants from both groups tried as many movement or mental strategies they wanted. This may explain the improvement of the yoked participants from pretest to transfer tests in measures of RTE, AE, and E. They may have found the correct strategy to improve their performance but could not refine the strategy because the schedule told them to switch to another task.

When self-control participants were asked when they chose to practice a different task, they reported that they switched tasks after good trials. When compared to the
mean scores of the pretest (mean AE = 847) and the 24-hour transfer test (mean AE = 354), self-control participants did in fact switch tasks after “good” trials during practice (mean AE = 381). In contrast, the yoked group switched tasks after trials in which their AE scores had a mean of 589. These results suggest that self-control learners use the control over their practice schedule to enable them to better confirm and refine strategies to a greater extent than the yoked group. Unlike the yoked group, self-control participants allocated as many trials as they desired to a task to refine a strategy until they felt they acquired proficiency with it. Once they felt they had proficiency in reproducing the relative timing requirements, they moved to another task. The results do not suggest the same for the yoked participants. Yoked participants switched practicing tasks after trials that had a greater AE than the self-control group. While the yoked group may be incorporating and evaluating the effectiveness of strategies, just like the self-control condition, the difference may be in the ability to refine the movement or mental strategy through the control of the practice schedule. As stated above, the questionnaire results indicate that both groups tried as many strategies as they wanted. In addition, both groups improved their performance due to practice; this suggests that the difference lies in the ability to control the practice schedule so participants can refine the strategies they produce. These results support the findings by Chiviacowsky and Wulf (2002), who used a feedback paradigm to find that when self-control participants and yoked participants were asked when they requested feedback, most reported that they preferred to have feedback after successful trials. The researchers suggested that learners of the self-control condition requested feedback after good trials because they were confirming the “correctness” of the performance.
Another purpose of Experiment 2 was to assess the manner in which self-control participants choose tasks within their practice environment to construct their overall practice schedules. Figure 3.7 demonstrates how self-control participants chose tasks during practice. In addition to switching tasks after good trials, many self-control participants chose to practice tasks in such a manner that the amount of contextual interference gradually increased as practice progressed. The practice schedules suggest that in the beginning of practice, self-control participants required more practice trials to acquire some level of proficiency. Once this level of proficiency was achieved, or a good trial was performed, participants switched tasks. They required more repetitions in the beginning of practice because the tasks were novel and they needed a greater number of repetitions to develop the appropriate strategies to obtain the goal pattern. Toward the end of practice, they needed less repetition of a task because they had acquired the appropriate strategy and performed with less error. Since their timing errors decreased toward the end of practice, they tended to switch tasks more frequently, creating a practice schedule with a greater amount of contextual interference.

In terms of the types of practice schedules produced, two participants chose to practice in a pure blocked manner (aaaaa, bbbbb, ccccc), demonstrating only two switches. In contrast, two participants switched 75 times (a pure random or serial schedule would contain 89 switches). Most of the self-control participants chose practice schedules that ranged from 5 to 71 switches, with practice schedules that increased the amount of contextual interference from the beginning to the end of practice. The results of the analysis indicate that there was a slight relationship between the number of task switches made and performance on the 24-hour transfer. The slope of the regression
equation was -2.9, indicating that the greater the switches the lower the AE in performance on the 24-hour transfer.

The manner in which self-control participants chose to practice the three tasks produced practice schedules that reflected a difference not only in practice schedules between participants, but also in schedules that changed in structure from the beginning of practice to the end. According to Magill, Porter, and Wu (2005), variations of blocked and random practice schedules provide alternative ways to create amounts of contextual interference that will benefit learning. When viewing self-controlled practice schedule from a contextual interference (CI) point of view, most self-control participants adjusted their practice from less CI at the beginning of practice to more CI towards the end of practice (see Figure 3.7). This ranged from a reduced number of repetitions of a particular task from the beginning of practice to the end. Specifically, most participants started out practicing in mini blocks (aaa bbb ccc bbb aaa ccc) and then progressed to serial or random styles of practice. While these explanations use a CI frame of reference, the key point is that the practice schedules change, and do so on the basis of performance. As stated above, self-control participants switched after “good” trials. This, taken in combination with the gradual shift in the amount of CI from the beginning to the end of practice, indicates that learners self-evaluated their movement or mental strategies and adjusted their practice schedule according to performance. The differentiation between individual practice schedules within the self-control condition suggests that learners are able to choose which task to practice based upon individual need. The difference between individuals with respect to what they need to be successful in practice is highlighted in Table 1, which reveals that a self-control participant who switched 18
times and another participant that switched 75 times received the two lowest mean scores of the experiment on the 24-hour transfer test.

Bernstein (1967) stated that proper practice is a type of “repetition without repetition.” Moreover, he suggests that proper practice entails the process of solving problems repeatedly with techniques that change from trial to trial. Bernstein suggests that within proper practice exists a pursuit for “optimal motor solutions” to attain the goal movement. Bernstein may help to explain the similarities in AE scores seen in the transfer performance scores of self-control participants, despite the disparate number of task switches or practice schedules mentioned above. Some self-control participants chose to switch far less than other self-control participants yet performed similarly on the 24-hour transfer test. These results indicate that repetition of a task does not hinder learning as long as the strategies or processes toward learning the task change to achieve the goal. In the case of self-control, participants may invoke self-regulatory processes, consisting of searching for the appropriate motor solution, evaluating the motor solution, and choosing the correct motor solution based on the feedback they receive. In the process, self-control participants may repeat tasks, but their learning process is not necessarily repetitive. That is, learners use repetition of tasks within practice without repetition in problem solving.

Experiment 2 revealed that self-controlled learning is generalizable to practice schedules when individuals learn multiple tasks. What remains unclear is whether the learning benefit of self-control is directly attributable to participants generating, evaluating, and selecting strategies based on performance. A possible avenue to explore whether self-controlled learners are developing strategies or using self-regulatory
processes in self-controlled learning is to provide a group of learners control over the practice schedule before practice begins and provide another group of learners control over their practice schedule during the practice phase. If the both groups acquire equal learning benefits, then self-regulatory processes would not be responsible for the learning benefit of self-controlled learning. Learners with control over their practice schedule before practice begins are not able to adjust or compare strategies according to their performance because they prepared their practice schedule before practice. The learning benefit of self-controlled learning would likely be attributed to choice.
CHAPTER 4.

EXPERIMENT 3: IS SELF-REGULATION RESPONSIBLE FOR THE LEARNING BENEFITS OF SELF CONTROLLED LEARNING?

INTRODUCTION

Experiment 2 provided evidence to support the generalizability of self-control for practice schedules when individuals learn multiple tasks. When learners were allowed to choose which task to practice, on a trial by trial basis and among multiple tasks, they received learning benefits similar to those that have been shown for choosing the frequency of feedback (Janelle, Kim, & Singer, 1995) or when to view a model while learning a motor skill (Wrisberg & Pein, 2002). In addition, experiment 2 showed that when learners selected the sequence of tasks to practice, they did so systematically. Specifically, once self-controlled learners performed a task successfully, they typically chose to switch tasks to practice another. Moreover, the continual search for and refinement of the appropriate movement strategies produced a shift in their practice schedule, from one of low contextual interference to high contextual interference.

Experiment 2 suggested that the learning benefit of self-controlled learning environments was due to the learner’s control over choosing tasks within the practice session, where they selected, evaluated, and refined movement strategies based upon their performance. These types of processes have also been identified by other studies as the potential cause for the learning benefit of self-controlled learning (Bund & Wiemeyer, 2004; Janelle et al, 1997; Janelle, Kim, & Singer, 1995).

While it has been inferred or suggested that self-regulatory strategies are responsible for the learning benefits of self-controlled learning, it remains unclear
whether learners are utilizing self-regulatory strategies. No direct evidence identifies self-regulatory processes as the cause for the learning benefits seen in self-controlled learning conditions. As a case in point, Janelle et al (1997) sought to explore the effectiveness of self-controlled feedback. The study consisted of four groups: self-controlled knowledge of performance, summary knowledge of performance, yoked control, and a knowledge of results group. Participants were asked to throw a tennis ball with their non-preferred hand to a target. Results of the retention test revealed that the self-control group performed better in accuracy and form when compared to the other groups. The experimenters suggest that a self-regulated learning style may lead to effective strategies of learning. However, the same question, as with many other self-controlled learning studies, arises: is the enhanced learning effect due to self-regulatory processes or is the benefit due to the availability of choice alone? What are the learners estimating and what are the processes responsible for the estimations of movement performance?

As a process, self-regulation involves an interaction of goal attainment, forming and steering strategies, feedback, and self-evaluation (Zimmerman, 1989). According to Baumeister and Vohs (2004), self-regulation entails monitoring one’s performance and making changes according to the requirements of the goal. If an element of this process constituting self-regulation is missing, then the process of learning ceases to be one of self-regulation. Thus, one way to investigate whether self-regulation explains the learning benefits of self-controlled learning is to remove one of the elements of the self-regulatory process. If an element of the process is removed during practice and learning benefits are still achieved, then self-regulation cannot be attributed to the learning
benefits of self-controlled learning. One means of creating such an environment in an experimental context is to allow one group of learners to choose their practice schedule before practice begins and allow another group of learners to choose their practice schedule during the practice session. The group that chooses their practice schedule before the start of practice will be unable to make adjustments during practice based on their performance; these learners will be prevented from engaging in the self-regulatory process of evaluating strategies based on performance and selecting the appropriate strategy. In contrast, the learners that choose during the practice session will be able to engage in this process by having the opportunity to select tasks based on their performance and the strategies that influence their performance. If both groups receive equal learning benefits, or if the group that chooses their schedule before the start of practice exhibits better performance on a transfer test, then self-regulation cannot be solely attributed to self-controlled motor learning. Based on the required elements of self-regulation that must be present for the process of self-regulation to incur, any learning benefit observed, for those who choose before practice, would be attributed to the availability of choice within the practice environment as opposed to the process of self-regulation. It is predicted that participants who self-control their practice schedules during the practice session will obtain a greater learning benefit (as determined by a transfer test) than participants that self-control their practice schedule before practice begins.

METHOD

Participants
Forty undergraduate (male and female) students participated in the experiment. All participants were provided informed consent. In addition, all participants had no prior experience with the experimental task, nor were they aware of the specific goals of the study.

**Materials**

A computer, computer keyboard, and color monitor were used for the study. The computer was situated on a table, and participants sat in a chair with the experimental equipment in front of them. The computer utilized a Microsoft XP operating system to execute a Lab View program that was created by the experimenters. Participants used the number key pad of a computer keyboard to perform each task.

**Task**

The task for this experiment was to sequentially depress a three number key sequence (2 - 4 - 6) according to three relative time sequences. All participants used the index finger of their preferred hand. The goal was to learn to depress the number sequence according to the three relative time structures and to be as accurate as possible in duplicating each relative time structure. The relative movement times were 900 and 700 ms (56% and 44% of the total movement time), 500 and 1100 ms (31% and 69% of the total movement time), and 1400 and 200 ms (88% and 12% of total movement time). The relative movement times were chosen so that the proportions of the total movement time were dissimilar from one another. The total movement time of 1600 ms was used because Chiviakowsky and Wulf (2002) and Simon and Bjork (2001) employed similar total movement times in which students learned similar key stroke tasks. Participants
were asked to perform the time sequences during the pretest, practice phase, 5-minute serial transfer, and 24-hour serial transfer tests.

**Design and Procedure**

Participants were randomly assigned to two conditions: “self-control-before” and “self-control.” Participants in the self-control-before group chose the order in which each relative time sequence would be practiced before the practice session began. Participants in the self-control condition were allowed to choose which task to practice before each trial was performed during the acquisition phase.

Participants listened to directions and observed a demonstration that illustrated the experimental task. All participants performed a 6-trial serial pretest, 90 trial acquisition phase, 5-minute serial transfer test, and 24-hour serial transfer test. The 6-trial pretest ensured that both groups started the experiment at the same performance level. In addition, the pretest was included so that it could be compared to the 5-minute serial transfer test to evaluate whether participants in both groups improved their performance after the practice session. The 5-minute and 24-hour serial transfer tests determined if performance was stable over time. Participants in the self-control-before condition were instructed to “choose the order in which you would like to practice the relative time sequences before you begin the practice session.” Participants in the self-control condition were informed that, during the practice session, they could “choose whichever relative time sequence you want before each trial is performed.” Both groups were told, “You will be tested on all three relative time sequences.” All participants were shown their movement time performance after every trial. After completion of the practice
phase, they were asked to complete a questionnaire (see Table 1). The questionnaire asked participants how they chose to practice and whether or not they employed as many movement or mental strategies as they wanted. The questionnaire was adapted from Chiviakowsky and Wulf (2002).

**Table 4.1 Summary of Post Practice Questionnaire**

<table>
<thead>
<tr>
<th>Employed as many movement strategies as they wanted.</th>
<th>Self-Control</th>
<th>Self-Control Before</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes:</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>No:</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>When you decided to practice a different task</td>
<td></td>
<td></td>
</tr>
<tr>
<td>after good trials:</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>after bad trials:</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>randomly:</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Other:</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Told to change task when not ready.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes:</td>
<td>n/a</td>
<td>11</td>
</tr>
<tr>
<td>No:</td>
<td>n/a</td>
<td>9</td>
</tr>
</tbody>
</table>

**Data Analysis**

The absolute error (AE) and total variability (E) were calculated to measure overall accuracy in performance. Specifically, AE and E were calculated by using the same methods as seen in Experiment 2.

Constant error (CE) was calculated by taking the average signed errors over two trials and variable error (VE) was calculated by taking the standard deviation of the CE measure. Absolute constant error (|CE|) was calculated by taking the absolute value of
the CE measure. The VE measure provides a measure of performance consistency while the CE score provides a measure of variability with respect to the goal movement times.

The relative timing error (RTE), which provides a measure of relative timing accuracy, was calculated by summing the absolute value of the proportion of the segment achieved by the participant subtracted by the goal proportion time. This was done for each movement segment where:

\[
\text{Total MT = Total Movement Time}
\]

\[
\text{MT1 = Movement Time 1}
\]

\[
\text{MT2 = Movement Time 2}
\]

and

\[
\begin{align*}
\text{RTE (for task 1)} &= |(\text{MT1}/\text{Total MT} \times 100) - 56| + |(\text{MT2}/\text{Total MT} \times 100) - 44| \\
\text{RTE (for task 2)} &= |(\text{MT1}/\text{Total MT} \times 100) - 31| + |(\text{MT2}/\text{Total MT} \times 100) - 69| \\
\text{RTE (for task 3)} &= |(\text{MT1}/\text{Total MT} \times 100) - 88| + |(\text{MT2}/\text{Total MT} \times 100) - 12|
\end{align*}
\]

A .05 significance level was used for all analysis of variance and regression.

At the end of practice, a questionnaire was provided (see Table 1) to assess when participants, from both groups, chose to switch tasks and begin practicing another task. The questionnaire was provided to evaluate the characteristics that were associated with switching tasks during practice. The open ended questions were analyzed using deductive and inductive coding procedures (Bogdan & Biklen, 1998). According to Chiviacowsky and Wulf (2005), self-control participants chose to switch tasks after “good trials”; similar task switching decisions were made in Experiment 2. In light of these results, a priori categories for task switches were constructed for the self-control group: switching tasks after good trials, bad trials, and switching tasks randomly. After
coding the responses of the self-control group additional categories emerged that better characterized the participants’ responses, most self-control participants stated that they switched trials after both good and bad trials thus creating a category of task decisions based on an overall analysis of performance. There were no a priori categories set for the self-control group. Two coders analyzed the open ended questions and agreed on 92% of the responses.

RESULTS

Task

In order to assess whether the three key-stroke tasks were equal in difficulty, a 2 x 3 x 3 ANOVA (group x task x test) with repeated measures on the last factor of the RTE was performed. The analysis did not reveal a significant main effect for task F (2, 234) = 2.73, p > .05. In addition, there was no interaction of condition x task x test, F (2, 234) = 0.198, p > .05. This indicates that participants in both groups did not significantly differ in their performance according to the condition they were assigned or test they performed. In this case, analyses of the dependent variables combined the three tasks within the analyses.

Pretest

The pretest was analyzed for both groups using a one-way analysis of variance (ANOVA) to ensure that both groups started the experiment with the same key-stroke performance level.

Relative Timing Error

Analysis of the RTE scores revealed no significant difference between the self-control-before (M = 59.9, SD = 62.0) and the self-control groups (M = 47.4, SD = 35.6)
(see figure 4.1), $F(1, 39) = 3.71, p > .05$. Moreover, the two groups did not significantly differ from one another in their performance with respect to achieving the goal proportion for each segment of the key pattern sequence.

![Average RTE (ms)](image)

**Figure 4.1** The mean RTE scores for the serial pretest, 5-minute, and 24-hour serial transfer test for the self-control and self-control-before groups.

**Absolute Error**

The AE pretest scores revealed that both the self-control-before ($M = 924.4, SD = 671.0$) and self-control ($M = 772.2, SD = 587.3$) (see figure 4.2) groups exhibited AE scores that were not significantly different from one another, $F(1, 39) = 3.5, p > .05$. 

![Average AE (ms)](image)
Figure 4.2 The mean AE scores for the serial pretest, 5-minute, and 24-hour serial transfer test for the self-control and self-control-before groups.

**Total Variability**

Both the self-control-before (M = 733.3, SD = 684.5) and self-control (M = 503.8, SD = 384.3) (see figure 4.3) groups had total variability scores that revealed no significant difference, F (1, 39) = 3.42, p > .05. This result indicated that the two groups were not significantly different from one another during the pretest with respect to the cumulative amounts of bias from the target and response variability.

![Total Variability Graph](image)

Figure 4.3 The mean E scores for the serial pretest, 5-minute, and 24-hour serial transfer test for the self-control and self-control-before groups.

**Absolute Constant Error**

The measures of absolute constant error, or bias from the goal proportions, indicated that the self-control-before (M = 580.4, SD = 580.6) group did not significantly differ from the self-control (M = 367.1, SD = 384.3) group, F (1, 39) = 3.75, p > .05, see figure 4.4.
Figure 4.4 The mean |CE| scores for the serial pretest, 5-minute, and 24-hour serial transfer test for the self-control and self-control-before groups.

Variable Error

Variable error scores revealed no significant difference between both the self-control-before group (M = 368.0, SD = 445.7) and the self-control (M = 286.8, SD = 194.3) group, F (1, 39) = 1.12, p > .05, see figure 4.5.

Figure 4.5 The mean VE scores for the serial pretest, 5-minute, and 24-hour serial transfer test for the self-control and self-control-before groups.
Practice

In order to evaluate the participants’ improvement in performance due to practice, the pretest and the 5-minute transfer test were compared using a 2 x 2 ANOVA (group x test) for both groups. A significant improvement in performance when comparing the pretest to the 5-minute transfer test would indicate that the participants improved their key-stroke performance due to practice. A separate analysis was done for each of the error measures.

Relative Timing Error

Both groups improved their relative timing errors due to the practice session, as evidenced by the comparison of the pretest to the 5-minute serial transfer test (see Figure 4.1). The analysis indicated a significant main effect for test, $F (1, 38) = 69.4$, $p < 0.05$, and a significant main effect for group, $F (1, 38) = 6.63$, $p < 0.05$. The group x test interaction was not significant, $F (1, 38) = 1.01$, $p > 0.05$.

Absolute Error

With respect to overall accuracy as determined by absolute error, both groups significantly reduced their absolute error between the pretest and both transfer tests (see Figure 4.2). Analysis of AE measures revealed a significant main effect for test, $F (1, 38) = 73.1$, $p < 0.05$, and a significant main effect for group $F (1, 38) = 4.1$, $p < .05$. This indicates that the self-control group significantly reduced their overall error shortly after the practice session at a greater rate than the self-control group. There was no significant group x test interaction, $F (1, 38) = 3.27$, $p > .05$. 
**Total Variability**

The self-control-before and self-control groups both reduced their amount of total variability from the beginning of practice to 24 hours after the practice session ended (see Figure 4.3). Specifically, analysis of the total variability scores revealed a significant main effect for test, $F(1, 38) = 31.5$, $p < 0.05$. The reduction in total variability indicates that participants from both groups reduced the cumulative amount of bias from the target and response variability. There was also a main effect for group, $F(1, 38) = 4.2$, $p < .05$, which indicates that the self-control group reduced their cumulative bias from both the target and response variability at a greater rate than the self-control-before group. There was no group x test interaction found, $F(1, 38) = 2.23$, $p > .05$.

**Absolute Constant Error**

The absolute constant error measures indicated that participants from both the self-control-before and self-control groups reduced the amount of response bias with respect to the goal movement times (see Figure 4.4). Analysis of $|CE|$ revealed a significant main effect for test, $F(1, 38) = 26.7$, $p < 0.05$. Due to the practice session, both groups had lower scores on both transfer tests than on the pretest. There was no significant main effect for group, $F(1, 38) = 4.01$, $p = .05$, and no significant group x test interaction, $F(1, 38) = 2.83$, $p > .05$.

**Variable Error**

In addition to response bias, the self-control-before and self-control groups also decreased the amount of response variability from the beginning of practice to 24 hours after practice (see Figure 4.5). Analysis of VE revealed a significant main effect for test,
F (1, 38) = 18.2, p < 0.05. The main effect for group was not significant, F (1, 38) = 1.89, p > .05, nor was the group x test interaction, F (1, 38) = .405, p > .05.

**Task Switching Characteristics**

In order to evaluate whether self-control participants switched tasks after successful trials, participants were asked in the questionnaire when they decided to switch tasks (see Table 4.1). To confirm their answers, a one-way ANOVA was performed to determine if the self-control group adjusted their practice schedules based on their performance. Absolute error was used and scores were taken from the trial that preceded a task switch. AE scores were used for this analysis because they may best represent the information self-control participants used as the basis for switching tasks. Specifically, participants compared their keystroke performance for each segment to the difference of the goal times required for each segment. In effect, they based their performance on an absolute error measure.

The mean AE for the trial that preceded a task switch revealed that the self-control-before group (M = 1480.1, SD = 508.9) did not significantly differ from the self-control group (M = 1502.6, SD = 517.7), F (1, 553) = .188, p > .05. However, the manner in which participants from both groups chose tasks within the practice session varied. The self-control-before group (M = 6.45, SD = 6.17) switched tasks fewer times during the practice session than the self-control group (M = 21.25, SD = 19.9). Ten of the 20 participants in the self-control-before group chose a blocked practice schedule in which there were only two task switches during the entire practice session. Alternatively, none of the participants in the self-control group chose a blocked schedule. Instead, most
self-control participants chose a mixed style of practice in which they practiced in mini blocks that varied in size from participant to participant (see Figure 4.6).

Figure 4.6 The figure depicts the trials on which a self-control-before participant and a self-control participant practiced each of the three tasks. Both participants were randomly chosen for display of the figure. The three colors of red, green, and yellow represent each of the three key stroke tasks participants were asked to learn. The practice schedules of both the self-control-before and self-control participants illustrate the difference in the number of task switches made during practice. The smallest colored squares represent one trial.

In addition to exploring why participants chose to switch tasks, how participants chose to structure their practice schedules and how their practice schedules affected the stability of their learning with respect to time was investigated. This was done for two purposes. The first was to explore the types of practice schedules the self-control participants chose for their practice session. A practice schedule with many task switches would indicate that self-control participants chose a schedule that involved a higher amount of contextual interference (random or serial practice), whereas a practice schedule with few switches would indicate that self-control participants chose a schedule that involved a lower amount of contextual interference (blocked practice). The second
purpose was to investigate the relationship between the number of task switches and performance on the 24-hour serial transfer test. That is, does organization of the practice schedule influence the 24-hour transfer performance (a test that measures the stability of performance after a period of time)? This question was investigated by analyzing the number of switches the participants made alongside their performance on the 24-hour transfer test; the number of switches made during practice was analyzed using simple linear regression. Figure 4.7 shows the number of times participants from both groups chose to switch tasks during the practice session and the corresponding AE score attained for the 24-hour transfer test. When viewing the number of task switches made during the practice session for each participant, the results indicated that there was no linear relationship between the number of task switches made during practice and performance on the 24-hour transfer test. Simple linear regression analysis with number of switches as the main factor and AE score for the 24-hour transfer test as the dependent variable, for both groups, revealed the following linear relationship: $y = -2.47 \times \text{(number of switches)} + 440.2$, $p > .05$. The linear relationship was non significant between the number of switches and the AE score received during the 24-hour transfer test.

**Transfer**

In order to assess the adaptability and stability of what was learned during practice, the 5-minute and 24-hour transfer was analyzed using a 2 x 2 ANOVA (group x test) with repeated measures test. A separate 2 x 2 ANOVA was performed for each error measure.
Figure 4.7 The figure shows the relationship between the number of switches the self-control group participants made during practice and their key-stroke performance (AE) during the 24-hour serial transfer test.

Relative Timing

The self-control group had significantly lower relative timing errors than the self-control-before group (see Figure 4.1). The group x test analysis using relative timing error revealed a main effect for group, F (1, 38) = 9.35, p < .05. There was no significant interaction found for group and test, F (1, 38) = 0.294, p > .05, nor was there a significant difference for the test factor, F (1, 38) = 0.342, p > .05.

Absolute Error

The self-control group had significantly lower AE scores than the self-control-before group (see Figure 4.2). The group x test analysis using absolute error for the 5-
minute serial transfer test revealed a main effect for group, $F(1, 38) = 7.11$, $p < 0.05$. A significant group x test interaction was not found, $F(1, 38) = 0.221$, $p > .05$, and there was no significant difference for the test factor, $F(1, 38) = 0.221$, $p > .05$.

**Total Variability**

With respect to total variability, the groups did not differ significantly from one another (see Figure 4.3). There was no significant main effect found for group, $F(1, 38) = 3.56$, $p > 0.05$, and no significant interaction for group x test, $F(1, 38) = 0.263$, $p > .05$. There was a significant main effect for test, $F(1, 38) = 7.56$, $p < .05$, with both groups performing better on the 5-minute transfer than the 24-hour transfer.

**Absolute Constant Error**

When examining response bias with respect to the target, one group did not outperform the other on either of the transfer tests (see Figure 4.4). The analysis did not reveal a significant main effect for group, $F(1, 38) = 1.53$, $p > 0.05$. While there was no significant main effect for group, there was a significant main effect for test, $F(1, 38) = 9.82$, $p < .05$, as both groups demonstrated less error on the 5-minute transfer test than the 24-hour transfer test. There was no significant group x test interaction, $F(1, 38) = 0.861$, $p > .05$.

**Variable Error**

The results indicate that both groups were not significantly different in the variability of keystroke performance (see Figure 4.5). The analysis of response variability did not reveal a significant main effect for group, $F(1, 38) = 3.65$, $p > 0.05$, or significant main effect for test, $F(1, 38) = 0.790$, $p > 0.05$. In addition, no significant interaction was found for group x test, $F(1, 38) = 1.22$, $p > .05$. 
Questionnaire

Table 4.1 reconstructs the questionnaire and the corresponding results. Upon completion of the practice phase, participants in the self-control group exhibited the following response rates when asked when they chose to stop practicing one task and start practicing another: “good trials” = 6 participants, “bad trials” = 5 participants, “randomly” = 4 participants, and “other” = 5 participants. Moreover, self-control participants gave a variety of answers when they were asked to explain why they chose to switch tasks during practice. Several explained that they switched tasks because they had acquired proficiency at a task (9 participants) or they were performing poorly on a task (5 participants). Others in the self-control group stated that they switched when they: felt they had enough practice (1 participant), after every trial (1 participant), or to ensure an even number of tasks were completed (1 participant). Upon coding the responses of both groups, two major categories emerged: “Task changes based on performance” (which had an additional level based on good performance and bad performance) and “Task changes based on distributing tasks equally” (see Table 4.2). Fourteen of the responses from self-control participants were assigned to the category that switched tasks based on evaluation of their performance while seven responses from the self-control-before participants were coded to the category that was based on allocating tasks evenly over the practice session. Examples of participants’ responses within the category in which they changed task based on performance include:

- “I stopped when I felt I had enough practice.”

- “It depended how I felt. In the beginning it was after good trials but then more and more randomly.”
“After good plus one.”

“I changed every time because I was trying to get a feel of all of them and trying to find a sequence.”

“To get a feel for the timing sequences.”

“I thought if I timed myself in my head I would do better and it would work at least once and then not work again. Once that happened I would go on to the next one.”

“After receiving a few scores close to the number I wanted I had an idea of a rhythm to use…selected task until I felt comfortable with that, then proceeded to another.”

“I began to practice another task when I felt I did well or when I was unable to perfect a specific task I moved on.”

“Because I thought I did enough number of trials and got bored.”

Table 4.2 Coded Responses to Categories

<table>
<thead>
<tr>
<th>Level 1 Category: Task changes based on performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Level 2 Category: Good Performance</td>
</tr>
<tr>
<td>Self-Control:</td>
</tr>
<tr>
<td>Self-Control:</td>
</tr>
<tr>
<td>Self-Control:</td>
</tr>
<tr>
<td>Self-Control:</td>
</tr>
</tbody>
</table>
Level 2 Category: Good Performance cont’d

Self-Control: “After receiving a few scores close to the number I wanted I had an idea of a rhythm to use. Went to a different task to get a feeling for the msec between keys, continued that selected task until I felt comfortable with that then proceeded to the last one”

Self-Control: “I began to practice another task when I did well a several task or when I was unable to perfect a specific task I moved on”

Self-Control: “I tried to get as close as I could to one task before moving on to another”

Self-Control: “Law of diminishing returns”

Self-Control: “After I felt I kind of had the task down timing wise, I would move on to another”

Level 2 Category: Bad Performance

Self-Control: “I stopped practicing a trial when my goal times and my result times were very different such as my goal times being 500 msec 1100 msec and my results were 1169 msec and 1169 msec. I then felt I needed to move on and practice a new goal time”

Self-Control: “Timed myself in my head I would do better and it would work at least once and then not work again, once that happened I would go on to the next one”

Self-Control: “I would practice one task and then start practicing due to bad trials that kept occurring”

Self-Control: “I felt that was as close as I was going to get to the exact score, the I would try one more and it would be completely off, so that’s when I changed”

Self-Control: “The numbers I was getting closer matched times for a different goal. I figured my timing for that goal would be better and could first match that goal before I moved on”

Level 1 Category: Task changes based on distributing tasks equally

<table>
<thead>
<tr>
<th>Group</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Control</td>
<td>“I did 15 of each task and then moved to the next one”</td>
</tr>
<tr>
<td>Self-Control-Before</td>
<td>“I just looked at the first number sequence and started from the smallest to largest and I decided to do 30 of each sequence in that order”</td>
</tr>
<tr>
<td>Self-Control-Before</td>
<td>“I spread out the movement time evenly in order to have the same amount of practice for each time”</td>
</tr>
<tr>
<td>Self-Control-Before</td>
<td>“I just wanted to make sure I practiced each sequence more than once”</td>
</tr>
</tbody>
</table>
Level 1: Task changes cont’d

Self-Control-Before: “Divide them up equally”
Self-Control-Before: “I tried to distribute them equally because I wasn’t sure which would be the easiest for me. When I was actually practicing I realized maybe I should’ve kept practicing a certain one”
Self-Control-Before: “Get a chance to practice all the sequences an even number of times”
Self-Control-Before: “I just divided the 90 trials among the 3 goals so 30 consecutive trials for each”
Other
Self-Control: “I changed every time because I was trying to get a feel of all of them and try to find a sequence”
Self-Control-Before: “I chose the task that has the slowest time between 2 to 4, then progressed towards the quicker 900 msec, followed by the 500 msec”
Self-Control: “I stopped when I felt that I had enough practice. On some I wanted to keep on practicing but I knew that I had to move on to the other goal movement groups”
Self-Control: “I determined my start/stop of a task by how close in time I was to the given goal times”

* Some participants were not included because they either did not provide a response or they did not answer the question.

Self-control participants also reported that they had ample opportunity to explore movement and mental strategies. Self-control participants thought the 900 and 700 millisecond task was the most difficult and the 500 and 1100 millisecond task was the easiest. Like the self-control group, 80 % of the self-control-before group stated that they tried as many movement or mental strategies as they wanted. In addition, 70 % of self-control-before participants stated that they would not have changed their practice schedule if they had the chance to do so. Self-control-before participants were almost evenly divided when asked, “Was there a point in practice where you wish you could
have practiced a task more but was unable because the practice schedule told you to do
another task?” (55% yes, 45% no) and “Would you have rather chosen which task to
practice during practice instead of before practice?” (40% yes, 60% no). Most self-
control-before participant responses to the question “What was your strategy or thought
process when you were choosing which tasks to practice before the practice session
began?” were coded into the category “Task changes based on distributing tasks evenly”.
Examples of participants’ responses include:

- “I looked at the first number and started from smallest to largest and decided to
do 30 of each in that order.”
- “I spread out the movement time evenly in order to have the same amount of
practice for each time.”
- “Just try out each different task, it interesting you don’t know what you might
get.”
- “Divide them up equally.”
- “I wanted to get used to a certain movement so I chose to do/focus on one
sequence at a time.”

DISCUSSION

Previous studies of self-control have shown that allowing learners to choose the
frequency of feedback, the number of times to view a model, and which tasks to practice
among multiple tasks is beneficial for learning. While most studies attribute self-
regulation as the driving force behind the enhanced learning effect, it is unclear whether
the learning benefit is due to choice or the process of self-regulation. If choice is
responsible for the learning benefits of self-controlled learning, then self-regulation is not

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the learning mechanism of self-controlled motor skill learning, as previous studies have contended. If self-regulation is responsible for an enhanced learning effect within the practice environment, then a learner must be able to monitor performance and make changes according to the requirements of the goal (Vohs and Baumeister, 2004). Thus, learners must be able to change their practice schedule based upon their performance in order to achieve the movement goals. In order to investigate whether choice or self-regulation is responsible for the enhanced learning effect seen in past studies of self-controlled motor learning, a self-control group that chose their practice schedules before the start of practice was compared to a self-control group that chose which task to practice during the practice session. It was hypothesized that choosing which task to practice during practice would be better for learning than choosing before practice. The results of the study support the hypothesis. The self-control group performed better than the self-control-before group on the 24-hour transfer test.

The results thus confirm that the process of self-regulation is responsible for the learning benefits observed in self-controlled learning. The self-control group, which exhibited lower error scores in both 5-minute and 24-hour transfer tests, exhibited fewer errors in producing proportional goal segments, overall error, and directional errors with respect to the target. Although participants from both groups were allowed to choose the order of tasks practiced, only the self-control group could choose the type of task on a trial-by-trial basis during practice. In effect, participants in the self-control group could switch tasks during practice based upon their performance, which provided self-control learners the opportunity to test various movement strategies against performance outcomes. Testing different movement strategies allowed them to generate, select, and
potentially refine the strategies they deemed conducive to the attainment of movement goals. As seen from the questionnaire data, the strategies used by the participants varied. In fact, some participants within the self-control group utilized opposing strategies. Nonetheless, the fact that self-control participants chose which task to practice based on performance of previous trials provided then an amenable practice schedule that accounted for differences in strategy selection and movement refinement.

Conversely, self-control-before participants deliberately chose their schedules to distribute trials equally among tasks. According to the questionnaire data, most of the self-control-before participants adopted strategies that were not based on an evaluation or prediction of their movement performance. For example, half of the self-control-before participants chose a block style of practice, which implies that they were trying to distribute the trials equally so they could devote an equal amount of practice to each task. According to most of the responses provided by the self-control-before participants, they did in fact base the design of their practice schedule on practicing each task the same number of times. In contrast, self-control participants chose to switch tasks according to their performance. Participants switched after trials they considered “good trials” or “bad trials.” With respect to the self-control participants that switched “randomly” or for some “other” reason, they indicated that they switched tasks according to how they perceived their performance level.

The comments from the self-control group indicate that participants chose tasks based on some estimation of their performance and also made an effort to confirm their movement strategies on the basis of performance outcomes. Their responses indicate that they were invoking self-regulatory strategies. Although the analysis of the AE scores for
trials preceding a task switch revealed no statistical difference between groups, the differences in strategy between the groups when asked why they switched task when they did illustrates self-regulation processes occurring with the self-control group but not the self-control-before group. The lack of difference in AE for the trial preceding a switch can be explained by the differences in strategy within the self-control group itself. Almost half of the participants in this group reported that they switched task after a bad trial; the other half switched tasks after a good trial. The remainder of the participants reported that they switched tasks “randomly” or for some “other” reasons stated previously. This suggests that self-control participants were utilizing varying strategies. Although the strategies differed among the participants, the common characteristic shared by all self-control participants was switching tasks on the basis of a subjective estimation of their own performance with respect to the goal time.

Previous studies (Shea & Morgan, 1979; Goode & Magill, 1986) have established that practice schedules with a greater amount of variability during practice (random practice) are better for learning than practice schedules that contain little practice variability (blocked practice). The results of this present study support those findings. Allowing participants to design their practice schedule as they are practicing, as opposed to designing the schedule before practice begins, creates robust differences in both the amount of practice variability and self-regulatory processes. Specifically, self-control-before participants chose practice schedules with little variability. In fact, half of the participants chose blocked practice schedules; the group as a whole averaged only 6.25 task switches over the entire practice session. Conversely, the self-control group averaged more than three times the number of task switches during practice (21.25 task
switches). This discrepancy in practice variability indicates that learners create a more variable practice schedule when they are able to choose tasks on a trial-by-trial basis, during practice, rather than choosing which task to practice before the practice session begins. The effect that self-regulation has on practice variability is all the more telling because the participants in the study had no knowledge of the different types of practice schedules and their influence on motor skill learning. When considering practice variability and its effect on the retention of learning motor skills, previous studies (Shea & Morgan, 1979; Goode & Magill, 1986) have established that practice schedules with a greater amount of variability during practice (random practice) are better for learning than practice schedules that contain little practice variability (blocked practice). The results of this present study support those findings.

In addition to practice variability, the timing (when choice was given) determined whether or not self-regulatory processes were initiated. According to Zimmerman (1989), self-regulation requires goal attainment, forming and steering strategies, feedback, and self-evaluation. If any of these are absent, then self-regulation cannot take place. As seen with the self-control-before group, an inability to adjust one’s practice schedule based on performance disabled participants from forming and adjusting strategies toward attainment of the movement goal. The responses of self-control-before participants revealed their inability to self-regulate. While self-control participants responded with explanations about outcome and their actions based on outcome, self-control-before participants were primarily concerned with dividing the tasks evenly over their respective practice sessions. Had self-control-before participants been allowed to choose during practice, their strategies of practice schedule design would likely have
pertained to their performance. The distribution of tasks among trials would have been a byproduct of their actual need based on their proficiency at the movement time.

Although previous studies have attributed the learning benefits of self-control to self-regulation, it has been unclear whether the learning benefits are driven by choice or the process of self-regulation. The results of the present study support the inferences of previous studies that self-regulation is responsible for the learning benefits of self-controlled motor learning.
CHAPTER 5.

GENERAL DISCUSSION

Until recently, research in motor learning has analyzed practice environments in which the experimenter controls all aspects of the design and structure of practice. Learning is ideally considered a “two-way street”, but within the various research paradigms of motor learning, from augmented feedback to practice schedules, the learning process has been a “one-way street” in which the experimenter decides what, when, and how the learner will practice a skill. Very few studies have investigated the learner as an active participant in the design or structure of practice.

To address this gap in motor learning research, a series of three experiments were performed to the answer the following questions: Is self-controlled learning generalizable to motor skill learning environments in which more than one skill is learned? If self-controlled learning exhibits a positive learning effect, in what manner do learners choose among tasks during their practice sessions? Is self-regulation the driving force behind the positive learning benefits seen in self-controlled learning environments?

IS SELF-CONTROLLED LEARNING GENERALIZABLE AND HOW MUCH CAN WE GENERALIZE?

Self-controlled motor skill learning has produced learning benefits in a variety of motor skill learning paradigms that include augmented feedback (Chiviacowsky & Wulf, 2002; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Janelle, Kim, & Singer, 1995), observational learning (Wulf, Raupach, & Pfeiffer, 2003), and physical assistance devices (Wulf & Toole, 1999). These studies have suggested that choice given to learners during practice invokes psychological processes that enhance learning when compared to learners that are allowed no choice during practice. While the observed
effect on learning has been positive, most of these studies required participants to learn only one motor skill. However, in most skill learning environments, it is likely that a coach or therapist will teach more than one motor skill during a practice or rehabilitation session. Whether a basketball coach is teaching players how to pass, dribble, and shoot, or a therapist is training patients how to type on a keyboard or grasp a cup, instructional environments require a variety of different movements to be learned.

The first two experiments aimed to determine whether self-controlled learning is generalizable to the acquisition of multiple motor skills. While Experiment 1 did not yield significant differences between the performance of a self-controlled and yoked group on a golf-putting task, the results did suggest that self-control participants chose their practice schedule based on a strategy. Specifically, participants chose to allocate most of their practice trials to the more difficult tasks and spent less time practicing the task that was easiest. Experiment 2 showed that participants who were allowed to choose which task to practice, on a trial by trial basis, performed better on three keystroke tasks than yoked participants who had the same practice schedule but had no control over the practice schedule. Thus, the results demonstrate that self-control can be generalized to learning multiple motor skills. The results also confirm previous studies that demonstrate enhanced learning effects when participants are given the same degree of control during practice.

Baumeister and Vohs (2004) state that self-regulation must not be influential merely from a theoretical standpoint but must also be influential from a practical standpoint. In following this rationale a practitioner may ask “how much control should be given to the learner?” Experiment 2 and previous self-control studies have
demonstrated that learners benefit from being given control during practice, but such studies have not adequately addressed the optimal amount or timing of learner control. From a practical standpoint, the amount of control granted to a learner is a critical question because the amount of control a learner possesses can vary greatly. In the case of motor learning, practical considerations facilitate learning environments that enable maximum learning.

Because the amount and timing of learner control in the learning environment are important issues, we can look to Mosston’s continuum of control to help identify and explain where self-controlled learners control their practice environment. According to Mosston and Ashworth (1986), three categories of control comprise a learning environment: the pre-impact set (how the unit of instruction is prepared), the impact set (how the prepared content is executed), and the post-impact set (how the learned content is evaluated). Experiment 2, in addition to previous studies of self-control, provided learners with control over only one category of the learning environment: the impact set. That is, the experimenter makes pre-impact decisions about the preparation of the learning environment, such as the task to be learned, the location of the learning environment, and the skill level of the participant. In addition, the experimenter controls the post-impact set: how the learning will be evaluated. This includes the number, type, and sensitivity of the evaluations. Because learners have only been given control over the impact set in past studies, the actual amount of control participants have been allocated has been quite small. Furthermore, even when participants were given control in the impact set with feedback, practice schedules, observational learning, and physical device assistance paradigms, they were only given control of one aspect of the impact set.
Self-control participants controlled when they received feedback, when to view a model, when to use a physical assistance device, or when to practice a particular task. In considering the numerous other decisions made by the experimenter in the impact set, as well as the pre- and post-impact sets, the amount of control actually given to the learner in practice has been minimal.

In response to Baumeister and Vohs’ (2004) concept of practical influence of self-regulation, it can be argued that learning is enhanced when learners are given a specified amount of control within a specified location in the practice schedule. In addition, self-control generalizes not only to paradigms of feedback, observational learning, and physical assistance devices, but also generalizes to learning multiple tasks. However, the amount of control given to learners can only be generalized to a limited extent. Thus far, the self-controlled motor learning research has investigated practice environments in which learners are provided with a small amount of control - participants have only controlled one parameter of the learning environment. Learning was enhanced when learners could make decisions about when to receive feedback, when to view a model, when to use a physical assistance device, or when to practice a task when multiple tasks were learned. But each of these decisions were made within the practice session itself and made on a trial-by-trial basis, so any increase in control or change of when control was granted in the practice session cannot be generalized at this point.

**HOW DO SELF-CONTROL PARTICIPANTS CHOOSE?**

Since the seminal study on practice variability by Shea and Morgan (1979), an extensive body of research has investigated different types of practice schedules and their effect on learning (see for instance Magill & Hall, 1990). In general, the findings from
these studies indicate that increased contextual variability of task enhances learning across task and skill level (Magill, 2006). Since self-controlled learning has been shown to generalize to the learning of multiple motor skills, it would be prudent to investigate how participants choose during their practice and whether or not participants choose a practice schedule with greater or less variability. Moreover, if participants choose schedules with greater variability, are the results consistent with previous findings on practice variability?

Experiments 2 and 3 revealed that most self-control participants chose schedules that contained mini blocks, instead of designing practice schedules that resembled a strictly block or random schedule. A unique characteristic that arose from self-control participants in experiment 2 was revealed in the participants’ responses to the questionnaire. Most of the self-control participants stated that they switched tasks after good performances. This is consistent with the findings of Chiviacowsky and Wulf (2002) in which most of the self-control participants requested feedback after good trials to confirm the success of their strategy. Similarly, self-control participants in experiment 2 reported that they switched tasks based on their performance.

Providing choice does not always cause participants to select practice schedules that are conducive to learning. The stage at which choice is given to the learner is crucial to the design of the practice schedule. The design of practice and in effect the variability of practice change drastically based on when participants are allowed to choose. The self-control-before participants in Experiment 3, who chose their practice schedule before the start of practice, designed practice schedules that were in stark contrast to self-control participants, who chose during practice. Self-control-before participants chose schedules
that had far less variability and resembled block practice schedules. They executed fewer task switches than self-control participants and provided rationale for the design of their practice schedule that also differed vastly from the self-control participants. Most self-control-before participants chose their tasks based on distributing the tasks evenly over the entire practice session so that they would have an equal opportunity to practice each task. This resulted in practice schedules with very few tasks switches, which in turn created little practice variability. This result was largely due to the fact that self-control-before participants were unable to observe their performance on each trial and choose based on the self-evaluation of their performance.

According to Chiviacowsky and Wulf (2002), when self-control participants requested feedback, they did so based on a strategy which was performance related. They did not choose feedback randomly but selectively used feedback to confirm a good performance. In the case of practice schedules, self-control learners chose which task to practice based on their performance, whereas yoked participants could not. In choosing which task to practice based on performance, self-control learners varied their practice more than yoked participants. The variation introduced into the practice session in the self-control conditions demonstrated that participants can choose effective practice schedules if the choice is provided to them at the appropriate time. This was supported in Experiment 2 in which a linear relationship was observed between the number of task switches and increased accuracy on the 24-hour transfer test. Specifically, as the number of task switches increased (or as task variability increased) the performance on the 24-hour transfer test improved.
From a practical standpoint, the question that arises is this: “when in the learning environment is it appropriate to give the learner control?” The results from experiment 2 and 3 would indicate that control at any point in the impact set would not enhance learning. As seen with the self-control-before group, control at any point of the impact set does not necessarily translate into enhanced learning effects. This series of studies suggests that learners should control their practice environment so that the changes made during practice are based on an evaluation of their performance during practice.

IS SELF-REGULATION RESPONSIBLE FOR LEARNING BENEFITS?

Many studies of self-controlled learning have suggested mechanisms that underlie the enhanced learning benefits observed in learners who choose the frequency of feedback, the number of model presentations, and which task to practice within their practice environment (Titzer, Shea, & Romack, 1993; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Wulf, Raupach, & Pfeiffer, 2005). For example, Janelle et al (1995) suggested that self-control practice schedules enhance learning because “the effect of control has an indirect beneficial effect on learning similar to motivational influences on cognitive processes.” Moreover, they argued that the motivational influences of self-controlled learning environments are due to the active involvement of the learner in practice. This active involvement in the design of the learning environment causes the learner to assume additional responsibility for accurately acquiring the movement pattern. Since the learner assumes additional responsibility, the motivation to perform well increases (Janelle et al, 1997). The researchers also stated that self-regulated learning paradigms may be more effective than rigid practice schedules because they allow the learner to invoke more effective learning strategies.
While much has been inferred about self-controlled learning environments, less has been done to explore the mechanisms underlying self-controlled learning environments. Self-regulated learning is generally considered the cause of the enhanced learning effect seen in self-controlled motor learning, but few studies have confirmed self-regulation as the process responsible for self-controlled learning. More concrete questions must be addressed: Is the enhanced learning effect due to the learners’ option to choose or is it due to self-regulatory processes? What are learners estimating and what are the processes responsible for the estimations of movement performance?

According to Vohs and Baumeister (2004), self-regulation is comprised of an individual’s attempt to regulate thoughts, emotions, impulses, and task performances. Moreover, self-regulation consists of an interaction of goal attainment, forming and steering strategies, feedback, and self-evaluation (Zimmerman, 1989). If an element is missing, then the process of learning ceases to be one of self-regulation. If self-regulation is not the underlying process behind self-controlled learning, then the enhanced learning effects may likely be due to motivational factors that are associated with choosing within one’s practice environment, as previous motor skill learning studies have suggested (Janelle, Kim, & Singer, 1995; Janelle et. al., 1997).

The results of experiment 3 indicate that self-controlled learning is driven by the process of self-regulation. While both groups were allowed to choose during practice, only the self-control group was able to steer their movement strategies based on feedback and self-evaluation during the practice session. The self-control-before group was allowed to control their practice session, but did so before practice began. They were not able to choose after seeing their performance. This prevented the self-control-before
group from basing their practice schedule on feedback and self-evaluation of performance. They could monitor their performance, via feedback, during practice but they did not possess control over the aspect of practice that would allow them to steer or change their practice schedule. In effect, the self-control-before group had control over their practice environment but was unable to self-regulate. In viewing participants’ responses to the questionnaire, self-control-before participants chose to control their schedule for reasons other than the self-evaluation of their performance. Instead, they chose practice schedules that were based on distributing tasks evenly so that they could practice each task an equal number of times. This result would be anticipated because as Zimmerman (1994) states, self-regulators use metacognitive processes to self-monitor, self-evaluate, and steer their learning strategies. In contrast, self-control participants controlled their practice environment and change their practice schedule based on an estimation of their performance to the respective goal. While self-control participants utilized varying strategies for choosing their practice schedule, the predominant strategy was to structure their practices schedule in response to their performance. Whether participants changed tasks due to successful or unsuccessful performances, participants in the self-control condition monitored their performance and developed strategies to adjust their practice schedule based upon self-evaluation of their performance. These findings indicate the self-regulation is indeed responsible for learning benefits.

FUTURE RESEARCH

While most practice design research has investigated distributed and random practice environments, Lee and Wishart (2005) suggest that alternatives to the traditional practice designs should be explored so as long as that they do not reduce the effectiveness
of learning but potentially improve the desire to practice through increased motivation. While Lee and Wishart (2005) encourage the exploration of effective practice schedules that promote deliberate practice through motivating the learner, the research interest of learner control within the practice environment appears to be promising. While some motor learning researchers have begun to investigate the effects of the learner controlling aspects of the practice environment, there is still much work to be done.

To begin with, the amount of control the learner possesses should be examined further. Studies thus far have addressed control at merely one level, the impact set. Moreover, they have given the learner only a small amount of control within the learning environment. With respect to Mosston and Ashworth’s continuum of control, only one teaching style has been explored in motor learning research: the practice style. Future studies should explore various amounts of learner control at various points in the learning environment using Mosston and Ashworth’s continuum of control as a framework. In using this framework, a systematic means of changing the amount and timing of participant control in the learning environment would serve as a useful and systematic tool for investigating the parameters of optimal learner control.

Thus far, all research on self-controlled motor learning has involved the use of novices. Considering that both novices and experts have various personal and performance characteristics at various stages of motor learning (Magill, 2006) the amount of control given to a performer during practice may have differing effects based on skill level. That is, is an expert performer able to control more of the learning environment than a novice? An answer to this question may help practitioners better design self-controlled learning environments to suit the skill level of the performer.
Should those who have high self-regulation skills receive more control in the practice environment than performers that are not able to self-regulate as well? Additional investigations may involve characterizing or assessing the degree to which a learner is able to self-regulate effectively. Within self-regulation research, self-regulation inventory questionnaires have been developed to assess the degree to which an individual can self-regulate (Ibanez, Ruiperez, Moya, Marques, & Ortet, 2005; Brown, Miller, & Lawendowski, 1999; Fluery, 1998). These types of self-regulation inventories can be investigated to explore whether there is a predictive component to assigning the proper amount of control to performers based on their abilities to self-regulate. This may provide practitioners the ability to assign the amount of control that is suitable to the performer’s ability to self-regulate.

Another avenue of future research would be to compare traditional practice schedules such as random practice to that of self-controlled learning schedules. Titzer, Shea and Romack (1993) found that the self-control group outperformed a block group on a delayed retention test but was not significantly different from the random group on a barrier knockdown task. Future studies can extend these findings using delayed transfer tests to identify the schedule that optimizes learning. Additional research in this area may demonstrate what processes yield the maximum learning benefit. That is, does the process of self-regulation have a greater impact on learning than the effects of contextual interference?

Future research of self-controlled learning is very promising. The interplay of control between the experimenter and learner brings about many avenues in which self-control can be investigated. This research line is not only important from a theoretical
perspective but is also important from a practical standpoint. As therapists rehabilitate their patients or as coaches train their athletes, there exists a common goal of helping the learner to become an independent problem solver. From a theoretical standpoint, future endeavors in self-controlled learning can move motor learning research from a “one way” to a “two-way” understanding of learning.
REFERENCES


APPENDIX 1

SELF-REGULATION OF LEARNING MOTOR SKILLS: A LITERATURE REVIEW

Thus far in skill acquisition research, numerous studies have explored learning in situations where the experimenter or instructor who shapes the practice environment. Researchers have investigated many concepts that explain how structuring practice properly can enhance the learning of motor skills. Specifically, they have examined how practice variability, practice distribution, modeling, and augmented feedback affect the learning of a motor skill. A common characteristic that exists among these varying learning paradigms is that the experimenter not only dictates how a skill should be performed but also controls the order, amount, and distribution of the practice environment.

The learning process is commonly referred to as a “two-way street” between the learner and instructor. While most skill acquisition research has focused primarily on understanding skill learning, with the investigator controlling the entire practice session, an understanding of the learner’s impact on practice has not been addressed to the same degree. Such learning environments lack the active involvement of the learner. The result may be a “one-way street” of learning and a “one-way” understanding of how humans acquire motor skills.

Evidence for the benefits of involving students in the structuring of their learning process has been demonstrated in educational research and is termed “self-regulated” learning. According to Schunk and Zimmerman (1992), self-regulated learning is the
degree to which learners are metacognitively, motivationally, and behaviorally active participants in their learning process. In short, this means that allowing students to participate in the design of the learning process and to structure the learning environment can motivate learners and induce them to think about their strategies of learning (a more detailed explanation of self-regulated learning will be discussed later in the review).

Anecdotally, self-regulated learning is rooted in the theories of Benjamin Franklin and Thomas Edison. These great American thinkers stressed self-directed learning along with personal efforts to apply knowledge for intellectual development (Schunk & Zimmerman, 1994). Experimentally, the study of self-regulation began from a national concern for the poor academic performance of American students. Instead of investigating why students were performing poorly, researchers set out to discover why successful students were performing so well. Wibrowski (1992) and Caplan, Choy, and Whitmore (1992) found that despite language barriers, gaps in schooling, discrimination, emotional scars, and economic difficulties, underprivileged inner city students and immigrant refugee students were still able to succeed in school. These students not only faced economic and social barriers, but also did not have the benefit of educated parents or schools with deep economic or academic resources. Despite such environmental limitations, these students succeeded academically because they could invoke concepts associated with self-regulated learning. These self-regulated concepts included the allocation of study time according to personal needs, individualized learning strategies, goal directedness, and a sense of self-efficacy.

Despite the demonstrated learning benefits produced by self-regulated learning, skill acquisition research has consistently neglected to investigate learner involvement in
skill learning. In the majority of studies, the experimenter makes all decisions regarding
the structure of practice. Moreover, the experimenter dictates what is to be learned, how
many skills should be practiced, the amount of time each skill should be practiced, and
the order in which multiple skills should be practiced. As a result, learners may not
process information as deeply, may be less motivated, or may take less responsibility in
their learning process (Chiviacowsky & Wulf, 2002).

This review will assess the tendency of past skill acquisition research to exclude
learners from actively participating in the learning process, and will propose new
investigative avenues for involving learners in the learning process. To begin, this
review will illustrate a framework of self-regulated learning. Next, the review will
describe the distribution of control that may exist between the teacher and student in
learning environments, which can provide a potential framework for incorporating self-
regulation to motor skill learning. The third part will present an overview of how self-
regulation enhances skill learning across motor learning paradigms. More importantly,
this section will explain what portions of the learning environment the student is able to
control. Finally, avenues for future research are proposed to facilitate a “two-way” of
understanding how people learn motor skills.

A Framework of Self-Regulation

*Self-Regulated Learning Defined*

Before examining a framework of self-regulation, an important issue of
terminology must be addressed. Several definitions have attempted to describe self-
regulation. For example, Schunk and Zimmerman (1994) defined self-regulation as “the
degree that individuals are metacognitively, motivationally, and behaviorally active
participants in their own learning process” (p. 3). In addition, they stated that self-regulation is learning that occurs largely from the influence of the “students’ self-generated thoughts, feelings, and actions which are systematically oriented toward attainment of their goals” (Schunk and Zimmerman, 1994, p. ix). Vancouver (2000) defined self-regulation as an individual creating new goals, new means to maintain or attain goals, or changing ways to assess current states. Vancouver also stated that self-regulation refers to “behaviors and mechanisms that improve the creating, affecting, and assessing features of a task” (p. 307). Moreover, Schunk and Zimmerman used the term self-regulated learning synonymously with self-regulation, while Boekaerts, Pintrich, and Zeidner (2000) described self-regulated learning as a narrower construct of self-regulation.

Because investigations of self-regulation have appeared in research journals in educational, organizational, clinical, and health psychology, a variety of constructs, terms, and descriptions have been used to describe self-regulation (Boekaerts, Pintrich, and Zeidner, 2000). Although many perspectives on self-regulation exist, common themes have surfaced among the variety of constructs and definitions. According to Boekaerts, Pintrich, and Zeidner (2000), such commonalities include the understanding of self-regulation as a systematic process of human behavior. Such human behavior includes setting personal goals and controlling behavior that aids in achieving those goals. Beyond this agreement, there seems to be even greater consistency among researchers that self-regulation requires a cyclic interaction of goal setting, steering processes and strategies, and self-evaluation that is mediated by feedback. Thus, the term “self-regulation” serves as an umbrella term to explain how individuals control their
efforts to attain goals. Whether used to discuss self-regulation of diet, addiction, or learning, “self-regulation” describes the way that individuals monitor and control their thoughts and actions toward the attainment of goals.

For the purposes of this review, the term self-regulation will refer to the way individuals control and monitor their efforts in academic and motor skill learning environments. Self-regulation will be used synonymously with self-regulated learning, learner control, and self-control. When these terms are used, they generally refer to the learner’s ability to make decisions within the learning environment. The next section of this review will discuss the processes underlying self-regulated learning.

**A Framework for Self-Regulation**

The cyclic interactions among goal setting, steering strategies, and self-evaluation form a framework of self-regulation. This framework involves one’s analysis of a previous performance and ability to make adjustments based on previous performance (Zimmerman, 2000). The cyclic nature of self-regulation described by Zimmerman (2000) consists of a triadic cycle (see Figure A.1.1) of personal, behavioral, and environmental factors. Most researchers agree that goal setting, steering processes and strategies, feedback, and self-evaluation are the basic concepts that define and conceptualize self-regulation (Boekaerts, Pintrich, and Zeidner, 2000). A close look at Zimmerman’s triadic cycle of self-regulation illustrates this concept quite well. This cycle of self-regulation is comprised of three major components: person, behavior, and environment. The personal component involves monitoring and changing cognitive states (Boekaerts, Pintrich, and Zeidner, 2000). For example, a learner visualizes how a golf ball would roll along the contours of a putting surface or changes the cognitive
strategy required to learn a new putting movement. In the behavioral component, the individual observes and adjusts performances (Boekaerts, Pintrich, and Zeidner, 2000). Thus, a learner could vary the golf putting distance during practice after ten consecutive putts have been made or change which golf club is used according to the amount of practice time available. The final component, the environmental component, refers to the individual observing and adjusting environmental conditions (Boekaerts, Pintrich, and Zeidner, 2000). For instance, if a golfer wants to practice putting in the rain, then he or she can wait for a rainy day to practice or water the putting surface to mimic a surface encountered in rainy conditions. Another example of the environmental component is when a golfer chooses to practice hitting the golf ball on various uneven surfaces as opposed to always hitting off a flat surface.

According to Zimmerman (1989), these three components are not isolated but, as can be seen in Figure 2, are connected by three components of self-regulation via strategy use and feedback loops. The personal and behavioral components are linked by behavioral self-regulation and a feedback loop. The feedback loop is enacted when a learner observes his or her own performance; self-regulation then enables a change in behavior based upon previous performance. For example, a golfer employs a feedback loop when he or she switches from using one type of putting stroke to another type of putting stroke because the feedback of the prior performance indicated that another style may be more conducive to achieving the goal. The golfer may continue to switch between the two styles, or even introduce a new style, in an effort to find which will produce the desired effect. The learner modifies his or her behavior, using different strategies to accomplish a goal movement.

The behavioral component is then connected to the environmental component via environmental self-regulation, without a feedback loop. Environmental self-regulation occurs when a learner changes environmental conditions based upon his or her performance (Boekaerts, Pintrich, and Zeidner, 2000). A golfer can change the environmental conditions by selecting a larger club size because the previous club did not enable a sufficiently long shot. The environmental component is then linked to the personal component through feedback and strategy. Once the learner receives feedback from the environmental component, then he or she can decide to keep the current strategy or use a different strategy.
According to Zimmerman and Martinez-Pons (1990), given the feedback that exists within the framework of self-regulation, self-efficacy has a direct effect upon strategy selection and use. If a golfer repeatedly utilizes a mental swing concept and it does not work, he or she will reduce the future use and selection of that strategy. Moreover, self-efficacy is highly correlated with the application of self-regulatory strategies. The greater the self-efficacy the learner possesses, the greater the amount of self-regulatory strategies instituted (Zimmerman & Martinez-Pons, 1990). Accordingly, self-regulation is not a “cookie cutter” process where the same strategies are employed over and over. Instead, self-regulation varies on the basis of personal efforts, behavior, and environmental context, all components of the framework of self-regulation described above (Zimmerman & Martinez-Pons, 1990).

**Self-Regulated Learning Conditions**

Schunk and Zimmerman (1994) stated that there are essential conditions required for self-regulated learning to occur. First is the availability of choice. Students must be able to choose and control elements in their learning environment, such as study strategies or study time. Another requirement is the students must have the option of choosing to participate or select conditions within their learning environment (Schunk & Zimmerman, 1994). Teachers cannot externally mandate students to participate in a particular strategy or learning environment. Support for students’ ability to select the appropriate learning strategies appears in a study by Lodico, Ghatala, Levin, Pressley, and Bell (1983). They taught elementary students two strategies of learning paired words. After the children had learned both strategies, students were given a new list of paired words and were told to choose a learning strategy. Results of the study showed
that a significant number of students demonstrated the ability to choose the more
effective strategy (Schunk & Zimmerman, 1994).

Another condition of self-regulation involves the students’ use of time.
Specifically, the amount of time given to students to complete tasks influences self-
regulated learning because different students require different amounts of time to learn
the same material. Support for this is provided by Block (1971). He demonstrated that
individual differences in students’ achievement are greatly reduced if they are given the
chance to work at their own pace (Schunk & Zimmerman, 1994).

Additionally, it is essential for students to have choice over their performance
outcomes so that they can engage in self-monitoring. Self-regulation is impaired when
students cannot monitor their behavior due to irrelevant or incorrect feedback. Moreover,
students should focus on and monitor the deficient portion of the performed skill,
provided by feedback, and attempt to improve on it. Self-regulation not only requires the
students’ willingness or motivation to participate, but also involves self-monitoring and
self-modulating outcomes of one’s performance (Schunk & Zimmerman, 1994).

A Continuum of Teaching Styles

As a learning environment is constructed, several decisions about its organization
must be made. Questions of organization may include the type of material presented,
how long the learning session will last, and who will do the learning. In the case of a
skill learning experiment, the type of task to be learned, how long participants will
practice, and the type of participants that will partake in the study must be determined.
Similarly, in a classroom setting, decisions must be made regarding the subject material
to be learned, how long the students will study the material, and what type of students the
material suits. In both cases, the interplay of control between the teacher and student results in various teaching styles.

This section of the review has two purposes. The first purpose is to identify the organization of learning environments and the teaching styles that are created based upon who makes the decisions regarding the students’ learning. The second purpose of this section is to provide a framework in which control can be distributed in the learning environment. This framework will not only describe the interplay between the teacher and student but can also serve as a framework for incorporating self-regulating learning into various motor learning research designs. While the terms “teacher” and “student” will be used consistently throughout the following section, one can also think of the interaction between the two as experimenter and participant.

*Categories of Teaching Decisions*

The organization of teaching a session or unit of instruction begins with an understanding of when and where an instructor and student can exhibit control or make decisions within the learning process. Specifically, instructors and students have the opportunity to control three categories that comprise the learning environment. According to Mosston and Ashworth (1986), these categories consist of a pre-impact set, impact set, and post-impact set. In other words, instructors or students can control how the unit of instruction is prepared, how the prepared content is executed, and how the learned content is evaluated.

The pre-impact set involves issues that are common to many teachers as they construct a syllabus or design a course. First, decisions of whom to teach must be determined (Mosston & Ashworth, 1986). For example, will a golf activities course be
designed for novice or advanced golfers? After decisions of whom to teach have been considered, additional pre-impact decisions include the material to be presented, the order of its presentation, the amount of time spent on each section of material, and the quantity of information presented. Pre-impact decisions also include where the learning will occur. For example, will the course be taught in the classroom or on the golf course? Will the students spend an equal amount of time practicing the chip, putt, and full swing?

The second control category is the impact set. This category is commonly known as the practice phase, and consists of executing the design that has been set by the decisions made in the pre-impact set. There are three ways in which the instructor or student can exercise control in this category. The first is by making decisions concerning the adherence to the pre-impact set. Specifically, are all aspects of the pre-impact design followed? The second is by making adjustments that may be required if the pre-impact set is not followed or if the class does not proceed as planned. For example, an activity class may be designed for advanced golfers, but what if novice golfers also want to take the course? Control can be exercised by adjusting the class design for beginners, adjusting the pre-impact set post hoc, or canceling the course (Mosston & Ashworth, 1986). The final way in which the instructor or student can exercise control involves adherence or adjustments to the scheduling of practice. This entails making decisions about the number of skills to be learned, the amount of time allocated to various skills, and how different skills should be distributed over the entire practice session. If we revisit the golf example and examine the amount of skills to be learned, a teacher or student may choose to only practice the chip and putt because there is not enough time to learn the full golf swing. With respect to the amount of time allocated to each skill, the
teacher or student may decide that the putt is learned much faster than the chip, so the amount of time allocated to the chip and putt is adjusted to spend more time on the more difficult skill of chipping. In examining the distribution of skills to be practiced during the class session, the student or teacher must decide the order of what skills should be taught first: the chip, the putt, or the full swing. After each skill has been taught, the student or teacher must determine the order of the skills to be practiced. Specifically, should students practice by repeating the same skill or should they practice so that one skill is not practiced more than two consecutive times?

The last category of control is the post-impact set. This category of control deals with the evaluation of students and the feedback given to students (Mosston & Ashworth, 1986). Student evaluation can be accomplished in a variety of ways. Using the golf class as an example, students can be evaluated with a skills test, a written exam, or a combination of the two. In terms of feedback, students can be given video feedback, verbal feedback, or no feedback at all. It is within the post-impact set that the instructor or students decide how they should be evaluated or what type of feedback they should receive regarding their performance.

Teaching Styles

The impact set discussed in the previous section organized the learning environment into three distinct parts in which the student or teacher may exhibit control. While it may seem that the student or teacher can exercise complete control of all the impact sets, or a combination of the impact sets within the learning environments, there are actually many different ways in which control is shared within and between impact sets. This interplay of control between the teacher and student creates different teaching
styles that exist within a continuum of control. This section will distinguish various teaching styles based on the amount of teacher and student control exercised within the learning environment.

The continuum of control within learning environments consists of complete teacher control at one end and student control at the other (see Figure A.1.2). Complete instructor control takes place when all decisions within the pre-impact, impact, and post-impact categories are made by the instructor, without student input. According to Mosston (1972), this type of instruction is known as the “command style”. The corresponding role of the student in “command style” learning is to respond, perform, and follow the instructions of the teacher. In short, the role of the student is to obey.

Students possess control of the pre-impact, impact, and post-impact sets at the opposite end of the spectrum. This learning environment is known as the “self-teaching style” (Mosston & Ashworth, 1986). This end of the continuum is in sharp contrast to what occurs in a “command style” environment. In the “self-teaching style”, the student has the freedom to make all decisions regarding preparation, content execution, and evaluation within the learning environment. In other words, the student not only designs

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**Figure A.1.2** Mosston’s continuum of control. Note: Adapted from “Teaching Physical Education, 3rd ed.,” by M. Mosston & S. Ashworth, 1986, p. vi.
questions and problems but is also responsible for problem solving and evaluation. Students that undergo this type of learning environment are tenacious and have a strong desire for learning the subject matter (Mosston & Ashworth, 2002). According to Mosston and Ashworth (2002), the self-teaching style does not exist in a classroom setting. Instead, the self-teaching style manifests itself when individuals have a strong desire to pursue hobbies or activities on their own. Even though the student exhibits the maximum amount of control, the self-teaching style is not necessarily the best distribution of control for self-regulated learning. In order to for students to be successful with this style of learning, they must have curiosity, wonder, and tenacity to overcome obstacles in the learning process (Mosston & Ashworth (2002).

Within the extremes of the continuum exist varying degrees to which the teacher or student has the ability to make decisions within the pre-impact, impact and post-impact sets. As the continuum moves from complete teacher control (“command style”) to complete student control (“a self-teaching style”), control of the learning environment incrementally shifts to the student. Specifically, the shift from “command style” to a lesser degree of teacher control is the “practice style” where control transfers from the teacher to the student at the impact level (Mosston & Ashworth, 1986). Returning to the golf class as an example, the teacher plans the course and conducts the evaluations, but the students decide where the class will take place. The students decide if they want to practice on the golf course, in a lecture room, or a combination of the two. Moreover, students decide how much time to allocate to a drill or teaching concept and the amount of time between each new drill and teaching concept. The teacher controls the pre-impact and post-impact sets.
At the opposite end of the continuum, the distribution of control is reversed. As control moves from a “learner’s initiated style” toward a “command style”, the teacher gains control at the preparation level while the student controls both content execution and evaluation. For example, golf students determine when class begins and where class takes place. The students also control the evaluation of their performance, deciding whether they will be evaluated by kinematic measures, performance production measures, or a written exam. The teacher controls the preparation level, which includes what course material will be taught. Thus, the teacher will decide whether or not it is appropriate to teach beginners the full golf swing or a particular shot type (such as curving the ball in different directions). Stages of control that are closer to the middle of the continuum consist of learning environments in which the teacher and students share control of content preparation, content execution, and evaluation (Mosston, 1972).

Such a continuum of control clearly reveals that self-regulated learning can occur within different portions of the learning environment. Instead of perceiving self-regulated learning as a paradigm in which the student controls every aspect of the environment, the continuum allows for a variety of teaching styles in which the student and teacher can share control of the environment.

Self-Regulation in Motor Skills Research

Self-regulation studies have extended to a wide range of disciplines (education, diet, substance dependency), most notably to motor skill acquisition research. Researchers have begun to allow learners to control various aspects of the learning environment to make learners, as Zimmerman (1994) described, active participants in the learning process. Learners are able to be more active within the learning environment
when they are allowed to choose within their learning environment. In motor skill learning research, for example, students may choose when to receive feedback, when to view a model, or when to use a physical assistance device while trying to learn a new skill. This section of the review will discuss various experiments that have incorporated these aspects of self-regulation into the skill learning process. Most importantly to this section of the review is not the comparison of each motor learning paradigm but to show that self-regulation has shown to be beneficial despite the motor learning paradigm being investigated. The purpose of this section is to show that incorporation of self-regulation into motor learning (whether it is augmented feedback, observational learning, use of physical assistance devices, or practice schedules) produces an enhanced learning effect compared to learning environments in which participants cannot exhibit control over their learning.

Before discussing this research, it is important to note that motor skill learning researchers have used a variety of terms to describe self-regulation, such as learner control, self-control, or subject control, even though learners are all engaged in a process of self-regulation. Although researchers may use different terms, they use self-regulation as a theoretical framework. Consequently, for purposes of this review, terms such as learner control or subject control will be used synonymously with self-regulation.

*Augmented Feedback*

The allocation of performance-related information, specifically augmented feedback, has proven to be a very effective tool for learning new motor skills. Distinct from task-intrinsic feedback, augmented feedback is a type of performance-related information that is received from a source external to the performer (Magill, 2004). For
instance, if a golfer tries to putt a ball into the hole and can see the ball miss the hole, then he or she is receiving task-intrinsic feedback. On the other hand, if the golfer obtains information regarding the angle of the putter at the point of impact from a computer or outside observer, then he or she is receiving augmented feedback. Thus, augmented feedback is information related to the performance of a skill that adds to sensory feedback (Magill, 2004). Most augmented feedback research has focused on answering questions regarding when and what type of augmented feedback should be allocated to the learner. In other words, the experimenter decides when augmented feedback will be given with no input from the learner.

One of the first studies to incorporate self-regulation into a skill learning environment was by Janelle, Kim, and Singer (1995). The researchers demonstrated the benefits of the learner’s option to choose when to receive performance related feedback, known as knowledge of performance (KP), which in this study was limb acceleration and limb position. The experimenters compared a self-regulated group to four other groups receiving predetermined KP schedules. The four groups with predetermined KP schedules (decided upon by the experimenters) included a summary condition in which participants received KP after every five trials, a fifty percent condition in which participants received KP on every other trial, a yoked control condition in which participants’ KP schedules were matched to the order of the self-regulated group, and a control group in which participants received no feedback. College-age participants were asked to perform an underhand ball toss as accurately as possible while exhibiting a desired form. Those who had control over their feedback schedule and chose when they received KP performed significantly better on a retention test than those who had a
predetermined feedback schedule. In addition, the self-regulated feedback group exhibited a fading schedule of feedback: as the number of trials performed increased, the amount of feedback requested decreased. In past research by Weinstein and Schmidt (1990), this fading effect was shown to be an effective means of scheduling feedback. Janelle et al. suggested that members of the self-regulated group processed information more efficiently and retain information more effectively because they performed a self-induced fading schedule. Of particular importance is that the yoked control group had the exact schedule as the self-regulated group; the difference is that the self-regulated group was given the option to choose. The self-regulated group performed significantly better than the group that had the same KP schedule but no choice.

Another study of self-regulated feedback provided similar results to those of Janelle et al. Janelle, Barba, Frehlich, Tennant, and Cauraugh (1997) used self-regulated knowledge of performance feedback to assist participants in learning to throw a ball. This study contained four groups: a KR (knowledge of results) only group, a summary KP group, a self-controlled KP group, and a yoked control group. The KR group consisted of participants receiving feedback about the performance outcome of the skill; examples of KR include distance thrown or speed of the ball. The summary KP group received knowledge of performance feedback after every five trials; the experimenter determined KP after every fifth trial. The self-controlled KP group received knowledge of performance feedback at their request. The yoked control group received KP based upon the order of the self-controlled KP group. The results revealed that the self-regulated group, or self-controlled KP group, demonstrated a higher level of throwing accuracy and form on a retention test than a yoked control group and the summary KR
group. Janelle, Barba, et al. (1997) concluded that self-regulation may indirectly enhance learning. This effect could possibly be due to motivational influences on cognitive processes. The authors contended that the learner is more active in the self-regulated learning plan. In addition, the learner must assume more responsibility for acquiring proficiency. Finally, the experimenters suggested that self-regulation can lead to more effective learning strategies than rigid feedback schedules.

To this point in the review, the self-controlled feedback research can only infer or make suggestions about the underlying processes that are responsible for the enhanced learning effect seen in self-controlled learning. The experimental designs have only sought to explore whether or not there was a learning benefit when compared to a predetermined feedback schedule. Many inference of self-regulation or motivation due to control over practice have been made but the experimental designs thus far have lacked the ability to identify the cause for the enhanced learning effect. In order to develop a theoretical approach to this new avenue of research there must be some attempt from a design standpoint to investigate the mechanisms that are responsible for this enhancement in learning. In an attempt to explore whether or not self-regulated feedback schedules are beneficial because they allow the learner to tailor their needs, Chiviacowsky and Wulf (2005) conducted a study in which participants requested feedback before a trial or after a trial was executed. Participants were asked to sequentially depress four keys on a number pad with goal segment movement times. The study consisted of two groups: one group decided before a trial if they wanted feedback or not, and the other group decided after a trial if they wanted feedback. Results of the transfer test, in which participants performed different movement times from those performed during practice, revealed that
the group that requested feedback after the trial was performed had significantly lower relative timing errors than the group that decided upon feedback before each trial. Although the groups were not significantly different on a retention test, the group that decided whether or not they wanted feedback after each trial performed better than the group that decided upon their feedback before the trial. Chiviacowsky and Wulf concluded that a critical factor for the effectiveness of self-regulated feedback is a function of the learner’s performance. That is, simply having control of feedback does not provide a learning benefit. The learner must be able to observe his or her performance to use augmented feedback effectively. These findings give much support to the framework of self-regulation discussed in the preceding section, in which learners must be able to observe their performance before making adjustments to movement strategies.

In an additional attempt to investigate the mechanisms of self-controlled learning Chiviacowsky and Wulf (2002) conducted a study to explain why self-regulated feedback is more beneficial than a predetermined schedule of feedback. The authors hypothesized that self-regulating the amount of feedback allows learners to use feedback more effectively because they request it when they need it. Conversely, learners with predetermined feedback schedules cannot request feedback when they need it. In order to explore their hypothesis, the experimenters had participants learn the relative timing structures of four keys on a number pad. Overall, transfer test results were consistent with the previous studies (Janelle, Kim, & Singer, 1995; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997) where the self-regulated group performed better than the yoked group (with a predetermined feedback schedule). In this particular case,
participants in the self-regulated condition produced lower absolute error scores than participants in the yoked condition. To explore why self-regulating is beneficial, the experimenters gave participants from the self-regulated group questionnaires that inquired when and why they asked for feedback and when they did not request feedback. Learners in the yoked condition were asked if they received feedback when they needed it, if they had the choice. Results of the questionnaires revealed that participants in the self-regulated group requested feedback mostly after good trials and did not ask for feedback after bad trials. Results of the acquisition phase confirmed their answers to the questionnaires, revealing that on average absolute timing errors were lower on trials for which feedback was requested when compared to trials in which feedback was not requested. In the yoked condition, most participants said they did not receive feedback when they needed it. The yoked participants said that they would have liked to receive feedback after trials in which they performed well. Chiviacowsky and Wulf (2002) concluded that self-regulating learners did not request feedback randomly. Instead, they developed a strategy to use feedback to confirm the accuracy of their performance. This particular result highlights the utilization of the self-regulating framework discussed previously. Learners in the self-regulated group developed a particular strategy, executed the strategy, and then used feedback to measure strategy’s effectiveness in relation to accomplishing the goal. Interestingly, the questionnaires also revealed that the yoked group would have adopted a similar strategy to the self-regulating group (which requested feedback after successful trials) had they not been constrained by a rigid schedule.
Observational Learning

From dance routines to golf swings, it is common to see instructors demonstrating movements and learners visually observing movements produced by an instructor. In many applied and research situations, the learning environment is structured so that the instructor or experimenter decides when it is appropriate for the learner to view a demonstration. One of the first investigations of self-regulation within an observational learning paradigm was a study by Wrisberg and Pein (2002). They gave learners the opportunity to control the frequency with which they viewed a skilled demonstration during initial practice of the badminton long serve. Wrisberg and Pein found that the participants who were allowed to control the frequency of viewing a demonstration acquired and retained a level of movement form that was equivalent to learners who viewed the demonstration 100% of the time. In addition, the self-regulated group’s performance was significantly better than a group who never viewed the demonstration. According to Wrisberg and Pein, the opportunity to choose is beneficial to acquiring proper form. Moreover, Wrisberg and Pein noted that the self-regulated group chose to view the model primarily during the beginning of practice and less often toward the end of practice. On the basis of the results from the acquisition phase, they suggested that the practice period for the self-regulated group was consistent with Gentile’s initial stage of learning, which states that at the beginning of practice the learner attempts to acquire a general movement pattern using information available within the environment (Magill, 2004). Wrisberg and Pein also suggested that they could not determine whether the self-regulated group’s performance was due to the availability of choice or to the reduced frequency of observation.
Wrisberg and Pein could not distinguish the learning benefits of the self-regulated group because their study did not include a yoked group. In an experiment that did include a yoked group, Wulf, Raupach, and Pfeiffer (2003) demonstrated that it was, in fact, the ability of learners to choose that was beneficial for observational learning. They separated the participants into two groups and asked them to learn a basketball free throw. Both groups were presented with an expert video model to observe during practice. In the self-control group, participants were given the option to choose when they would like to view a model. The second group, or the yoked group, could not choose when to view or observe a model. Each participant in the yoked group was paired to a member of the self-control group; the same number of observational requests occurred at the same time during practice for both groups. The only difference was that there was no availability of choice for the yoked condition. The results showed that the self-control group, which could view the video anytime they requested it, demonstrated a more effective movement form than the yoked group, which did not have the ability to choose. Wulf et al. demonstrated that the option for learners to choose when they viewed a model was responsible for the enhanced learning effects.

*Physical Assistance Devices*

Wulf and Toole (1999) used self-regulation of the use of physical assistance devices to instruct students to learn a ski slalom skill. Subjects in the self-regulated group were allowed to use ski poles as physical assistance when requested. The other two groups consisted of a yoked group and a group with no assistance at all. Although there were no differences in the two groups’ performance during practice, the self-regulated group performed significantly better on a retention test than a group whose
practice schedule was yoked to the self-regulated group. Questionnaire data, given during acquisition only, revealed no differences in participants’ fear of falling, but they did reveal that participants with a predetermined schedule overestimated their abilities to reproduce the skill on a retention test. Wulf and Toole contended that learners used the poles to try out different techniques or strategies. According to the authors, the use of poles allowed the performer to better explore the goal movement. They concluded that learners chose practice conditions that were conducive to learning. The consistent findings between the self-regulated groups of the observational learning and physical assistance device studies were that learners explored or discovered the general movement pattern. Such learning was revealed through the reduced amount of requests for observation or use of the assistance devices. In addition, the process of yoking participants that could not choose within their learning environment to the self-regulated condition supports the theory that reduced frequency of feedback was not the primary factor for beneficial learning effects.

**Practice Schedules for Learning Motor Skills**

Thus far in the review, the studies of augmented feedback, observational learning, and physical assistance have addressed learning environments in which only one skill was learned. In many real world learning environments, such as in the golf class example, more than one skill must be learned within a practice session. Self-regulation has been found to produce learning benefits in practice environments where multiple skills must be learned. Specifically, learners benefit from the opportunity to choose the style of practice or which skill to practice for each repetition. One of the first studies to test this concept was Titzer, Shea, and Romack (1993), which compared a self-regulated
practice condition to random and block practice schedules. Random practice is a way of
distributing multiple skills within a learning environment. For example, if an instructor
was required to distribute the putt, chip, and full swing within a practice session, the
practice schedule would consist of a random distribution between the putt, chip, and full
swing. In contrast, a blocked practice environment would consist of practicing all the
putting repetitions, then the chipping repetitions, and finally the full swing repetitions.
Using a barrier knockdown task, in which learners were required to knockdown barriers
with a ball using three prescribed patterns, Titzer et al. compared three groups. The first
group was a self-regulated group, in which participants generated their own practice
schedule. The second group used a random practice schedule, and the third group
practiced under a blocked schedule. Results showed that the blocked and self-regulated
group exhibited significantly faster reaction times than the random group during practice.
The self-regulated group again demonstrated a significantly faster reaction time than the
blocked group on an immediate retention test after practice. Also during the immediate
retention test, the self-regulated group had significantly faster movement times than the
random and blocked groups. In a retention test 24 hours later, the self-regulated and
random groups made fewer errors than the blocked group. Also, the self-regulated group
chose schedules that consisted of mixed styles of blocked practice, serial schedules
(similar to random practice, but the learner knows which skill will be practiced for the
upcoming trials), and random schedules.

Using a different approach from the studies previously reviewed, Bund and
Wiemer (2004) investigated the effects of self-controlled learning with respect to self-
efficacy beliefs of the participants. Specifically, they investigated whether the control
over a preferred or non-preferred aspect of practice would affect self-controlled learning. The experimenters had participants control parameters of a table tennis forehand stroke. Specifically, participants controlled the direction and length of the ball trajectory, as delivered by a machine. Results indicated that the self-control groups performed significantly better on forms scores of the forehand stroke than yoked groups. While the investigators incorporated the learning of different tasks, they did not specifically investigate whether or not learners are able to self-control multiple tasks. Instead, their purpose was to investigate learners’ preferences and self-efficacy ratings on preferred (schedule of video instruction) and non-preferred (variability of practice) practice conditions. This experiment provided a unique approach to self-controlled learning because much of the self-control research discussed to this point has made many inferences of motivational factors that are due to learner involvement but have not sought to investigate them directly.

In 2004, Wu and Magill had participants learn to putt a golf ball from three different distances, determined by index of difficulty. Two groups were included in the study. The first was a self-regulated group, in which individual participants could choose three distances at the beginning of each trial during acquisition. Participants in the second group, with a predetermined schedule, had their practice schedule yoked to the self-regulated group. Although no significant differences were found on transfer tests, the self-regulated group performed better than the yoked condition in both a 5-minute and 24-hour transfer test. Wu and Magill suggested that actively involving learners during practice, by giving them the ability to structure the schedule of practice trials, can produce learning processes that enhance motor skill learning. In this particular study, the
sensitivity of the way the putts were scored may provide an explanation for a lack of observed statistical differences. Instead, of using concentric rings to measure error, the use of radial error would have been a more sensitive means of measurement.

Although self-control is a new avenue of research in motor learning, there have been clear findings that demonstrate the benefit of the learner controlling some aspect of the practice environment. The studies in this review provide a clear depiction of the benefit of self-controlled learning over predetermined practice environments but lack the ability to extend their findings to the causes of self-controlled learning. In addition, these studies do not seem to follow a framework as to how control should or can be distributed within the learning environment (this will be described in further detail later in the review). In each of the studies reviewed, there was little explicit reference to where the learner was given control over the practice session. From a practitioner’s standpoint, this may makes it difficult to extend the use of self-controlled learning outside of the experimental design of each study.

**Task Characteristics**

Does the experimental task affect the learning benefits of self-regulated learning as it relates to skill learning? The answer to this question, from the research presented, seems to be no. The self-regulated learning of motor skills appears to be generalizable across many task characteristics. Experiments have used both laboratory and non-laboratory tasks to demonstrate the learning benefits of self-regulation. For example, Wulf, Rupach, and Pfeiffer (2003) used a basketball free-throw to demonstrate the self-regulated learning benefits in a non-laboratory task while Chiviacowsky and Wulf (2002) used a keypad sequence task to demonstrate learning benefits using a laboratory task. In
addition to laboratory and non-laboratory tasks, learning benefits of self-regulation have also been demonstrated in discrete (definite beginning and end to a skill), continuous (no definite beginning or end to a skill), and serial tasks (series of discrete skill). Using a ball throw task, Janelle, Kim, and Singer (1995) demonstrated the generalizability of self-regulation to discrete tasks. Both a barrier knockdown task (Titzer, Shea, & Romack, 1993), known as a serial task, and a ski slalom simulator, known as a continuous task (Wulf & Toole, 1999) were used to demonstrate the learning benefits promoted by self-regulation.

The various areas of skill learning research demonstrate a relatively generalizable effect of self-regulation on skill learning. Experiments have used both laboratory (Chiviacowsky & Wulf, 2002) and non-laboratory tasks (Wulf, Rupach, & Pfeiffer, 2003) to demonstrate the learning benefits of self-regulation. In addition, learning benefits of self-regulation have also been demonstrated in discrete tasks where there is a definite beginning and end to a skill (Janelle, Kim, and Singer, 1995), continuous tasks where there is no definite beginning or end to a skill (Wulf & Toole, 1999), and in tasks where there are a series of discrete skills, known as serial tasks (Titzer, Shea, & Romack, 1993). This suggests that learning benefits are not a byproduct of task but a product of self-regulation.

Motor Learning Research and Mosston’s Continuum

Mosston’s continuum of learning provides a framework for learning environments in which the learner or experimenter can have a range of control. Thus far in the motor learning research, from the least amount of control (command style) to the greatest amount of control (self-teaching style) the amount of learner control exhibited in each of
the experiments has been the same. That is, participants in each of the studies previously
discussed allow the learner control within the impact set. Moreover, participants are only
controlled one aspect of the impact set. When learners controlled their feedback, they
were only allowed to control when in the practice session they would receive feedback.
This was the same for the observational learning, use of physical assistance devices, and
practice schedule paradigms. In short, the literature indicates that the amount of learner
control within the practice environment was small when viewing it from Mosston’s
continuum of control. Mosston’s continuum of control provides a framework of control
that is shared between the experimenter and the learner in which multiple decisions can
be made at the pre-impact, impact, and post-impact set. Relating this to the studies
mentions previously, the experimenter decided what was going to be practiced, the
number of trials, and how the performance was to be evaluated. In other words, the
experimenter controlled all parts of the learning environment except for one aspect of the
impact set.

After using Mosston’s continuum control as a framework to organize the amount
of learner control exhibited in previous motor learning research it is now apparent that the
scope of control in motor learning research is limited. There lies ahead much more to be
investigated in the amount of control given to the learner and the potential learning
effects that may accompany increased amounts of control. Another finding that has come
to light in using Mosston’s continuum of control as a framework is the fact that the
learner needs only to possess a small amount of control within practice to receive
learning benefits. This shows that self-regulated motor learning environments do not
completely surrender control to the learner but instead they provide the learner with a small amount of control that is able to enhance learning.

Motor Skill Learning Explanations for the Benefits of Self-Regulation

Self-regulated motor skill learning has demonstrated that learners benefit from the ability to control their learning environment. From skill learning paradigms of augmented feedback to practice schedules, self-regulation has demonstrated the learning benefits that come by allowing the learner to control portions of the learning environment. In this part of the review, we will examine why self-regulation produces learning benefits. This explanation will include an emphasis on problem solving within the learning environment, accounting for learning differences, and appropriate practice for performance environments. Before we move on, an important point to consider when discussing self-regulated motor skill learning is that they are not discovery learning environments. Within all the studies discussed thus far, experimenters gave participants a minimum amount of instruction regarding the performance production of the motor skill. Some degree of instruction is required to prevent the learner from self-regulating towards incorrect goals. For instance, if novice golfers do not receive initial instruction of how to perform the chip, putt, or full swing, they may develop incorrect goals.

*Explanations Using Motor Skill Learning Paradigms*

The benefits of self-regulated learning are best illustrated by the study of Chiviacowsky and Wulf (2002), which explored why learners choose feedback. Questionnaire results revealed that learners in the self-regulating condition did not choose their feedback in a random fashion. Instead, participants employed a strategy for choosing their feedback that was based upon performance. They chose feedback to
confirm that their performance was successful and to fine tune their technique if the performance was not successful. Moreover, Chiviacowsky and Wulf suggested that feedback was not chosen after poor trials because it would have been redundant to the learners. This indicates that learners in the self-regulated group were utilizing the triadic processes of self-regulation. The opportunity to control when and how much feedback they received allowed learners to evaluate their strategies based upon prior performance. In contrast, learners in the yoked condition reported that they did not receive feedback after the appropriate trials. They indicated that if they had the opportunity to request feedback, they would have requested it after successful trials. Since these learners were not allowed to request their feedback, they were unable to effectively evaluate their performance and appropriately adjust their movement strategies if they were incorrect.

The feedback schedule exhibited by the learners also matched well with previous findings established by optimal feedback schedules. According to Weinstein and Schmidt (1990), “fading” the frequency of feedback, or reducing the amount of feedback over the practice session, is beneficial for learning. Learners in the Chiviacowsky and Wulf (2002) study unknowingly showed signs of “fading” when they chose feedback schedules comprised of many feedback requests at the beginning of practice and less feedback toward the end. This showed that learners, given the opportunity to choose, can independently institute an effective means of practice.

The study by Chiviacowsky and Wulf (2005) provided further evidence to support that skill learners utilize the triadic processes, which consists of a learner’s cyclic interactions among goal setting, steering strategies, and self-evaluation. Learners who had the option to choose to receive feedback after each trial performed better than
learners who chose before each trial. This increase in learning suggests that learners use feedback from their performance on previous trials to adjust their movement strategies for future trials. Learners who chose before each trial to receive feedback could not use the feedback to gain information about the movement pattern that was produced. In effect, they could not effectively strategize the allocation of their feedback based upon their outcome performance. According to the triadic process, or the framework of self-regulation, the learner must use feedback to compare performance to the goal. The learner is then able to compare and adjust behavioral components (such as mental imagery) and environmental components (such as the amount of feedback) to accomplish the goal movement.

Why it works - Explanations Using Motor Skill Learning Concepts

Studies suggest that individual differences should be considered in learning environments. Magill (2004) stated that if two individuals are given equal training experience and practice for a given activity, they may not perform at the same level due to differing levels of motor abilities for a given task. Rigid practice schedules do not account for individual differences because they treat learners as having equivalent motor abilities and learning rates. For example, one learner may need five trials to fully evaluate a movement strategy while another learner may require ten trials. Allowing the learner to choose within the practice environment can account for the differences associated with individual disparities among skill learners.

Transfer-appropriate processing may also help explain the learning benefits exhibited in self-regulated learning environments. According to Morris, Bransford, and Franks (1977), it is not the amount of processing that enhances learning but the
appropriateness of cognitive processing for retention or transfer. Not allowing learners to control their practice environment may inhibit them from fully performing the problem solving activities required on a test or real world activity. Tests or real world environments require the learner to problem solve independently of an experimenter or instructor. Predetermined practice schedules may inhibit learners from properly using learning strategies because they may develop reliance on external sources (the experimenter or instructor, for example) that are not present in transfer environments. Moreover, if an external source determines the practice schedule, learners may become reactionary to the experimenter as opposed to reactionary to their performance. The learners should evaluate performance and associate future trials to successfully achieving the movement goal rather than wait for the instructor to provide them with advice.

Thorndike (1914) explained transfer effects of task and environmental characteristics as “identical elements.” He stated that positive transfer will increase if the elements within practice are identical to the elements present in the test environment. These elements may include limb coordination patterns and environmental cues. The “element” of independence and the individual’s control over the environment, present in self-regulated learning, can provide positive transfer of learning. Contrastingly, in rigid practice schedules, the learner cannot be independent nor have control of the environment, which may inhibit performance in a transfer environment. Lee (1988) stated that learning is optimized when processing activities promoted by the practice conditions resemble the processing requirements in a test. In addition, Lee stated that transfer-appropriate processing allocates a greater role to the learner as an active processor of information. The question then arises: When in a real world activity such as
driving a car or playing golf is there an external source prescribing a schedule of tasks? Real world activities are typically determined by an individual’s interaction with the environment, not according to a prescribed schedule. Instead, in real world activities, the performer makes independent decisions about what tasks to perform and in what order. For example, the golfer chooses which club to use or which type of golf shot to execute based on his or her own analysis of the situation. The success within the environment is based upon the individual properly self-evaluating performance in order to achieve the specified action goal. Self-regulated learning environments match well with real world environments because learners problem solve on an independent basis with minimal reliance on an external referent.

Recently in the motor learning literature, cognitive effort has been used to describe the mental effort that is generated with various motor learning environments that enhance learning. Lee, Swinnen, and Serrien (1994) discussed three motor learning paradigms (observational learning, augmented feedback, and contextual interference) and associated cognitive effort as the driving force behind enhanced learning effects in specific practice designs associated with each of the different learning paradigms. The authors define cognitive effort as “the mental work involved in making decisions” and suggest that because there is a greater amount of cognitive effort in specific practice environments learning is enhanced. Lee et. al. state that learners should not be “lazy thinkers” in their learning process because in order for learners to be “functionally independent” practice should be designed so that learners are able to think and act independently.
The concept of cognitive effort may help to explain the enhanced learning effect seen in self-controlled learning compared to predetermined practice schedules. In self-controlled learning, participants must self-evaluate their performance and think of the best ways to adjust practice according to their performance. In effect, metacognitive processes are initiated because the self-control participants generate movement strategies, evaluate movement strategies, and then change the movement strategies based on an evaluation of their performance. When it comes to self-control participants estimating their performance, Chiviacowsky and Wulf (2002) found that self-controlled learners were effective in estimating their errors and were aware of the differences between good and bad performances. Moreover, this indicates that self-controlled participants elevate their cognitive activity in practice by continually estimating their error throughout practice while thinking of strategies to structure their practice. The fact that self-control learners are able to control some aspect of their learning environment encourages them to become independent problem solvers through forming strategies, testing strategies, and changing strategies if they are not effective. This increases their cognitive effort and helps them to become functionally independent performers outside of practice because the flexibility of the practice environment allows them to find, refine, and make movement decision on their own. Within predetermined practice environments, the demands of practice are far less. The participants may very well self-evaluate performance but to a lesser degree because their self-evaluation has no effect on the structure of practice. In addition, participants with predetermined practice schedules are unable to fully explore and evaluate movement strategies they generate because the experimenter or instructor dictates the structure of practice. For example, if a learner
generated a new movement strategy and wanted to evaluate the efficacy of the strategy by practicing the task for five consecutive trials he or she would not be allowed to do such because the predetermined schedule may require them to practice another task before they are able to confirm the effectiveness of the strategy. On the other hand, if the predetermined schedule allowed for ten consecutive trials to be practiced when the participant only needed 5 trials, this may cause the participant to have low cognitive effort because the learner may repeat the movements without much planning (Lee, Swinnen, & Serrien, 1994). The ability to structure the practice environment based on one’s performance enables the learner to constantly self-evaluate performance and adjust movement strategies or the structure of practice based on their performance toward pursuit of the movement goal thereby increasing their cognitive effort.

Implications for Future Research

The skill learning research discussed in this review provides a basis for exploring the learning benefits of allowing the learner to control portions of practice. Initial studies of learners controlling their feedback schedule showed beneficial learning effects that were not demonstrated when the experimenter dictated all the practice variables. Although various studies of learner control (e.g. observational learning, physical assistance devices, and augmented feedback) have shown that self-regulated learning is generalizable to different skill learning paradigms, skill learning studies must continue to explore other paradigms in which the learner has choice. As a result of the this review, the following section will focus on directions for future research and testable hypotheses for researchers that wish to continue the study of self-regulation of learning motor skills. Mosston’s continuum will be discussed because its continuum of teacher-student control
offers a framework for future studies. In addition, learning multiple skills will be discussed because most motor skill learning studies of self-regulation only address learning of one distinct motor skill when many practical applications consist of learning multiple motor skills.

*Mosston’s Continuum of Control within Motor Skill Learning Environments*

The skill learning studies discussed in the preceding section are very much alike when considering the amount of control given to the learner. When speaking of the categories of control that comprise a learning environment (i.e. pre-impact, impact, and post-impact), all of the studies discussed involved the learner in only the impact set. Furthermore, learners possessed control of no more than two aspects of the impact set. In the augmented feedback studies, learners controlled only when and how much feedback they received. In the observational learning studies, learners controlled only when they wanted to view a model and when they did not want to view a model. Similar to the learners in the augmented feedback studies, learners who used physical assistance devices controlled two variables within the impact set: the number of times they used physical assistance and when they used physical assistance. Also, the learners who practiced multiple barrier knockdown tasks chose their practice schedule, that is, when and how many times they would practice a pattern.

In terms of Mosston’s continuum, skill learning studies conducted thus far are located at the end of the continuum where the teacher exhibits the most control in the learning environment. Specifically, the environment in which the learners operate would be categorized as the “practice style”, which is the first shift from teacher control (“command style”) to student control. In the practice style, the teacher or experimenter
shifts control of the impact set to the learners by allowing them to make decisions that may include order of tasks, time interval between tasks, starting time per task, ending time per task, or pace and rhythm (Mosston & Ashworth, 1986). In previous skill learning studies, the learner has been granted a limited amount of control. The teacher or experimenter has been responsible for all of the pre-impact decisions that consist of content, the type of students that will do the learning, and evaluation of performance.

So far, a very small portion of the continuum of control has been explored using motor skills. While there is strong support for these particular decisions within the impact set of the “practice style”, many decisions are still left unexplored within the “practice style”, such as the order of tasks when several tasks must be learned. Outside of the “practice style”, many aspects of Mosston’s continuum have not been investigated such as learner control over the decisions in the pre-impact and post-impact sets of the learning environment. Future studies need to include practice environments in which learners make decisions regarding the type of feedback given, the type of performance evaluation, or the number of tasks to learn.

With respect to Mosston’s continuum of control, a self-regulated practice environment will produce greater learning benefits than a predetermined practice environment as long as external sources, such as the teacher or experimenter, do not prevent self-regulatory processes. An example of a teaching style that prevents self-regulation is the command style. Since the teacher makes all of the decisions in the learning environment, the student cannot utilize the cyclic interactions of goal setting, steering strategies, and self-evaluation. Support for this can be seen in the study provided by Chiviacowsky and Wulf (2002), in which learners reported they would have preferred
to receive feedback after successful trials. The reports suggested that learners requested feedback after successful trials to confirm the movement strategies they employed. Learners in the yoked condition were unable to confirm their movement strategies because if they wanted to confirm a movement strategy, the experimenters might not have provided them with feedback. Learners in the yoked condition reported that if given the opportunity, they would have chosen feedback after successful trials.

*Learning Multiple Tasks*

Learning a variety of different skills versus learning varying parameters of the same skill has been an extensively researched topic in skill acquisition. From studies of distributed practice to contextual interference, researchers have made an effort to investigate the learning processes that are associated with scheduling practice for multiple tasks. While most skill learning studies have focused their efforts on predetermined schedules of practice, few studies have investigated self-regulation of the order in which multiple tasks are practiced.

Titzer, Shea, and Romack (1993) and Wu and Magill (2004) conducted studies that allowed learners to choose the manner in which they practice multiple skills. Unfortunately, both studies did not perform an analysis of the acquisition results to determine why participants chose to schedule practice the way they did. This includes asking participants why they switched from practicing one skill and started practicing another. Further exploration of self-regulated learning of multiple tasks should include an acquisition analysis of why learners choose the way they do. In addition to asking why learners choose, future studies should include quantitative data that probes the “randomness” of the practice schedules that learners design for themselves.
With respect to learning multiple skills, it is hypothesized that when learners are required to learn multiple tasks, self-regulating students will show greater amounts of learning than learners who use predetermined practice schedules. The basis for this hypothesis is derived from the cyclical process of self-regulation (see Figure 2) and the studies provided by Titzer, Shea, and Romack (1993) and Wu and Magill (2004). In their studies, they allowed learners to choose the order of tasks practiced. This gave learners the opportunity to invoke the cyclic process of self-regulation, which gave learners the opportunity to test strategies and find if the particular strategies they employed were successful. In rigid practice schedules, external sources may interrupt the learners’ evaluative process during acquisition, disabling performers from invoking self-regulatory processes. For example, a learner may be trying a new strategy but needs additional repetitions to confirm its effectiveness. If an outside source determines the practice schedule, the learner is then unable to fully evaluate the use of the strategy employed because the schedule may require the learner to progress to another task before he or she is ready to.

In a self-regulated learning environment, learners find the appropriate learning strategy through self-monitoring their performance; they are then able to adjust their learning environment appropriately. As seen in the discussion of individual differences, all learners do not have the same rates or the same styles of learning. This leads to a hypothesis with respect to acquisition. Because self-regulated learning schedules allow learners to employ their own styles of learning, an analysis of acquisition would reveal that learners do not employ the same learning schedule because of individual learning differences, such as the rate of learning and the style of learning. Specifically, it is
hypothesized that learners will not practice tasks the same number of times or in the same order. In addition, learners will likely change the task they are practicing based upon their performance as opposed to changing a task because they preplanned a schedule.

While researchers have produced exciting findings in the field of skill acquisition, previous studies have neglected to fully examine the learner’s impact on practice. Future studies that address increased learner control over the practice environment will prove fruitful to the diverse disciplines implicated in skill acquisition research. Hopefully, future studies will enable a true “two-way street” between the learner and instructor, which would allow the student to become a more active participant in the learning process.
Chapter 3: ALLOWING LEARNERS TO CHOOSE: SELF-CONTROLLED PRACTICE SCHEDULES FOR LEARNING MULTIPLE MOVEMENT PATTERNS

Self-Control Task Selection during Acquisition (each color represents a different task)
Chapter 4: SELF-CONTROLLED LEARNING: IS SELF-REGULATION RESPONSIBLE FOR THE LEARNING BENEFITS?

Self-Control Task Selection during Acquisition (each color represents a different task)
Chapter 4: SELF-CONTROLLED LEARNING: IS SELF-REGULATION RESPONSIBLE FOR THE LEARNING BENEFITS?

Self-Control Before Task Selection during Acquisition (each color represents a different task)
APPENDIX 3: CONSENT FORMS

Louisiana State University-Baton Rouge Campus Consent Form I: To Dictate or Not: The Exploration of a Self-Controlled Practice Schedule Using a Golf Putting Task

Study Title: To Dictate or Not: An Exploration of a Self-Regulated Practice Schedule

Performance Sites: LSU Motor Learning Lab

Investigator: Will Wu, Telephone: (225) 578-4395 M-F: 10am-11am

Purpose of Study: The purpose of this study is to investigate transfer performances of self-regulated practice in comparison to transfer performances of a yoked practice schedule.

Participant inclusion: This study will include 60 LSU students who agree to participate

Participant Exclusion:
  a. Any student who does not wish to participate
  b. Physical/Mental disability
  c. Any other reason that may exclude participation

Description of Study: This experiment will consist of a putting green that is made up of a synthetic grass. Subjects will be required to use a putter-like golf club to putt a golf ball to specified targets. The study will last 2 days in total.

Benefits: Subjects can acquire improved skills in golf putting.

Risk: There are no risks associated in this task, other than those involved in putting a golf ball

Alternatives: There are no alternatives

Removal: The study will take approximately an hour to complete. Once the subject has completed all phases of the study they have fulfilled their requirement of participation

Right to Refuse: You will be expected to complete all phases of this study as they are prescribed. However, you may choose at any time not to participate in this experiment and your grade will not be affected.

Privacy: There will not be a link between your name and your performances. All recorded materials will be kept confidential.
Release of Information: Only the raw data will be released. No personal information will be released.

Financial Information: There will be no cost to you for participation in this study

Signatures:

The study has been discussed with me and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. I can also contact the IRB Chair Robert Mathews @ 578-8692 with any other questions or concerns I may have. I also understand that the data collected in this study will not be used for any purpose not approved by the participants and the IRB. I also understand that I have the right to withdraw from this study at any given time. By signing below, I agree to the terms above and acknowledge that I have received a copy of this consent form.

Signature of volunteer: ___________________________ Date: __________
Study Title: Self-regulated Learning

Performance Sites: LSU Motor Behavior Lab

Investigator: Will Wu, Telephone: (225) 578-4395 M-F: 10am-11am

Purpose of Study: The purpose of this study is to investigate transfer performances of self-regulated practice in comparison to transfer performances of a yoked practice schedule.

Participant inclusion: This study will include 30 LSU students who agree to participate

Participant Exclusion:
   a. Any student who does not wish to participate
   b. Physical/Mental disability
   c. Any other reason that may exclude participation

Description of Study: This experiment will consist of learning 3 computer tasks using a desktop computer. The study will last 2 days in total.

Benefits: Subjects can acquire improved computer skills.

Risk: There are no risks associated in this task, other than those involved in looking at a computer screen.

Alternatives: There are no alternatives

Removal: The study will take approximately an hour to complete. Once the subject has completed all phases of the study they will have fulfilled their requirement of participation.

Right to Refuse: You will be expected to complete all phases of this study as they are prescribed. However, you may choose at any time not to participate in this experiment and your grade will not be affected.

Privacy: There will not be a link between your name and your performances. All recorded materials will be kept confidential.

Release of Information: Only the raw data will be released. No personal information will be released.
Financial Information: There will be no cost to you for participation in this study.

The study has been discussed with me and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. I can also contact the IRB Chair Robert Mathews @ 578-8692 with any other questions or concerns I may have. I also understand that the data collected in this study will not be used for any purpose not approved by the participants and the IRB. I also understand that I have the right to withdraw from this study at any given time. By signing below, I agree to the terms above and acknowledge that I have received a copy of this consent form.

Signature of volunteer: Date:
Study Title: Self-Controlled Learning: Is Self-Regulation Responsible for the Learning Benefits?

Performance Sites: Motor Behavior Laboratory, Department of Kinesiology and Health Sciences

Investigator: Will Wu, Telephone: (714) 278-2963 M-Th: 10 am - 11am

Purpose of Study: The purpose of this study is to investigate transfer performances of two types of self-controlled practice schedules.

Participant inclusion: This study will include 50 CSUF students who volunteer to participate.

Participant Exclusion:
   a. Any student who does not wish to participate
   b. Physical/Mental disability
   c. Any other reason that may exclude participation
   d. Participants under the age of 18

Description of Study: This experiment will consist of learning 3 timing sequences using the number keypad of a computer keyboard. The study will last 2 consecutive days in total. Approximately 1 hour the first day and 15 minutes the second day.

Benefits: Subjects may acquire improved computer keyboard skills.

Risk: There are no risks associated with this task, other than those involved in looking at a computer screen and pressing buttons on a keyboard.

Alternatives: There are no alternatives

Removal: The study will take approximately 1 hour to complete. Once the subject has completed all phases of the study they will have fulfilled their requirement of participation.

Right to Refuse: You will be expected to complete all phases of this study as they are prescribed. However, you may choose at any time not to participate in this experiment and your grade will not be affected.

Privacy: There will not be a link between your name and your performance. All recorded
materials will be kept confidential to the extent allowed by law.

Release of Information: Only the raw data will be released. No personal information will be released.

Financial Information: There will be no cost to you for participation in this study.

The study has been discussed with me and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. I can also contact the IRB Office @ 278-2106 with any other questions or concerns I may have. I also understand that the data collected in this study will not be used for any purpose not approved by the participants and the IRB. I also understand that I have the right to withdraw from this study at any given time. By signing below, I agree to the terms above and acknowledge that I have received a copy of this consent form.

Signature of volunteer:                Date:
APPENDIX 4: QUESTIONNAIRE SUMMARIES

Experiment 2

Self-control group

Did you feel you were able to try as many mental/movement strategies you wanted?
14 Yes
0 No

When did you choose to practice a different task?
6 After good trials?
3 After bad trials?
0 Randomly
5 Other (all 5 participants said they practiced each task equally)

Yoked group

Did you feel you were able to try as many mental/movement strategies you wanted?
11 Yes
2 No

Was there a point in practice where you wish you could have practiced a task more but was unable because the schedule told you to do another task?
11 Yes
2 No

If the answer was yes, when would you have preferred to start practicing another task?
7 After good trials?
3 After bad trials?
2 Randomly
0 Other
Experiment 3
Questionnaire for Self-Control group

When did you choose to practice a different task?

<table>
<thead>
<tr>
<th></th>
<th>6</th>
<th>After good trials?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>After bad trials?</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Randomly</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Other</td>
</tr>
</tbody>
</table>

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

<table>
<thead>
<tr>
<th></th>
<th>18</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>No</td>
</tr>
</tbody>
</table>

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>900 msec and 700 msec (12 of 18 participants ranked as most difficult)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>500 msec and 1100 msec (9 of 18 participants ranked as moderately difficult)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1400 msec and 200 msec (13 of 18 participants ranked as least difficult)</td>
</tr>
</tbody>
</table>

Questionnaire for Self-control-before group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

<table>
<thead>
<tr>
<th></th>
<th>16</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>No</td>
</tr>
</tbody>
</table>

If you had the chance to go back and change the way you chose to practice, would you change it?

<table>
<thead>
<tr>
<th></th>
<th>6</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>No</td>
</tr>
</tbody>
</table>
Experiment 3 cont’d

If the answer was yes, when would you have preferred to start practicing another task?

3. After good trials?
2. After bad trials?
1. Randomly
0. Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

11. Yes
9. No

Would you have rather chosen which task to practice during practice instead of before practice?

8. Yes
12. No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec (13 of 15 participants ranked as most difficult)
2. 500 msec and 1100 msec (12 of 15 participants ranked as moderately difficult)
3. 1400 msec and 200 msec (13 of 15 participants ranked as least difficult)

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

☑ Yes
☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?

☑ Yes
☐ No

If the answer was yes, when would you have preferred to start practicing another task?

☐ After good trials?
☐ After bad trials?
☐ Randomly
☐ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

☐ Yes
☐ No

Would you have rather chosen which task to practice during practice instead of before practice?

☐ Yes
☐ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

☐ 900 msec and 700 msec
☐ 500 msec and 1100 msec
☐ 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

I used a counting strategy - about 1/2 sec for 1-100
(similar to dance steps counts)
1 sec for 50-900
2.5 sec for 100-1400
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

X Yes

No

If you had the chance to go back and change the way you chose to practice, would you change it?

Yes

X No

If the answer was yes, when would you have preferred to start practicing another task?

After good trials?

After bad trials?

Randomly

Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

Yes

X No

Would you have rather chosen which task to practice during practice instead of before practice?

Yes

X No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

X 900 msec and 700 msec

500 msec and 1100 msec

1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

No, I just divided the 90 trials among the 3 goals. 30 consecutive trials for each.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

✓ Yes

☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?

☐ Yes

☐ No

If the answer was yes, when would you have preferred to start practicing another task?

☐ After good trials?

☐ After bad trials?

☐ Randomly

☐ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

✓ Yes

☐ No

Would you have rather chosen which task to practice during practice instead of before practice?

✓ Yes

☐ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1  900 msec and 700 msec

2  500 msec and 1100 msec

3  1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

Repetition of one task and associating a time span and keeping rhythm for each time practice.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?
   X Yes
   No

If you had the chance to go back and change the way you chose to practice, would you change it?
   X Yes
   No

If the answer was yes, when would you have preferred to start practicing another task?
   X Randomly
   Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?
   X Yes
   No

Would you have rather chosen which task to practice during practice instead of before practice?
   X Yes
   No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec
2. 500 msec and 1100 msec
3. 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

I would initially plug in the sequence and see what were first results were. Then I would try to recall whether or not I pressed quickly hit the numbers so I could gauge the timing. If I paused too long it would be a bit too short or if paused too short it would be a bit too long. A lot of mental planning and execution was important.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

- Yes
- No

If you had the chance to go back and change the way you chose to practice, would you change it?

- Yes
- No

If the answer was yes, when would you have preferred to start practicing another task?

- After good trials?
- After bad trials?
- Randomly
- Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

- Yes
- No

Would you have rather chosen which task to practice during practice instead of before practice?

- Yes
- No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

- 900 msec and 700 msec
- 500 msec and 1100 msec
- 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

I choose the task that had the slowest time between 2 → 4, the progression towards the quicker 900 msec, followed by the 500 msec.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

☑ Yes
☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?

☐ Yes
☐ No

If the answer was yes, when would you have preferred to start practicing another task?

☐ After good trials?
☐ After bad trials?
☐ Randomly
☐ Other

Was there a point in practice where you wish you could have practiced a task more but were unable because the practice schedule told you to do another task?

☑ Yes
☐ No

Would you have rather chosen which task to practice during practice instead of before practice?

☑ Yes
☐ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

☐ 900 msec and 700 msec
☐ 500 msec and 1100 msec
☐ 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

Yes

No

If you had the chance to go back and change the way you chose to practice, would you change it?

Yes

No

If the answer was yes, when would you have preferred to start practicing another task?

After good trials?

After bad trials?

Randomly

Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

Yes

No

Would you have rather chosen which task to practice during practice instead of before practice?

Yes

No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec

2. 500 msec and 1100 msec

3. 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

At first I tried to "sense" what the time was like. Half way through the practice, I tried counting to myself.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

X  Yes

□  No

If you had the chance to go back and change the way you chose to practice, would you change it?

X  Yes

□  No

If the answer was yes, when would you have preferred to start practicing another task?

□  After good trials?

X  After bad trials?

□  Randomly

□  Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

X  Yes

□  No

Would you have rather chosen which task to practice during practice instead of before practice?

X  Yes

□  No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1  900 msec and 700 msec

2  500 msec and 1100 msec

3  1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

Counting the seconds between each movement.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

☐ Yes
☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?

☐ Yes
☒ No

If the answer was yes, when would you have preferred to start practicing another task?

☐ After good trials?
☐ After bad trials?
☐ Randomly
☐ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

☐ Yes
☒ No

Would you have rather chosen which task to practice during practice instead of before practice?

☐ Yes
☒ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

☐ 900 msec and 700 msec
☐ 500 msec and 1100 msec
☒ 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)
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Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?
× Yes
____ No

If you had the chance to go back and change the way you chose to practice, would you change it?
____ Yes
× No

If the answer was yes, when would you have preferred to start practicing another task?
____ After good trials?
____ After bad trials?
____ Randomly
____ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?
× Yes
____ No

Would you have rather chosen which task to practice during practice instead of before practice?
× Yes
____ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)
1 900 msec and 700 msec
2 500 msec and 1100 msec
3 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

I wanted to get used to a certain movement so I chose to do/focus on one sequence at a time.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

___ Yes

✓ No

If you had the chance to go back and change the way you chose to practice, would you change it?

___ Yes

✓ No

If the answer was yes, when would you have preferred to start practicing another task?

___ After good trials?

___ After bad trials?

___ Randomly

___ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

✓ Yes

___ No

Would you have rather chosen which task to practice during practice instead of before practice?

___ Yes

✓ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1  900 msec and 700 msec

2  500 msec and 1100 msec

3  1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

Get a chance to practice all the sequences

an even number of times.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

☐ Yes
☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?

☐ Yes
☐ No

If the answer was yes, when would you have preferred to start practicing another task?

☐ After good trials?
☐ After bad trials?
☐ Randomly
☐ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

☐ Yes
☐ No

Would you have rather chosen which task to practice during practice instead of before practice?

☐ Yes
☐ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1 900 msec and 700 msec
2 500 msec and 1100 msec
3 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

I tried to distribute them equally because I wasn’t sure which would be the easiest for me. When I was actually practicing I realized maybe I should’ve kept practicing a certain one.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?
    ___ Yes
    □ No

If you had the chance to go back and change the way you chose to practice, would you change it?
    □ Yes
    ___ No

If the answer was yes, when would you have preferred to start practicing another task?
    □ After good trials?
    ___ After bad trials?
    ___ Randomly
    ___ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?
    ___ Yes
    □ No

Would you have rather chosen which task to practice during practice instead of before practice?
    □ Yes
    ___ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec
2. 500 msec and 1100 msec
3. 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

    I thought I'd start with the slowest one, work my way up to the faster one than slow, fast, med, slow. I thought if I do good with the slowest one, that would drive me to do better with the other two (pos reinforcement).
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

Yes
No

If you had the chance to go back and change the way you chose to practice, would you change it?

Yes
No

If the answer was yes, when would you have preferred to start practicing another task?

After good trials?
After bad trials?
Randomly
Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

Yes
No

Would you have rather chosen which task to practice during practice instead of before practice?

Yes
No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec
2. 500 msec and 1100 msec
3. 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

Divide them up equally.
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Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?
✓ Yes
☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?
☐ Yes
✓ No

If the answer was yes, when would you have preferred to start practicing another task?
☐ After good trials?
☐ After bad trials?
☐ Randomly
☐ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?
✓ Yes
☐ No

Would you have rather chosen which task to practice during practice instead of before practice?
✓ Yes
☐ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec
2. 500 msec and 1100 msec
3. 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

Just try out each different task, it's interesting and you don't know what you might get.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?
   ✔ Yes
   ☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?
   ✔ Yes
   ☐ No

If the answer was yes, when would you have preferred to start practicing another task?
   ☐ After good trials?
   ☐ After bad trials?
   ☐ Randomly
   ☐ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?
   ✔ Yes
   ☐ No

Would you have rather chosen which task to practice during practice instead of before practice?
   ✔ Yes
   ☐ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1 900 msec and 700 msec
2 500 msec and 1100 msec
3 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

I just wanted to make sure I practiced each sequence more than once.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

✓ Yes

☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?

✓ Yes

☐ No

If the answer was yes, when would you have preferred to start practicing another task?

☐ After good trials?

☐ After bad trials?

☐ Randomly

✓ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

✓ Yes

☐ No

Would you have rather chosen which task to practice during practice instead of before practice?

✓ Yes

☐ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1 900 msec and 700 msec

2 500 msec and 1100 msec

3 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

In order to...
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

☐ Yes
☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?

☐ Yes
☐ No

If the answer was yes, when would you have preferred to start practicing another task?

☐ After good trials?
☐ After bad trials?
☐ Randomly
☐ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

☐ Yes
☐ No

Would you have rather chosen which task to practice during practice instead of before practice?

☐ Yes
☐ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

☐ 1 900 msec and 700 msec
☐ 2 500 msec and 1100 msec
☐ 3 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

I thought the ones/numbers closest to each other would be easy because its fast. The other two were just random choices
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

✓ Yes

No

If you had the chance to go back and change the way you chose to practice, would you change it?

✓ Yes

No

If the answer was yes, when would you have preferred to start practicing another task?

✓ After good trials?

--- After bad trials?

--- Randomly

--- Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

✓ Yes

No

Would you have rather chosen which task to practice during practice instead of before practice?

✓ Yes

No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

2. 900 msec and 700 msec

1. 500 msec and 1100 msec

3. 1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

In practicing each trial, I felt there was a pattern to each goal time so I kind of put a musical rhythm to the timing patterns of each goal time.
Questionnaire for Self-Control BEFORE group

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

☐ Yes
☐ No

If you had the chance to go back and change the way you chose to practice, would you change it?

☐ Yes
☐ No

If the answer was yes, when would you have preferred to start practicing another task?

☐ After good trials?
☐ After bad trials?
☐ Randomly
☐ Other

Was there a point in practice where you wish you could have practiced a task more but was unable because the practice schedule told you to do another task?

☑ Yes
☐ No

Would you have rather chosen which task to practice during practice instead of before practice?

☑ Yes
☐ No

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1  900 msec and 700 msec
2  500 msec and 1100 msec
3  1400 msec and 200 msec

What was your strategy or thought process when you were choosing which tasks to practice before the practice session began? (Briefly explain)

I just looked at the first number sequence and started from smallest to largest (500, 900, 1400) & decided to do 30 of each sequence in that order.
Questionnaire for Self-Control group

When did you choose to practice a different task?
   X After good trials?
   ___ After bad trials?
   ___ Randomly
   ___ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?
   X Yes
   ___ No

When practicing, why did you stop practicing one task and start practicing another?
(Briefly explain)

I had the rhythm in my head of the task after practicing it a few times. After I felt that I kind of had the task down timing wise, I would move on to another one. Sometimes, I'd randomly switch back to an old task to see if I still remembered it.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1  900 msec and 700 msec
2  500 msec and 1100 msec
3  1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

☐ After good trials?
☐ After bad trials?
☐ Randomly
☐ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

☐ Yes
☐ No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

Lack of diminishing returns. Also, wanted to practice more difficult ones – 900/900 & incorporate them into the testing sequence to simulate test conditions.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec
2. 500 msec and 1100 msec
3. 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

☐ After good trials?
☐ After bad trials?
☐ Randomly
☐ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

☐ Yes
☐ No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)
I tried to get as close as I could to one task before moving on to another. Sometimes if my results for one task were closer to the goal time of another task I would then try that task.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

2 900 msec and 700 msec
1 500 msec and 1100 msec
3 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

After good trials?

✓ After bad trials?

___ Randomly

___ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

✓ Yes

___ No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

The numbers I was getting closer match times for a different goal. I figured my timing for that goal would be better and could just match that goal before I moved on.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

2 900 msec and 700 msec

3 500 msec and 1100 msec

1 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

____ After good trials?
____/ After bad trials?
____ Randomly
____ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

____ Yes
____ No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

I felt that was as close as I was going to get to the exact score, then I would try one more and it would be completely off, so that's when I would change.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

____ 1 900 msec and 700 msec
____ 2 500 msec and 1100 msec
____ 3 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

- After good trials?
- After bad trials?
- Randomly
- Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

- Yes
- No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

I would practice one task and then start practicing due to the bad trials that kept occurring. If I could not reach the ideal goal, I would move on to the next goal.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1  900 msec and 700 msec
2  500 msec and 1100 msec
3  1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

___ After good trials?
✓ After bad trials?
___ Randomly
___ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

✓ Yes
___ No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

I determined my start/stop of a task by how close in time I was to the given goal times. That way I would be able to get the feel of timing in between key strokes.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1 900 msec and 700 msec

2 500 msec and 1100 msec

3 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

[ ] After good trials?
[ ] After bad trials?
[ ] Randomly
[ ] Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

[ ] Yes
[ ] No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

Because I thought I did enough number of trials and got bored

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

2 900 msec and 700 msec
1 500 msec and 1100 msec
3 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

_____ After good trials?
_____ After bad trials?
X _____ Randomly
_____ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

x _____ Yes
_____ No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

I began to practice another task when I felt I did well at several tasks. Or when I was unable to perfect a specific task I moved on.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

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1 _____ 500 msec and 1100 msec
3 _____ 1400 msec and 200 msec
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Questionnaire for Self-Control group

When did you choose to practice a different task?

____ After good trials?

x After bad trials?

x Randomly

____ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

x Yes

____ No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

After reviewing a few scores close to the number wanted, I had an idea of a rhythm to use. Went to a different task to continue getting a feeling for the msec between keys that selected task until I felt comfortable with that then proceeded to the last one.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1 900 msec and 700 msec

2 500 msec and 1100 msec

3 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

- After good trials?
- After bad trials?
- Randomly
- Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

- Yes
- No

When practicing, why did you stop practicing one task and start practicing another?
(Briefly explain)

"Well I thought if I timed myself in my head I would do better and it would work at least once and then not work again. Once that happened I would go on to the next one."

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

- 1 900 msec and 700 msec
- 2 500 msec and 1100 msec
- 2 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

- After good trials?
- After bad trials?
- Randomly
- Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

- Yes
- No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

To get a feel for different timing sequences.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec
2. 500 msec and 1100 msec
3. 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

- After good trials?
- After bad trials?
- Randomly
- Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

- Yes
- No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)
I changed every time because I was trying to get a feel of all of them and try to find a sequence.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

- 1 900 msec and 700 msec
- 2 500 msec and 1100 msec
- 3 1400 msec and 200 msec
**Questionnaire for Self-Control group**

When did you choose to practice a different task?
- ☒ After good trials?
- _____ After bad trials?
- _____ Randomly
- ☒ Other after good plus one more

Did you feel you were able to try as many mental/movement strategies you wanted during practice?
- _____ Yes
- _____ No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

Not really, I only did that once with the 1400/200 one because I feel really confident with that one to give me confidence to get the others right.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

- 2  900 msec and 700 msec
- 1  500 msec and 1100 msec
- 3  1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

_____ After good trials?
_____ After bad trials?
_____ Randomly
_____ Other: it depended on how I felt. In the beginning it was after good trials but then more and more randomly.

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

_____ Yes
_____ No

When practicing, why did you stop practicing one task and start practicing another?
(Briefly explain)

When it felt like I was getting the hang of it, I changed but I went back again to control it.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec
2. 1400 msec and 200 msec
3. 500 msec and 1100 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

_____ After good trials?
_____ After bad trials?
______ Randomly
     ______ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

     _____ Yes

     ____ No

When practicing, why did you stop practicing one task and start practicing another?
(Briefly explain) I did 15 of each task and then moved to the next one.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

_____ 1  900 msec and 700 msec
_____ 2  500 msec and 1100 msec
______ 3  1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

- After good trials?
- After bad trials?
- Randomly
- Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

- Yes
- No

When practicing, why did you stop practicing one task and start practicing another?
(Briefly explain) I stopped when I felt that I had enough practice. On some I wanted to keep on practicing but I knew that I had to move on to the other goal movement groups.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

1. 900 msec and 700 msec
2. 500 msec and 1100 msec
3. 1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

_____ After good trials?
_____ After bad trials?
_____ Randomly
_____ Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

_____ Yes
_____ No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

I stopped practicing a trial when my goal times and my result times were very different such as my goal times being 500 msec, 1100 msec and my results were 1169 msec and 1164 msec. I then felt I needed to move on and practice a new goal-time.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

3  900 msec and 700 msec
1  500 msec and 1100 msec
2  1400 msec and 200 msec
Questionnaire for Self-Control group

When did you choose to practice a different task?

- [ ] After good trials?
- [ ] After bad trials?
- [ ] Randomly
- [ ] Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?

- [ ] Yes
- [ ] No

When practicing, why did you stop practicing one task and start practicing another? (Briefly explain)

I would stop and practice another one when I felt comfortable and had roughly 3 or 4 good trials in a row.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

- [ ] 3 900 msec and 700 msec
- [ ] 2 500 msec and 1100 msec
- [ ] 1 1400 msec and 200 msec
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Notes:
- Column 1 represents the first column of data.
- Column 2 represents the second column of data.
- Column 3 represents the third column of data.
- Column 4 represents the fourth column of data.
- Column 5 represents the fifth column of data.
- Column 6 represents the sixth column of data.
- Column 7 represents the seventh column of data.
- Column 8 represents the eighth column of data.

Additional notes or comments can be added here if necessary.
Questionnaire for Self-Control group

When did you choose to practice a different task?
____ Y After good trials?
____ Y After bad trials?
____ Y Randomly
____ Y Other

Did you feel you were able to try as many mental/movement strategies you wanted during practice?
____ Y Yes
____ Y No

When practicing, why did you stop practicing one task and start practicing another?
(Briefly explain)
I became relatively close or I became frustrated.

Rank the movement sequences from 1 to 3 on the basis of which gave you the most difficulty during PRACTICE (1 = the most difficult, 2 = moderately difficult, 3 = the least difficult)

2 900 msec and 700 msec
1 500 msec and 1100 msec
3 1400 msec and 200 msec
VITA

Wilbur Fong Wah Wu was born on July 4, 1975, in Hollywood, California. He was raised in Walnut, California, in which family, academics, and sports were stressed. It was from his father Liang Chu Wu he was taught a variety of sports that provided the roots for Wilbur’s interest in motor behavior, even though his father never played the sports he taught. Upon graduating from Bishop Amat Memorial High School, Wilbur completed his Bachelor of Science degree from the University of California, Los Angeles, in psychobiology. It was at UCLA Wilbur met his loving wife Emily Liu. They were married on August 5, 2006. Upon Wilbur’s arrival at Louisiana State University he was awarded with the Doctoral Student Enhancement Award. While at LSU he studied and researched with Dr. Richard Magill in which they sought to discover ways to enhance the motor skill learning process. After completing his degree Wilbur will continue his role as cofounder of Human Performance Consulting, a consulting group that provides sport science consulting to various athletes to optimize learning and performance.