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An Experiment to Chronometrically Examine the Effects of Self-Controlled Feedback on the Performance and Learning of a Sequential Timing Task

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I am submitting herewith a thesis written by Andrew Duvier Bass entitled "An Experiment to Chronometrically Examine the Effects of Self-Controlled Feedback on the Performance and Learning of a Sequential Timing Task." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Kinesiology.

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An Experiment to Chronometrically Examine the Effects of Self-Controlled Feedback on the Performance and Learning of a Sequential Timing Task

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ABSTRACT

Research in the motor learning domain regarding the underlying mechanism of self-controlled feedback has speculated that learners who are given the option to control their feedback schedule may engage in deeper levels of information processing, yet no study has measured information processing during a self-controlled protocol. The purpose of this study was to examine the effects of self-controlled feedback on information processing during the learning of a sequential timing task. Little known about the underlying mechanism of the self-control benefit. Participants were randomly assigned to self-control (SC) (*n* = 10) and yoked (YK) (*n* = 10) groups. SC participants were allowed to request feedback in the form of knowledge of results (KR) regarding their planning time (PT), segment times (ST), and overall movement times (MT) following any trial while YK participants received KR according to the schedule created by their SC counterparts. The acquisition phase consisted of six 10-trial blocks. Participants practiced a sequential key-pressing task similar to the one used by Chiviacowsky and Wulf (2002, 2005). Retention and transfer tests each consisted of 10 trials and were administered approximately 24 hours after acquisition. Retention procedures were identical to those used during acquisition, except no feedback was administered to either group. Transfer used the same procedures as retention with the exception of the task, which required different segment times. Results indicated that the SC group produced significantly longer PT and was significantly more accurate in meeting the MT goal during acquisition and retention ($p < .05$). The observation of longer PT for the SC group was consistent with information processing accounts of self-control effects.

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CHAPTER 1
INTRODUCTION

Self-regulated learning has been described as a process during which an individual metacognitively engages in his or her own learning (Zimmerman, 1986). According to Zimmerman, self-regulation refers to an individual's desire to regulate learning and performance via an understanding of a specific cognitive strategy, namely, methods that learners use to problem solve. The provision of self-regulation has been shown to provide learning benefits in education as well as athletics (Chapari, Marshoodi, and Kazemzedah, 2013; McCombs, 1986; Paris & Newman, 1990; Paris & Paris, 2000; Zimmerman, 2002). In the motor domain, self-regulation has been associated with the learner's capability to *control* some aspect of the instructional setting during practice of one or more motor skills. The term *self-control* has been adopted by many motor-learning researchers as a way of describing experimental manipulations used to examine self-regulated learning. Self-control effects have been examined using a variety of instructional support modalities, including control over the administration of feedback (Aiken, Fairbrother, & Post, 2012; Ali, A., Fawyer, B., Kim, J., Fairbrother, J.T., & Janelle, C., 2012; Chen & Singer, 1992; Chiviacowsky & Wulf, 2002; Chiviacowsky, Wulf, & de Medeiros, 2008; Fairbrother, J.T., Laughlin, D.D. & Nguyen, T.V., 2012; Janelle, Kim, & Singer, 1995), the use of a physical assistance device (Wulf, 2007), the amount of practice (Post, Fairbrother, & Barros, 2011; Post, Fairbrother, Barros, & Klupa, 2014), and practice scheduling (Keetch & Lee, 2007). The self-control of augmented feedback – as either knowledge of results (KR) or knowledge of performance (KP) has received the most attention in the research literature. Self-controlled KR KP has been show to benefit a wide range of motor skills: sequential timing (Chiviacowsky & Wulf, 2002; Patterson & Cater, 2010; Wu & Magill, 2011; Wulf, Chiviacowsky, & Lewthwaite, 2010), object manipulation and projection (Aiken, Fairbrother, &

Post, 2012; Janelle, Barba, Frehlich, & Tennant, 1997; Post, Fairbrother, & Barros, 2011; Wulf, Clauss, Shea, & Whitacre, 2001; Wulf, Raupauch, & Pfeiffer, 2005), and balancing (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012). The benefits of self-control in facilitating learning have typically been seen in comparison to so-called *yoked* control groups. Early research on self-controlled feedback effects used yoking procedures to match feedback schedules and frequencies as these factors have been previously shown to affect motor performance and learning. The use of a yoked comparison group has been widely adopted in the self-control research, even when feedback is not the independent variable of interest.

Although a growing body of research indicates that self-controlled feedback facilitates motor learning compared to a feedback schedule controlled by the experimenter (e.g., a yoked schedule), the underlying mechanisms for these effects remain unknown. Some researchers have argued that the provision of self-control enhances motivation, which in turn facilitates learning (Sanli, Patterson, Bray, & Lee, 2012; Su & Reeve, 2011). The provision of self-control is thought to support a *basic psychological need* for autonomy as described in *Self-Determination Theory* (Deci & Ryan, 2000). From this perspective, autonomy refers to feelings of willingness and option in regard to engaging in a specific activity. As the perception of autonomy increases, so will motivation to engage in an activity. A learning environment that contributes to the basic psychological need for autonomy produces a more satisfying and engaging experience. It is unclear, however, if motivation to *participate* in an activity (as opposed to not participating) is equivalent to the type of motivation implied by self-control researchers, which presumably relates to active cognitive engagement in the moment-to-moment processes associated with learning.

Another idea forwarded to explain self-control effects is related to the capability to tailor the feedback schedule to meet individual needs and preferences (Chiviacowsky & Wulf, 2002). In Laughlin et al (2015), participants explicitly reported the strategic use of self-control to further their learning goals. Additionally, there is evidence that participants prefer to request feedback following trials on which they performed relatively well compared to those on which they performed poorly (Chiviacowsky & Wulf, 2002). The preference for feedback following so-called *good* trials compared to *bad* trials has been interpreted by some as indicating that the confirmation of success might enhance motivation. It is also plausible that feedback after successful attempts provides positive reinforcement. Other evidence, however, indicates that the good-trial feedback preference may be influenced by task complexity, the feedback modality, and the design of the instrument used to assess preferences. Aiken et al. (2012) found no preference for feedback after good trials when examining self-control effects on the learning of a basketball set shot using video KP. Aiken et al. argued that the complex task coupled with the information-rich source of feedback allowed participants to identify both the well-performed and poorly-performed elements in any given trial. Laughlin et al. further revealed that participants used feedback to identify and correct errors as well as confirm success when learning 3-ball cascade juggling.

A third explanation for self-control effects forwarded the idea that the provision of self-control promotes more effective information processing (Chen & Singer, 1992; Chiviacowsky et. al, 2010; Janelle et.al, 1997). A number of studies have reported effects consistent with this argument, but none have implemented a direct measurement of information processing. For example, Post, Fairbrother, and Barros (2010) found that a group allowed to control the total amount of practice was better able to recall the number of completed trials than a yoked control group. In a subsequent study, Post, Fairbrother, Barros, & Klupa (2014) found that a self-control group had longer mean pre-shot preparation times when practicing a basketball set shot. Aiken et al. (2012) reported that self-control participants viewed a poster board with instructional cues more frequently than yoked participants, suggesting more task engagement. And although both studies reported the preparation time as a possible signifier of deeper information processing, none were designed to directly address the issue of information processing as it connects to self-controlled feedback.

One well-established approach to examine information processing involves a chronometric examination of responses to presented stimuli. In its simplest form, this approach involves the measurement of reaction time (RT). Examinations of information processing (e.g., Sternberg, 1969) have been based on the idea that stimulus-response pairings that require more extensive processing in preparation for the response will produce longer RT latencies. It is important to note that strategies to promote more extensive information processing may actually degrade performance when the task requires a rapid reaction. If the provision of self-control promotes more extensive information processing, it is plausible that a chronometric approach to examining response preparation might reveal performance decrements relative to a yoked condition in this aspect of performance. This expectation would be particularly relevant for early learners because the meta-cognition associated with self-control might occupy cognitive resources necessary for successful execution of the movement. Externally imposed sources of cognitive load (e.g., self-controlled feedback) may interfere with the initial learning of a task that requires a higher degree of cognitive interactivity (Kanfer & Ackerman, 1989; Sweller, 1994). If such decrements were to occur, a logical question is whether they would be associated with facilitation of learning as measured by delayed tests. It is possible that learning benefits resulting from higher quality or more thorough processing of task-related information could offset any performance penalty associated with longer preparation time.

A chronometric examination of response preparation within a self-control paradigm should yield insight into the purported effects of this intervention on information processing. It would be expected that the provision of self-control would result in longer preparation intervals, reflective of more thorough information processing. The purpose of the current study was to examine the effects of self-controlled feedback on the performance and learning of a task requiring a rapid response to a stimulus. It was expected that the self-control group would produce longer reaction times compared to the yoked group. Given the broad generalizability of self-control benefits on *learning* seen in previous research, it was also expected that self-control would facilitate the learning of the movement demands of the task.

Purpose of the Study:

The purpose of this study was to examine the effects of self-controlled feedback on the performance and learning of a task requiring a rapid response to a stimulus.

Research Hypotheses: The following hypotheses were based on previous research examining the effects of self-controlled feedback on motor learning (e.g., Chiviacowsky & Wulf, 2002; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997):

1.) During acquisition, the SC group will produce a significantly longer mean preparation time (PT) than the YK group.

2.) During retention, the SC group will demonstrate significantly lower error scores related to meeting the criterion times of the movement than the YK group.

3.) During transfer, the SC group will demonstrate significantly lower error scores related to meeting the criterion times of the movement than the YK group.

Delimitations:

The study was delimited in the following ways:

1.) Participants have no prior experience with the task.

2.) Participants will be at least 18 years of age.

Assumptions:

The following assumptions were made for the present study.

1.) Participants put forward their best effort.

2.) Participants react and move as quickly as possible.

3.) Participants have no prior knowledge of the task before beginning.

Exploratory Issues:

Little is known about the effects of self-control on measures of information processing. Accordingly, expectations could not be formulated for the effects of self-control on preparation time during retention in transfer. On the one hand, the longer preparation times expected during acquisition might eventually result in faster preparation times (compared to the yoked group) during retention and transfer when feedback was withdrawn and participants had presumably gained some mastery of the task. On the other hand, participants in the self-control group might establish a tendency to spend more time in preparation that will last throughout the testing phase.

Definition of Terms:

The following terms were defined as used in this study:

Acquisition: Acquisition is the period of time when an individual first acquires the designated motor skill. Acquisition can also be referred to as the practice phase.

Augmented Feedback: Feedback that originates from an external source outside of the inherent, sensory feedback of the individual following execution of a motor skill (Salmoni, Schmidt, & Walter, 1984).

Absolute Error: The absolute difference between the goal for a trail and the actual performance on the trial (Chiviacowsky & Wulf, 2002).

Feedback: Information given to the individual regarding the quality or results of their performance (Magill, 2001).

Information Processing (IP): Analysis of information from the environment through one of the sense organs and selection of proper motor response (Stelmach, 2014).

Knowledge of Results (KR): Augmented feedback that informs the individual about performance of their actions with respect to the intended outcome goal (Salmoni, Schmidt, & Walter, 1984).

Knowledge of Performance (KP): Augmented feedback that informs the individual about the quality of their movement (Salmoni, Schmidt, & Walter, 1984).

Mental Chronometry: The use of reaction time during a stimulus response task as a method of inferring duration of cognitive operations (Stelmach, 2014).

Meta-cognition: Recognition and understanding of ongoing cognitive strategies (Lee & Wishart, 2005).

Movement Time: The time required to execute the entirety of a motor response following response initiation.

NASA-TLX: A subjective, multi-dimensional, workload, Likert scale questionnaire used to measure cognitive and temporal demand in within various human-machine environments (Hart, 2006).

Outcome Goal: Objectives for performance that focus on the end result of a task (Zimmerman, 2002).

Reaction Time (RT): Elapsed time between the onset of stimulus and the beginning of an individual's reaction to the stimulus.

Retention: The period of time in which the individual is tested on what they have learned during acquisition of a novel task. No feedback is given during this time. The same task practiced during acquisition is practiced once again during retention, but only after a delay interval, typically 24 hours, has passed between the two phases.

Self-Control (SC): The condition in which participants choose whether to receive feedback regarding task performance (Janelle, 1995).

Sequential Timing Task: Sequential timing task refers to the experimental task that will be used in this study. Participants will be required to press a series of keys in an allotted time following reaction to an onscreen stimulus. The task is similar to one used in previous self-control literature (Chiviacowsky & Wulf, 2002).

Transfer: The period of time in which the individual is tested on their ability to transfer one or more novel skills to related to those practiced during acquisition to a different task.

Verbal-Cognitive Stage of Motor Learning: Initial stage of motor learning characterized by complete unfamiliarity with the task (Schmidt & Wrisberg, 2000).

Yoked (YK): Yoked refers to a condition in this study wherein participants are matched with a counterpart in the self-controlled group. Each member of the yoked group receives feedback on respective trails in which their counterpart in the self-control condition requested feedback. The condition is typically used in self-control studies as a means of balancing the frequency of feedback across both yoked and self-control groups. Therefore, each group receives the same amount of feedback.

CHAPTER 2
LITERATURE REVIEW

Early literature in motor learning suggested that skill acquisition was improved due to the provision of knowledge of results (KR) (Bilodeau, 1956). Additionally, similar research argued that no learning occurred in the absence of KR. Later research concerning the provision of KR revealed that learners' performance improved from receiving 100% KR during acquisition, but abated significantly during retention tests as opposed to those who received less frequent KR (Salmoni, Schmidt, & Walter, 1984). Salmoni et al. proposed the *guidance hypothesis*, which argued that learners become dependent on feedback that "guides" them during acquisition. Consequently, offering less frequent KR to learners has been viewed as a means to facilitate learning.

Over the next few decades, interest grew in identifying the optimal schedule for administering feedback. Topics such as absolute frequency of feedback (Adams, Goetz, & Marshall, 1972), relative frequency of feedback (Winstein, 1987), delayed feedback (Schmidt, Young, Shapiro, & Winnen, 1989), and fading feedback schedules (Winstein & Schmidt, 1990) all aided in providing more insight into the most effective methods of feedback delivery for to facilitate motor learning. However, not until mentioned by Chen and Singer (1992), and initially explored by Janelle, Kim, and Singer (1995), was the responsibility for feedback scheduling was not placed on the learner until rather recently.

Research on so-called self-control feedback effects on motor learning emerged from earlier work on self-regulation and academic achievement. (Seigler, 1991; Zimmerman, 1989). Students who were allowed to engage in academic self-regulation processes like goal setting and self-instruction demonstrated significant increases in classroom motivation and academic performance (Zimmerman, 1989). Paris and Newman (1990) noted that self-regulated learners seemed to display an understanding and commitment to academic learning that led to a deeper awareness of themselves as learners. When students were given control over some aspects of their learning environment by planning, organizing, self-instructing, self-monitoring, and self-evaluating during various stages of the learning process, they perceived themselves as competent, self-efficacious, and autonomous. Thus, in the cognitive domain, learners who engage in self-regulation become more active and may even attain a deeper level of information processing (Seigler, 1991; Zimmerman, 1986, 1989).

Janelle, Kim, & Singer (1995) conducted one of the first studies to examine the effects on motor learning of allowing the performer to control the feedback schedule. The task required participants to toss a golf ball underhanded with their non-preferred hand. The objective was to lob the ball as closely to the center of a target as possible. Individuals in the self-controlled (SC) group could ask for knowledge of performance (KP) such as "You threw the ball with (too much or not enough) force that time" or "Your arm swing wobbled from right to left (left to right) that time." A yoked (YK) group was given the same KP according to schedules that matched those of their counterparts in SC group. The study revealed that the SC group outperformed the YK group during retention testing; providing initial evidence of the self-regulated learning advantage within the context of motor learning.

In the motor domain, SC manipulations are characterized by the learner being allowed to control some aspect of the learning environment. Typically, the learner is allowed to decide when to receive KR or KP (Aiken, Fairbrother, & Post, 2011; Chiviacowsky & Wulf, 2002,2005,2007; Wu & Magill, 2011). However, other self-control manipulations include when to terminate practice (Post, Fairbrother, & Barros, 2011), viewing written instructions and video KP (Aiken et al., 2011), use of physical assistance (Chiviacowsky, Wulf, Lewthwaite, &

Campos, 2012; Wulf & Toole, 1999), or choice of task complexity (Andrieux, Danna, & Thon, 2012). Self-control effects have also been examined in a wide variety of populations including older adults (Carter & Patterson, 2012), individuals with cerebral palsy (Hemayattalab, 2014), and children (Chiviacowsky, Kaefer, Wally, & Wulf, 2008).

The literature demonstrates that regardless of self-control manipulations or differences in population the self-control effect confers a benefit to those allowed to regulate some aspect of their learning environment as opposed to those not given the option. Those not given the option to control some aspect of their learning environment are often put into what is called a yoked (YK) group. In an effort to control for potentially confounding effects of differential feedback frequency, self-control protocols often use YK groups as controls that allow effects to be attributed to the provision of self-control. Each participant in the yoked group is linked to a counterpart in the self-control group. Their schedules and frequency of feedback are predetermined by their self-controlled counterpart.

Chiviacowsky and Wulf (2005) conducted a study looking at feedback preferences within self-control. In their study two group, self-before and self-after, were formed as a method of testing a hypothesis regarding the underlying mechanism of self-control: the benefit stems from the preference of the learner requesting feedback primarily after “good” versus “bad” trials. Namely, that learners use the requested feedback for success confirmation rather than error correction. This study was motivated by Chiviacowsky & Wulf (2002), which reported that participants had “a clear preference for feedback after good trials” (p. 412). Results from a questionnaire administered after learning a sequential timing task indicated that the majority of SC participants requested feedback most after what they considered to be a good trial (67%), while not one participant reported requesting feedback after a poor trial. 7 of the 11 participants in the yoked group declared that they would have preferred feedback good trials, whereas only 1 reported desiring feedback after poor trials., However, the “clear preference” for feedback was potentially influenced by the way the assessment was conducted. The questionnaire presented questions such as “When and why did you ask for feedback?” followed by options such as “mostly after you thought you had a good trial” “mostly after you thought you had a bad trial.” This format lent itself to dichotomized answers related to a concept that is likely more nuanced. Subsequent research on this topic has demonstrated that feedback preferences are more complex.

Aiken, Fairbrother, and Post (2012) studied the effects of self-controlled video feedback on the learning of a basketball set shot. After the completion of all trials both groups were asked a series of questions concerning why and how they requested or used feedback. Unlike the questionnaire in Chiviacowsky and Wulf (2002), Aiken et al. used a Likert scale that allowed participants to indicate the extent to which they requested feedback after good or poor trials – e.g., “never, “seldom, “occasionally,” “often,” and “always”. Results indicated that the SC group requested feedback *occasionally* after both good and bad trials. The YK group reported that they received feedback when they needed it occasionally, and that they received feedback occasionally after both good and bad trials. Less than half of the YK group stated a preference for feedback after good trials, while the rest stated a preference for feedback after bad trials. Aiken et al. illustrated that the desire for feedback is more complex than initially thought. It should be mentioned that the tasks for both studies were markedly different, which may also have contributed to the different findings. Chiviacowsky and Wulf used a simple, sequential key-pressing task while Aiken et al. used a more complex basketball set shot.

Another possible underlying mechanism for the self-control benefit stems from a potential increases in motivation. Several researchers have argued that individuals who are given the option of controlling some aspect of their learning environment inherently perceive a greater feeling of autonomy and thus experience stronger motivation to engage in the task (Chivacowsky, 2014; Saemi, Porter, Ghotbi-Varzaneh, Zarghamni, & Maleki, 2012; Wulf, Chiviacowsky, & Cardozo, 2014). The concept that an increase in autonomy can lead to an increase in motivation stems from self-determination theory. Self-determination theory (SDT; Ryan and Deci, 2000) is a theoretical social-cognitive theory of motivation that has been applied to a range of sport, educational, and exercise contexts. Because individuals are motivated to master their environment, SDT explores the factors that facilitate or weaken forms of motivation. Enhancing, or satisfying, three basic psychological needs determine facilitation: competence, relatedness, and autonomy. In particular, the basic psychological need for autonomy has been examined as a driving force behind self-controlled learning as a means of increasing motivation (Chiviacowsky, 2014; Wulf, Chiviacowsky, & Cardozo, 2014). Autonomy refers to one's desire to have some perception of control over their behavior. Information that is perceived to satisfy this need tends to have a positive impact on self-determined motivation, while information that is perceived to detract from these needs tends to have a negative impact.

Autonomy is essential to intrinsic motivation, and stems from a deeply evolved tendency and desire to self-regulate behaviors or actions. When humans exert a level of control over their environment, they engage in a more specified, processed, and hierarchical manner that compliments their own sense of desire in relation to the behavior. A lack of perceived control over a situation leads to an undermining of intrinsic motivation, whereas providing choice over a given context enhances it (Zuckerman, Porac, Lathin, Smith, & Deci, 1978). The perception of autonomy as a result of choice may increase intrinsic motivation for a task because it also triggers the reward processes in the brain. Leotti and Delgado (2011) found that the anticipation of choice for a key-pressing task activated the striatum, which is thought to be involved in reward processing. Thus, simply having the opportunity to choose may increase motivation by activating reward centers

Choice also increases the sense of self-initiation (deCharms, 1968). Autonomy drives self-motivated behavior in the sense that it creates an experience of choice and that choices determines behavior. This helps individuals develop a sense of congruency between their behavior, desires, and resources as they emerge within a learning framework. The autonomy of self-controlled learning may increase motivation within a motor skill because it allows the learner to modify the environment based on their own perceptions of resources and desires as they relate to the task.

Motivation cannot be directly attached to the underlying mechanism of the self-control benefit. Although researchers into self-determination theory have thoroughly examined the concept of basic psychological need satisfaction as a means of increasing motivation, it is not completely known whether an increase in autonomy leads to the performance benefit in motor learning so often displayed by self-control. For one, several studies cite a tailored feedback schedule as a possible cause for the self-control benefit (Chiviacowsky et. al, 2012; Chiviacowsky & Wulf, 2002, 2005, 2007; Hartman, 2007; Huet, 2009), while several also cite motivation (Bund & Weimeyer, 2004; Saemi et al., 2012; Wulf et al., 2014). The discrepancy regarding the underlying mechanism points toward a need for further examination of the self-control paradigm.

A third reason why self-control facilitates learning stems from the idea that learners who are more metacognitively engaged in their learning environment (i.e. by being given control over some aspect of their environment) may enter a deeper level of information processing. The information-processing model of human action follows three stages that link the input of a stimulus to the output of a motor response. These three stages combine to create reaction time (RT). First, the stimulus must be identified and analyzed to the point where it arouses a proper memory association. Following identification, the individual must select a proper response. Finally, the set of abstract ideas and concepts that formed during identification and selection must be formed into a set of nervous system commands that will guide the muscular actions defining the movement output. The temporal combination of all three stages is commonly referred to as reaction time. Mental chronometry, the use of reaction time as a way to infer sequencing of cognitive operations, is often used as a measure of information processing during a task that involves the presentation of a sensory stimulus followed by a subsequent behavioral response (Posner, 1978).

The relationship between the duration of stimulus encoding and its affect on the duration of the proceeding response selection was seen clearly by William Edmund Hick and Ray Hyman's experiment in 1952. The Hick-Hyman Law states that reaction time increases by a constant amount every time the number of stimulus and response alternatives double. That is, an increase in the number of stimulus-response alternatives is a measure of the amount of information to be processed. The more alternatives introduced during a given task lead to greater amounts of processing required to complete the task. Introducing self-regulated feedback as a stimulus during skill acquisition may facilitate deeper information processing, thereby cultivating stronger performance of the skill long-term. But it could also significantly increase RT or *planning time* (PT) during acquisition. If the skill requires rapid processing for success (i.e., short duration RT or PT), then any lack of task familiarity which increases the number of perceived functional response alternatives, will degrade performance (Kanfer & Ackerman, 1989).

Previous literature indicates a need to further examine the effect of self-controlled learning on information processing. Numerous studies have argued that self-controlled feedback may lead to more extensive information processing (Patterson & Carter, 2010; Post et al., 2011; Wu & Magill, 2011;Wulf & Toole, 1999; Wulf, Raupach, & Pfeiffer, 2005) whereby the learner invokes greater self-regulatory processes, more deliberate response identification, longer response selection for the proper motor solution, and stronger correction techniques based on requested feedback (Wu & Magill, 2011). However, no studies have implemented a method of direct chronometric measurement as a means of gauging the effect of self-controlled learning on information processing. If the goal of a task is to respond as quickly as possible then more time spent in deeper levels of processing would be a disadvantage for a task requiring short reaction time. Therefore, the purpose of this study is to expand upon the assumption of previous research that learners who engage in self-controlled learning activate deeper levels information processing.

The greater the cognitive load placed upon the processing system of an individual, the more stress is placed on attentional and cognitive resource capacity. Kanfer and Ackerman (1989) demonstrated this phenomenon through a series of experiments designed to test the cognitive load of U.S. Air Force trainees in order to observe how motivation interventions affected performance. When a person first begins learning a task, any process that mediates self-regulation could hinder acquisition. Individuals normally apply their cognitive resources towards understanding the nature of the skill during the early stages of practice. However, allowing performers the opportunity for self-regulation, while facilitating motivation, could impede their learning due to overloading attentional capacity.

During the first stage of motor learning, verbal-cognitive, the individual engages in a good deal of self-talk (verbal) and must consciously focus on the intricacies of the movement in order to successfully execute the task (cognitive). It is very difficult for a person learning a novel task to process certain environmental information related to task (Wulf & Weigelt, 1997). The majority of their cognitions must be directed toward the general motor program necessary to complete the movement. Thus, giving someone the option to regulate his or her feedback during the verbal-cognitive stage of learning could disrupt the processing of basic motor learning information required during the early acquisition of a novel task. Furthermore, most of research exploring self-controlled feedback rarely shows significant effects between self-control and yoked participants during acquisition.

Most of the benefits of self-controlled feedback are not seen during acquisition (Wrisberg & Wulf, 1997; Wulf & Lee, 1993). In fact, several studies demonstrate the effectiveness of self-controlled feedback primarily during retention, transfer, or both (Aiken et al.; 2012; Post et al., 2011; Wu & Magill, 2011 Chiviacowsky & Wulf, 2005; Chiviacowsky & Wulf, 2002). Specifically, because the self-regulated learning effect is seen primarily during retention or transfer, and not during acquisition, such a phenomenon could be interpreted as being consistent with overloaded attention offsetting any gains seen from improved motivation. Once the task becomes more familiar, the beneficial motivational properties of self-controlled learning may take greater effect. Thus, simultaneously balancing the cognitive load necessary for acquiring a new task along with the information processing qualities of self-regulated feedback may interfere, initially, with performance. Alternatively, when the nuances of the task become more familiar and the inner working of the task become more automatic, the positive effects of self-controlled feedback may become more apparent.

Increasing the number of alternative responses during a task may increase additional preparation time due to the required cognitive load by affecting the KR delay interval when the participant was supposedly engaged in subjective evaluation of the previous trial. In 2011, Post Fairbrother, and Barros investigated the increase in the processing time by asking participants to learn a dart-throwing task with their non-dominant hand. The SC group could perform as many practice trials as they wished, while their YK counterparts completed an equal amount based on the number performed by the SC group. Although not significant, the average preparation time (APT) for each trial of the SC group during acquisition was longer across trials than the APT in the YK group. Thus, if the SC group's APT, was longer than the YK group, it could signify the deeper levels of processing required to subjectively evaluate their trial prior to the decision to extinguish practice trials.

The SC group was more accurate in recalling the number of trails completed during acquisition. The more accurate recall on a specific number of performed trials was interpreted as stronger monitoring of a heavier cognitive load within the SC group than the YK group. The strain of greater cognitive load on the SC individuals' information processing in the study appears to have created a positive effect with regard to a more accurate recall of completed trials accurately remembered. Although, if the goal were to respond and complete a task as quickly as possible (shorter RT or PT) rather than maintain accuracy (dart throwing) the significantly longer APT for the SC group could be an indicator of possible low levels of performance as a result of self-controlled feedback.

The previous literature concerning the underlying reasons for the benefit of self-controlled learning indicates a need to directly examine the role that information processing. Given what is known about the learners during the verbal-cognitive stage of learning (Schmidt & Wrisberg, 2000), coupled with the findings of regarding cognitive load and information processing as it relates to self-controlled feedback (Kanfer & Ackerman, 1989; Post, Fairbrother, & Barros, 2011), it serves that individuals who engage in self-controlled learning would display longer reactions times as a by product of deeper information processing. The purpose of the current study is to broaden the line of research by ascertaining if self-controlled feedback produces to longer reaction times during a sequential timing task, therefore representing deeper levels of information processing.

CHAPTER 3
METHOD

Participants

Twenty male (*n* = 11) and female (*n* = 9) university students (*M* age = 23.3. years, *SD* = 3.81) volunteered to participate in the experiment after Institutional Review Board approval was obtained for the this study. All participants read and signed an approved informed consent form notifying them of their right to participate and withdraw from the study at any time. Each participant was naïve to the nature of the study. Participants were randomly assigned to the SC group (*n* = 10) and the YK group (*n* = 10).

Apparatus and Task

The apparatus and task for the study were adapted from Chiviacowsky and Wulf (2002). Participants sat at a table equipped with a keyboard, monitor, and pc-compatible computer (*Dell Optiplex 960*). A customized computer program written in E-Prime (*Psychological Software Tools, Inc.*) was used to present the stimuli, record responses, and control the experimental procedures. Figure 1 shows a diagram depicting the movement sequence required by the task. Participants pressed four keys in a specified sequence using the number pad of the keyboard. Colored stickers were placed on the 2, 4, 6, and 8 keys to distinguish the keys used in the pattern from the rest of the number pad.

Procedure

A flowchart depicting the order and steps of the experiment is given in Figure 1, and an overall depiction of the procedure is shown in Figure 2. Upon arriving at the laboratory, participants were assigned to either the Self-Control (SC) or Yoked (YK) group. Participants in the SC group were told that they could request feedback following any trial during acquisition. Participants in the YK group were told that they would receive feedback after some trials but not others. The feedback schedules for the yoked participants were created by using the schedule of requests created by their counterpart in the SC group. Once the participant was seated, the experimenter provided verbal instruction regarding the task and experimental procedures. Written instructions were also displayed on the monitor. The experimenter then demonstrated the task once to familiarize the participants with the experimental procedures. Participants were instructed that the task goal was to complete the movement sequence so as to match the criterion segment times (200 ms – 400 ms – 300 ms) and the overall movement time (900 ms). They were also instructed to initiate their movement as soon as they were ready. Efficient preparation and accurate movement were equally emphasized.

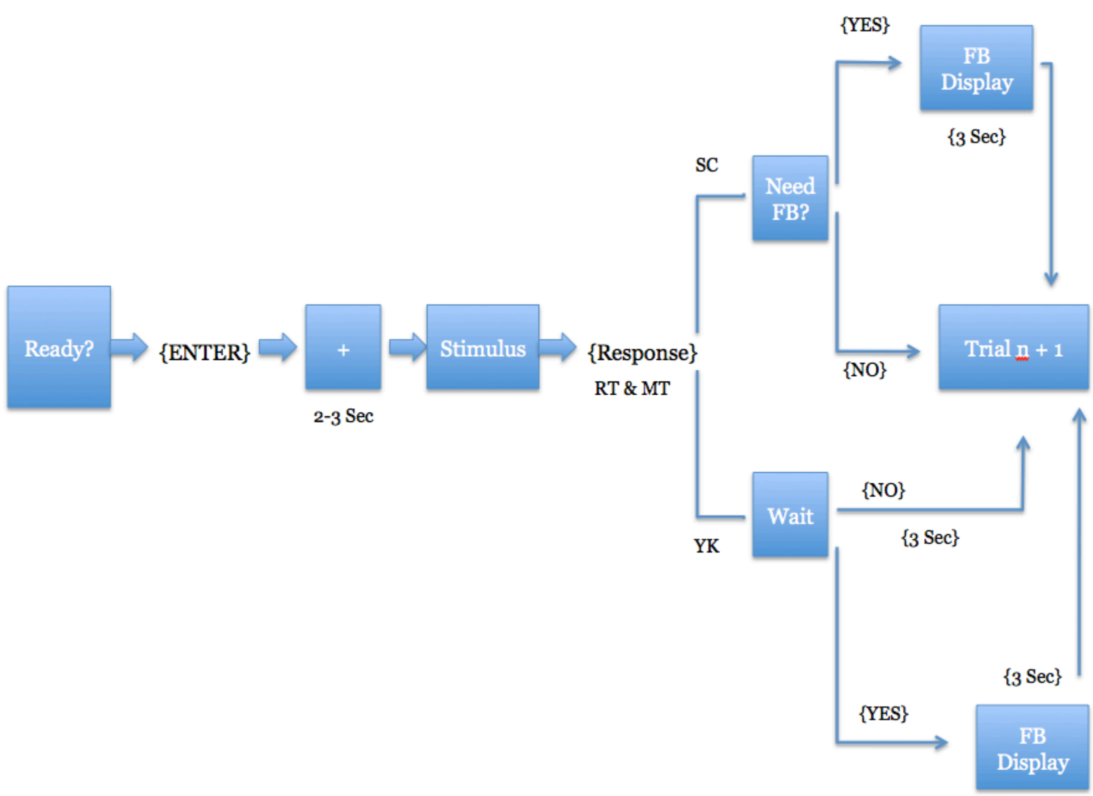

Figure 1. Individual Trial Flowchart

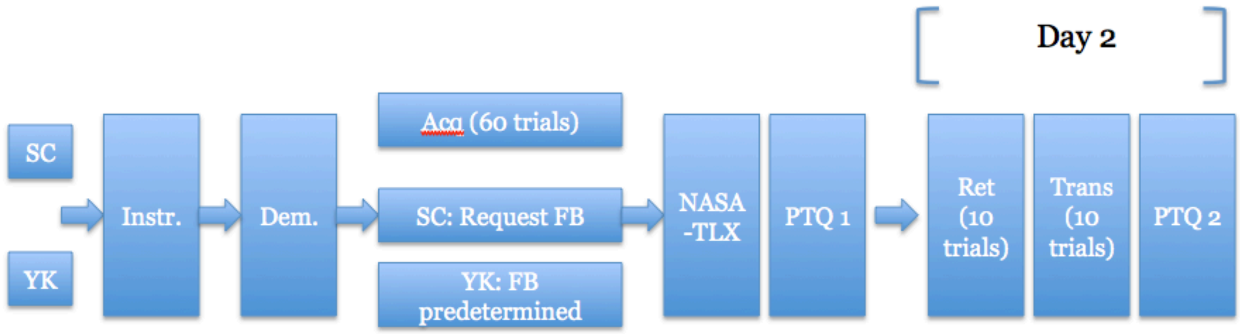

Figure 2. Procedural Flowchart

The movement began once the individual depressed the first key (2), and concluded with the depression of the final key (6). After each trial in the SC group, participants were asked if they NEEDED feedback, whereby they were given the option of pressing ENTER to receive feedback regarding the previous trial, or could wait for the subsequent trial to begin. That is, after each trial, they had the option of pressing of the ENTER key if they desired to receive knowledge of results (KR) of their reaction time (RT), individual segment times (200ms, 400ms, 300ms), and overall movement time (900ms). A representation of the KR screen is shown in Figure 3. The participant's time was shown beneath each particular KR segment of the trial in order to demonstrate the discrepancy between each specific goal and the actual time achieved. Participants in the YK group were given the same instructions as the SC group, except following each trial they were told to wait on the instructor to press ENTER in order to receive feedback. If not, they were told to wait until the next trial began.

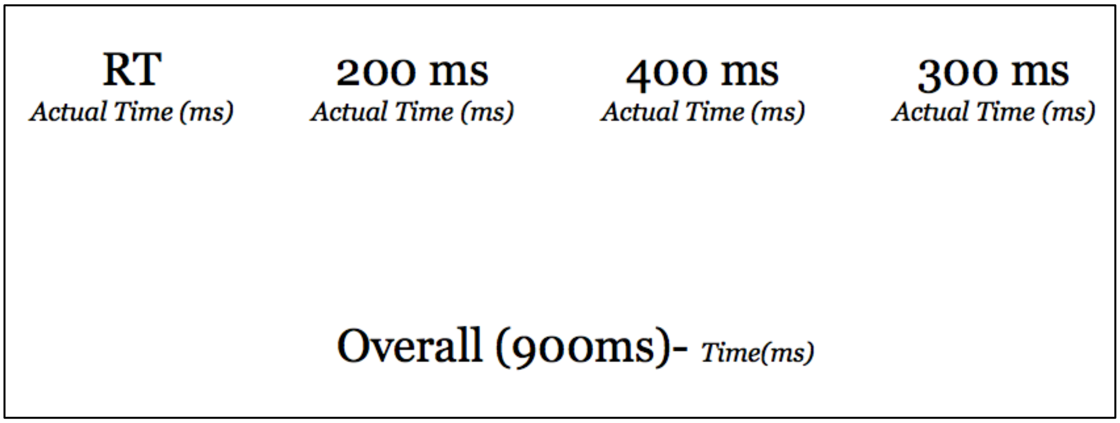

Figure 3. KR Feedback

Following the 60 trial acquisition phase (6 blocks of 10), both groups completed the NASA Task Load Index (TLX) questionnaire (Hart, 2006), a validated multidimensional subjective assessment tool of perceived workload during task performance. Furthermore, the test provided insight into the differences of perceived cognitive demand for the task between each group. Following completion of the NASA-TLX, both groups completed a day one exit interview. Participants in the SC group were given a questionnaire regarding their perceptions of the task and, more specifically, how the ability to control their feedback affected their experience. Alternatively, participants in the YK group were given a questionnaire regarding their perceptions of the task and how the lack of control over their feedback affected their experience. These questionnaires were adapted from those used by Aiken et. al. (2011) and Laughlin (2012).

Participants returned 24 hours following acquisition to complete the retention and transfer phases. Retention consisted of 10 trials on the practice version of the task (900ms). The 10 transfer trials consisted of the same movement pattern but with longer individual segment times (300-600-450ms) and, thus, a longer overall timing goal (1,350ms). No feedback was provided for either retention or transfer in both groups. Upon retention and transfer completion, both groups were asked an identical set of open-ended questions concerning their experience learning the task. The open-ended questionnaire was also adapted from Aiken et.al. (2011) and Laughlin (2012).

Data Treatment and Analysis

The primary dependent variable was overall movement time and planning time in relationship to stimulus onset. Absolute error, the absolute timing performance of each trial, were computed by taking the difference between the overall movement goal (MT) and the actual MT of the participant ($AE_{abs.tim.}$). Planning time was the elapsed time from stimulus onset to the depression of the first key (2).

During acquisition, $AE_{abs.tim.}$ was averaged into six 10-trials blocks and examined using a 2 (group) x 6 (block) ANOVAs with repeated measures on the last factor. When violations of sphericity were detected, *p*-values were recorded using the Greenhouse-Geisser degrees of freedom adjusted value. For retention and transfer, $AE_{abs.tim}$ was examined using a one-way ANOVA comparing the SC and YK groups. Post hoc analyses were completed using Sidak procedures. For all analyses, the alpha level was set to 0.05.

NASA-Task Load Index (TLX). The NASA-TLX (Hart, 2006) is an instrument used as a subjective workload assessment tool for individuals working with various human-machine systems. Specifically, it is a multi-dimensional scale designed to gather workload estimates from one or more individuals while they are performing a task or immediately afterwards. The questionnaire is rated based on perceptions of mental demand, physical demand, temporal demand, performance, effort, and frustration as a method of measuring perceived workload. The assumption for the test being that the combination of the previously mentioned dimensions represent “workload” experienced by an individual performing a task. Each item, or dimension, is rated on a Likert scale (Very Low, Low, Moderate, High, Very High).

Post -Training Questionnaire (PTQ) Day 1.Scores were rated based on perceptions of the participant regarding each question (1- Never; 2-Seldom; 3-Occasionally; 4- Often; 5-Always). The questionnaire was intended to explore how individuals from both groups used feedback when they requested/received feedback. Questions such as “Before you began practicing, you were instructed to **request** feedback only when you felt you **needed** it to learn the task. In general, how often did you ask for feedback when you needed it?” were posed to the SC group. Alternatively, questions such as “Before you began practicing, you were instructed that you would **receive** feedback after some trials but not after others. In general, how often did you receive feedback when you **needed** it?” were posed to the YK group.

Post-Training Questionnaire (PTQ) Day 2. The exit interview following retention and transfer was a series of open ended questions designed to further understand if participants implemented any particular strategies while learning the task, and what they thought about the quality and quantity of the feedback. The primary investigator analyzed responses. Frequency counts were taken of themes found within each quotation.

CHAPTER 4
RESULTS

Acquisition

The SC group requested feedback on 27% of the trials. The frequency of requests was consistent across all six trial blocks (*M* = 18%), with a slight increase during Block 2 (*M* = 23%).

Preparation Time. Figure 4 shows the mean PT across acquisition for the SC and YK groups. The SC group displayed higher mean PT than the YK group. Both groups decreased mean PT across acquisition blocks. These observations were supported by a significant main effect for Group, F (1, 18) = 4.59; p = 0.046, η^2 = 0.20), and for Block, F(5, 90) = 7.42, p = .001, η^2 = 0.29 . Post hoc analyses for the Block effect revealed that mean PT during Block 1 was significantly longer than during Blocks 3-6 (p < .032). The Group × Block Interaction was not significant, F(5, 90) = 0.73, p = 0.51. Despite a log transform, there were violations in the assumption of equality of covariance (p = 0.039) and equality of error variances for Blocks 5 and 6 (p = .042). Thus, the probability was increased for a Type I error (rejecting the null hypothesis).

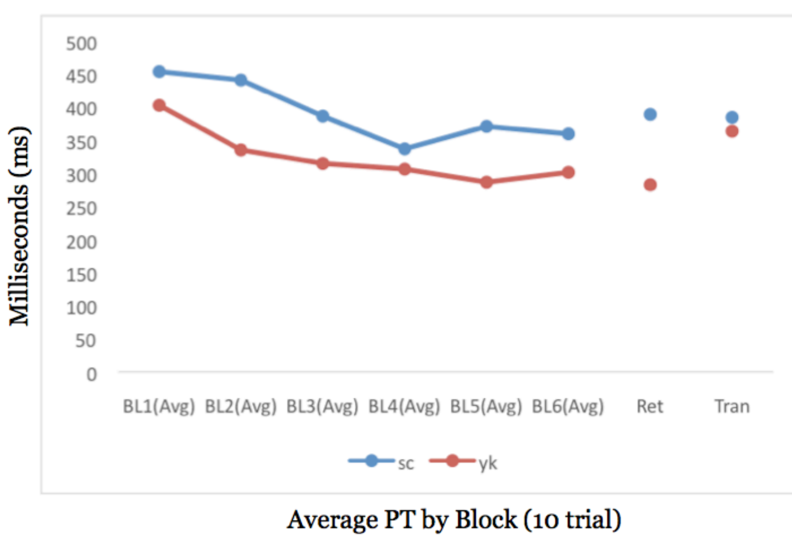

Figure 4. Average PT (ms) across all blocks (Time from onset of stimulus to beginning of trial)

Error scores:

AE$_{abs\ tim.}$: Figure 5 shows the mean absolute error scores during acquisition. Although the YK group showed a significant improvement between Blocks 1 and 2 as compared to the SC group, SC had significantly lower absolute error scores in relation to the overall timing score of 900 ms versus the YK group, F (1,18) = 6.87, p = .017.

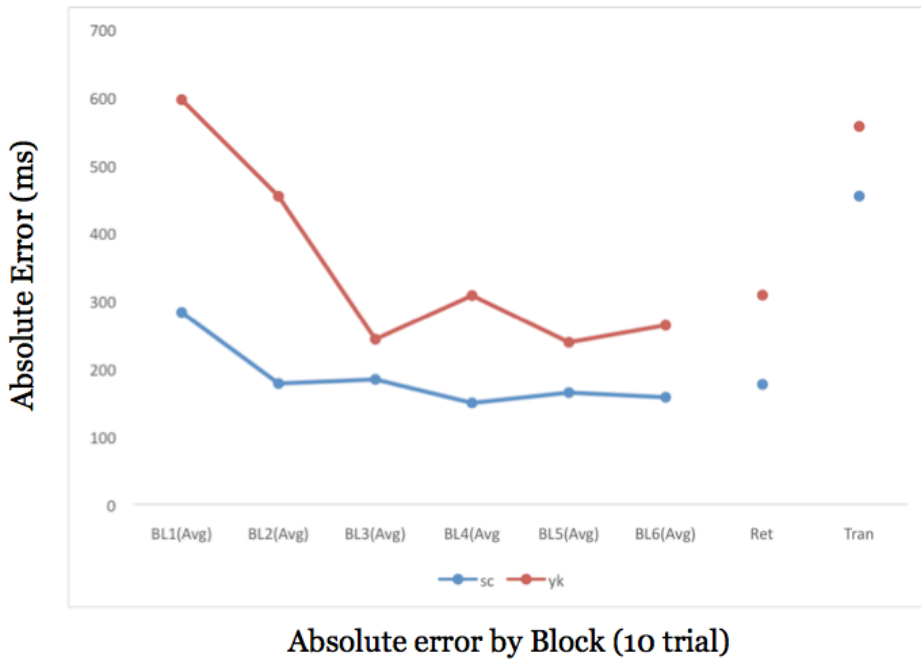

Figure 5. Absolute Error in ms (Overall Time. Acq. & Ret: 900ms; Trans: 1,350ms)

AErel: Absolute error scores of relative timing were all non-significant. Despite the log transform, all the tests for variance were significant, but all of them contained violations so they were not included.

Exit Survey (PTQ Day 1): The SC group (n= 10) reported that they *requested* feedback when they felt they needed it *occasionally* (M = 3.41; 3 = occasionally). The YK (n= 10) group indicated that they *received* feedback when they needed it *occasionally* (M = 3.23; 3 = occasionally).

Participants were also asked in what ways they used the feedback they requested/received using descriptive statistics suggested that self-control learners ask for feedback due to more complex reasons than error correction or success confirmation. According to the questionnaire within the present study and as shown in Table 1, SC participants did not show a preference for feedback after "good" or "bad" trials.

Participants may have used feedback for different reasons beyond error correction (bad trials) or success confirmation (good trials). The findings insinuate that individuals may use feedback for reasons more complex than error correction or success confirmation.

Table 1. SC vs. YK Error Correction and Success Confirmation (0 = Never; 1 = Seldom; 2 = Occasionally; 3= Often; 4 = Always)

Condition	Error Correction	Success Confirmation
SC	M = 3.20 SD = 1.47	M = 3.00 SD = 1.33
YK	M = 4.50 SD = 0.84	M = 3.90 SD = 0.99

NASA-TLX: TLX (Hart, 2006) scores for each of the 6 items (mental, physical, temporal, performance, effort, frustration) were summed to calculate an overall workload score and are seen in Figure 4. A higher score indicates a higher workload. The overall NASA-TLX (Hart, 2006) scores showed differences between groups (SC M = 2.68, SD = .35 YK M = 2.60, SD = .28).

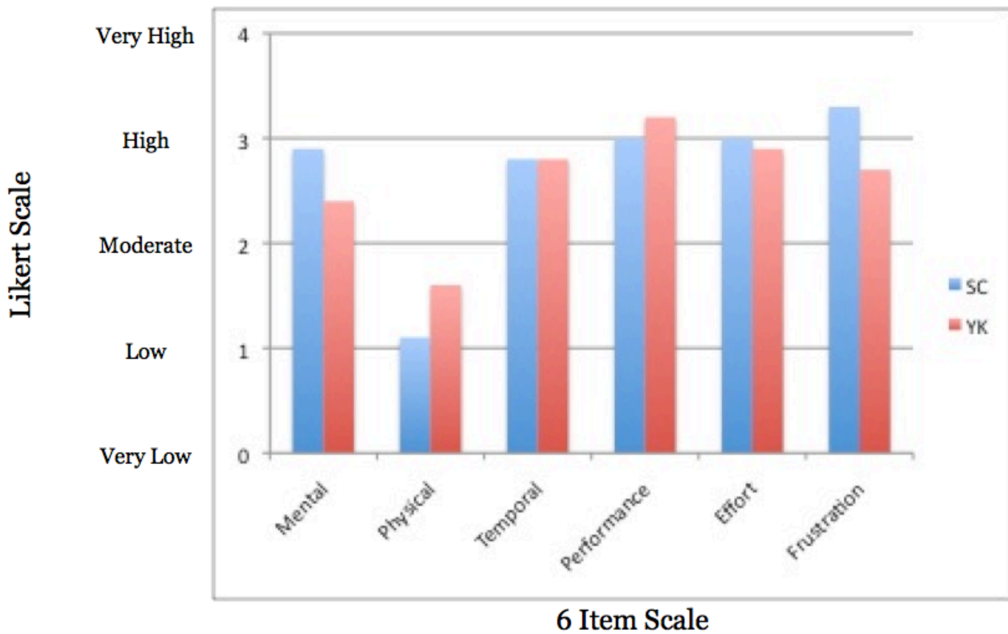

Figure 6. NASA-TLX Overall Scores (0 = Very Low; 1 = Low; 2 = Moderate; 3 = High; 4 = Very High)

PTQ Day 2: The results from the open-ended questions revealed that participants from both groups attempted to find a "rhythm" or to "get some kind of musical pattern" within key presses as a method of reaching their goals. Additionally, several participants from both groups mentioned listening to the "sound and strikes" of the keys as a measurement of knowing how close they were to the individual segment times. Of the twenty participants, 12 mentioned creating a strategy that dealt with either "rhythm" or some form of musical pattern. 70% of the SC group (n = 7) and 50% of the YK group (n = 5) for an average of 60% (n = 12) described implementing such a strategy when learning the task. Quotations from each participant are included in Table 2.

Table 2. PTQ Day 2 Results (Strategy Quotes of Rhythm/Music: Bold & Underlined)

ID	Group	Quote
<u>101</u>	SC	Did not look at the computer screen, and just kept my eyes on the numbers. I played around with my breath to keep myself from jumping and messing the **<u>rhythm</u>** up from the 2 to the 4 too quickly and I noticed that every time I jumped too quickly I was holding my breath
<u>102</u>	SC	In the first day I counted out a second in my head and tried to get the overall timing and **<u>rhythm</u>** just under that. And today I just estimated a little bit longer (transfer).
<u>103</u>	SC	I just tried to get a **<u>rhythm</u>**. Get something in my head that I thought was breaking it up as consistently as possible. Stayed consistent and just tried to get it more accurate
<u>104</u>	SC	I counted 1 through 4 in my head when I was hitting the keys. Creating a **<u>rhythm</u>**. The rhythm became more constant depending how fast or slow I was supposed to do each segment
105	SC	Go slower and I figured out how to do it better.
<u>106</u>	SC	I attempted to pace my fingers... to get in a routine. I tried to find a **<u>rhythm</u>**. I would say that I started feeling more comfortable as the trials progressed. Today (retention), I tried to hit the two faster today and hit enter (to begin the trial) a lot faster to get into more of a routine when I worked through the task.
107	SC	No
<u>108</u>	SC	I was trying to recognize the **<u>sound of the keys as a method</u>** of memorizing or recalling the sequence. It stayed consistent
<u>109</u>	SC	I figured out, or, became aware of the **<u>rhythm</u>** between the keypunches. Or the rhythm between the time delays and referenced that. I refined my existing strategies rather than try a bunch of different things
110	SC	Not really
<u>201</u>	YK	I tried to go slower between keys and try to stop and I guess count it in my head. Originally I was not really counting I was kind of just guessing and today I was counting and using my finger as a **<u>metronome</u>.**
202	YK	Not really
<u>203</u>	YK	I tried to figure out where the **<u>rhythm</u>** of the segments. It took me a while to figure it out but once I did it did not change
<u>204</u>	YK	I had a **<u>rhythm</u>** that I was going for. It changed when i got feedback the first time to change the rhythm to shorten it or lengthen.
205	YK	To press the first key quickly and then have a pattern of going around and pressing all the keys. So kind of going through the same motion. Repition. It stayed pretty constant because the trials were all the same.
206	YK	Just trying to get the timing aspects down.

207	YK	I tried to. If I felt like I was close to a time limit with a certain i would try to keep that same **rhythm**. If I felt like I was a little off I would try to slow down or speed. Just try to adjust when i got the feedback
208	YK	Just trying to use the same movement speed. I based the transfer off the first time and tried to make each segment longer. First one was more memorization and the second one was more about actual time than just memorization
209	YK	No
210	YK	What I did was to immediately, get the reaction and get that out of the way. That became second nature after a while. Then after that when I realized it wasn't to do everything as quickly as possible I would do the first segment as quickly as possible and then slow down a good bit for the second segment, and then speed up slightly for the third. To get that kind of **rhythm** going. And then after that just be as close as possible with the times.

CHAPTER 5
DISCUSSION

The purpose of the present study was to examine the effects of self-controlled feedback on the performance and learning of a sequential timing task. Three hypotheses were forwarded based on the self-control literature. Hypothesis 1 was that the SC group would produce longer mean PT than the YK group during acquisition. Hypotheses 2 and 3 were that the SC group would produce lower error scores during retention and transfer, respectively.

The most important contribution of the study was the demonstration that the SC group had significantly slower preparation time during acquisition. This was the first demonstration that the provision of self-control affects a measure reflecting information processing. The result was consistent with previous speculations that self-control prompts more thorough information processing (Janelle et.al., 1995; Post, Fairbrother, & Barros, 2011).

Previous literature demonstrates the self-control benefit within the motor domain (Chiviacowsky & Wulf, 2005; Janelle et al., 1997; Keetch & Lee, 2007; Post et al., 2011) but there is much speculation as to the underlying cause of the benefit. Several studies conjecture that an increase in motivation (Chiviacowsky, 2014; Wulf, Chiviacowsky, & Cardozo, 2014; Leotti & Delgado, 2011), a tailored, or preferential, learning schedule (Aiken, Fairbrother, & Post, 2010; Chiviacowsky & Wulf, 2002; Chiviacowsky & Wulf, 2007), or deeper information processing (Patterson & Carter, 2010; Post et al., 2011; Wu & Magill, 2011;Wulf & Toole, 1999; Wulf, Raupach, & Pfeiffer, 2005) may lead to a more efficient learning environment. And although researchers have speculated the latter, deeper information processing, no study has implemented a direct measurement of information processing during a task involving self-controlled feedback. The results of the study support hypothesis 1 wherein, during acquisition, the SC participants displayed significantly longer reaction times (deeper information processing) compared to their YK counterparts.

Hypothesis 3, the SC group would display more accurate timing scores than the YK group during retention and transfer (Wrisberg & Wulf, 1997; Wulf & Lee, 1993), and not during acquisition (Aiken et al.; 2012; Post et al., 2011; Chiviacowsky & Wulf, 2005; Chiviacowsky & Wulf, 2002; Wu & Magill, 2011) was not demonstrated. Significant differences in reaction time were found during acquisition as were significant differences regarding absolute error in regard to the overall timing goal, but no differences were found in errors or reaction time during retention or transfer. Literature suggests that the SC benefit is not found during acquisition due to a possible overabundance of cognitive load, and is instead seen during retention and transfer because the learner now possesses the necessary skills to attend to performance strategies (Aiken et al.; 2012; Post et al., 2011; Wu & Magill, 2011 Chiviacowsky & Wulf, 2005; Chiviacowsky & Wulf, 2002). The discrepancy between the literature and the current study could stem from two causes. First, more participants are needed in order to increase statistical power of the data. Second, only 10 trials of retention and 10 trials of transfer were performed. Perhaps more trials would provide more statistical evidence that could lead to a significant difference between both groups regarding reaction time and absolute error.

The exit interviews provided certain hints pertaining to how individuals use feedback. Participants in neither the SC nor the YK group showed a preference for feedback predominantly after good or bad trials. These findings contrast those of Chiviacowsky and Wulf (2002,2005) but mirror those found in Aiken et al.'s study (2011). Individuals appear to use feedback for more complex reasons than error correction or success confirmation. The open-ended exit interviews demonstrated that both groups implemented a similar strategy in an effort to learn the task. A majority of participants across the study used the concept of "rhythm" as a means of enhancing their task performance. It appeared that both groups chose to concentrate on task execution rather than quick reaction time in response to the stimulus. Concentration on the execution rather than responding quickly points to unconscious information processing within the SC group. The SC group, like the YK group, focused on the "rhythm" of the task rather than quick response time. And yet, there was a significant difference in reaction time between both groups during acquisition. Even though both groups chose to focus on task execution, the SC group still engaged in deeper levels of information processing without being consciously aware of doing so. Further exploration of this phenomenon is necessary in order to fully understand how the unawareness of deeper information processing can facilitate performance.

No significant statistical differences were found between groups for the NASA-TLX. However, the non-significant differences could result from different perceptions that were unable to be measured with the test. The SC group could have experienced a more subjective workload due to the cognitive strain of handling the responsibility of feedback that could then have lead to an increase in frustration, effort, or mental demand. Whereas the YK group, although not burdened with the demand of feedback responsibility, could have perceived greater frustration, effort, or mental demand due to the uncertainty of the feedback schedule. Open-ended questions to go along with the NASA-TLX (Hart, 2006) items could be used in further studies to distinguish the possible "perceptions" of each group. Questions such as "what specifically was it that led you to rate item name a Likert scale number*?"* could provide additional evidence as to the perceptual workload differences between both groups. Particularly, such open-ended questions could demonstrate the specific disparities between workload perceptions even if each group appeared to score the same on the workload scale, as was the case for the present study.

The results of the present study suggest that an underlying cause to the benefit of a self-controlled feedback schedule may be deeper information processing. Previous studies have advocated for several possible reasons for the self-control benefit: and increase in motivation (Chiviacowsky, 2014; Wulf, Chiviacowsky, & Cardozo, 2014; Deci & Ryan, 2000), customized schedule tailored to the learners' needs (Aiken et al., 2012; Chivacowsky & Wulf, 2002,2005), or deeper information processing (Patterson & Carter, 2010; Wu & Magill, 2011). The results of the questionnaire concerning the learners experience throughout skill acquisition parallels those found by Aiken et al. (2011) and contrasts those found by Chiviacowsky and Wulf (2002). It appears that learners do not desire feedback predominantly after "good" or "bad" trials. Rather, learners process the feedback in a variety of reasons related to the perception of their performance. The current study investigated the effects of self-controlled learning on information processing. The results revealed that learners engaged in a self-controlled learning protocol display longer reaction times than their YK counterparts. The present study, contrary to earlier research (Chiviacowsky & Wulf, 2002,2005; Hansen, Pfeiffer, & Patterson, 2011; Wulf & Toole, 1999) displayed a significant performance increase during acquisition, but not during retention and or transfer. The self-control group showed significant elevated PT during acquisition. Participants in the SC both took more time to begin each trial, and were more accurate in regard to overall timing.

Longer reaction times in response to a stimulus indicate deeper levels of information processing. Learners in the SC group also exhibited fewer absolute timing errors during acquisition than their YK counterparts. Furthermore, learners in both groups chose to focus on the "rhythm" of task execution as a strategy for learning the task. The choice of "rhythm," coupled with the significant differences in reaction time during acquisition, points to unawareness of deeper levels of information processing in a self-controlled protocol. And yet, without being aware that their reaction times were indeed slower due to their concentration on task execution, participants in the SC group did produce longer mean reaction times while implementing a similar performance strategy as their YK counterparts. Overall, the present findings indicate that a SC protocol does lead to deeper, and unconscious, information processing as opposed to a protocol feedback schedule entirely dictated by an instructor.

Summary of Procedures

Upon arrival to the facility, participants were informed about the parameters of the study and signed an informed consent form (Appendix A). Participants were randomly assigned an ID number and placed either in the SC or YK group. They were instructed that, while completing a specified key pressing pattern on the number-pad of a keyboard, they were to react as quickly as possible, strive for individual segment times, and thus attempt to reach an overall timing goal. Once participants witnessed the stimulus (200ms-400ms-300ms) which also informed them of each of the individual timing goals, they were to react as quickly as possible by pressing the “2” key. Movement time from depression of the “2” key to depression of the “4” key required a time of 200ms. Movement time from depression of the “4” key to depression of the “8” key required a time of 400ms. And movement time from the depression of the “8” key to depression of the “6” key required a time of 300ms for an overall movement time of 900ms.

Participants in the SC control group were told that they could request feedback regarding their reaction time, segment times, and overall movement time following any trial. Upon completion of a trial, SC participants were given the prompt “Do you NEED feedback?” Wherein they could press ENTER to receive KR regarding the previously mentioned times, or they could wait approximately 4 seconds for the next trial to begin. Participants in the YK group were told they would receive feedback after some trials, but not after others. Following completion of a trial, YK participants were given the prompt “Please wait for instructions. Press ENTER if told to do so. If NOT, please wait for the next trial to begin.” If no instructions were given to receive feedback the participant waited approximately 4 seconds for the next trial to begin.

Following 60 acquisition trials (6 blocks of 10 trials) participants in both groups completed the NASA-TLX (Hart, 2006) questionnaire as well as a Day 1 exit interview. SC participants were asked questions regarding their experience having control over their feedback schedule, while YK participants were asked questions regarding their experience with no control over their feedback schedule. Participants returned 24 hours later to complete a 10 trial retention and 10 trial transfer test. The 10 trial transfer test consisted of different segment, and overall, movement times (300ms-600ms-450ms for 1,350ms vs. 200ms-400ms-300ms for 900ms). Participants in both groups completed a Day 2 exit interview that consisted of open-ended questions regarding their overall learning experience.

Summary of Findings

The experiment revealed significant results for reaction time as chronometric measure of information processing within a self-controlled protocol. Furthermore, several non-significant findings related to questionnaire responses revealed both consistencies and inconsistencies with previous research.

Feedback. The SC group requested feedback on 27% of the trials. Frequency of feedback stayed consistent over all 6 blocks (M = 18%) with a slight increase in block 2 (M = 23%).

Reaction time. Analysis of scores revealed a significant group effect, F (1,18) = 4.83; p = .05). The SC group displayed higher mean reaction time scores than the YK group throughout acquisition, with the largest difference occurring in Block 5. Higher mean reaction time served as a chronometric measurement of information processing. The SC group, having longer mean reaction time, engaged in deeper levels of information processing than the YK group.

Absolute error. Although the YK group showed a significant improvement between blocks 1 and 2 as compared to the SC group, SC had significantly lower absolute error scores in relation to the overall timing score of 900ms in relation to the YK group, F (1,18) = 6.87, p = .017.

Questionnaire data: The NASA-TLX (Hart, 2006) showed no significant differences between the SC and YK groups. The SC group (n= 10) reported that they requested feedback when they felt they needed it *occasionally* (M = 3.41; 3 = occasionally). The YK (n= 10) group indicated that they *received* feedback when they needed it occasionally (M = 3.23); 3 = occasionally). SC participants did not show a preference for feedback after "good" or "bad" trials. Participants in the SC group tended to use the feedback more for error correction (M = 3.00; 3 = occasionally) than for success confirmation (M = 1.10; 1 = Never).

Retention. There were no significant results within reaction time or absolute error during retention.

Transfer. There were no significant results within reaction time or absolute error during transfer.

Conclusions

The findings of the present study suggest the following conclusions:

1. Self-control leads to deeper levels of information processing as demonstrated by the longer mean reaction times within the SC group. The deeper levels of information processing may provide a reason behind the self-control benefit.

2. The benefits of self-control were not dependent upon requesting feedback either after good or bad trials. Reasons for requesting feedback may be more complex than the difference between success confirmation or error correction.
3. Engaging in deeper levels of information processing is unconscious during a self-control protocol.

Limitations

1. Only 20 participants were gathered (10 each group). Future endeavors will need to use more participants as a means of strengthening statistical power.
2. The average age of all twenty participants (*M* = 23) may limit the external validity of the data.

Recommendations

The following recommendations for future research are suggested by the present findings:

1. More participants are required to increase statistical power.
2. More retention and transfer trials to exhibit a SC effect within performance and information processing.
3. An examination of a more tasks varying in complexity as well as feedback modalities to better understand the underlying benefit of self-control.
4. An examination of how a self-control protocol affects the instructor and not simply the participant.
5. Open-ended questions to include in conjunction with the NASA-TLX in order to verify the perceptions between each group.

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APPENDICES

Appendix A

INFORMED CONSENT STATEMENT

An experiment to examine the effects of feedback on the performance and learning of a sequential timing skill

Introduction

You are invited to participate in a research study that will investigate how feedback influences the performance and learning of a motor skill. A total number of 30 individuals will participate in the study. You will be asked to perform a speeded response key-pressing task on desktop computer. During the study, you will participate in two separate data collection sessions held on two consecutive days. The first session will last approximately 60 minutes and the second session will last approximately 15 minutes. Data from your performance will be recorded and stored on a personal computer for later analysis.

The task you will be learning will require using your hand to press a series of computer keys in a specified order. Goal times will be set for movements between successive keys and for the overall movement. You will complete 60 trials on the first day, followed by a brief questionnaire. On the second day, you will complete 20 trials, followed by brief exit interview.

If you volunteered for this experiment through the SONA system for credit in a UTK Psychology course, your participation will be reported to that website. The experimenters conducting this study are not directly involved in awarding course credit. They simply report whether or not you participated in the study.

The information in the study records will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study unless you specifically give permission in writing to do otherwise. No reference will be made in oral or written reports that could link you to your performance or to the study. The results of this study will contribute to a better understanding of the factors that influence the learning of movement skills.

___________ Participant's initials

Risks and Benefits

The task used in this study poses no risks to the participants beyond those inherent in light physical activity**.**

Participants may gain some insight into their personal preferences for feedback when learning a simple motor skill. The results of the study will contribute to current understanding of the potential mechanisms underlying self-control effects on motor performance and learning, which may in turn inform instructional approaches in a range of domains.

The University of Tennessee does not automatically reimburse subjects for medical claims or other compensation. However, the task you will learn presents no foreseeable health risks. In the event of an injury due to your participation, or if you have questions at any time about the study or the procedures, please contact Andy Bass or his faculty supervisor, Dr. Jeffrey T. Fairbrother, via the telephone numbers or email addresses indicated below. If you have any questions about your rights as a participant, contact the Research Compliance Services section of the Office of Research at (865) 974-7697

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed, your data will be returned or destroyed.

I have read the above information and agree to participate in this study. I have received a copy of this form.

Participant's name (please print): ___________________________________

Participant's signature: ____________________________________ Date: _________

Investigator's signature: ___________________________________ Date: _________

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Appendix B
NASA-TLX

How mentally demanding was the task?

Very Low Low Moderate High Very High

How physically demanding was the task?

Very Low Low Moderate High Very High

How hurried or rushed was the pace of the task?

Very Low Low Moderate High Very High

How successful were you at accomplishing what you were asked to do?

Failure Poor Moderate Good Perfect

How hard did you have to work to accomplish your level of performance?

Very Low Low Moderate High Very High

How insecure, discouraged, irritated, stressed, or annoyed were you?

Very Low Low Moderate High Very High

Appendix C
SC Questionnaire (Day 1)

Each question is to be read by the experimenter. Participants' responses are to be read by the experimenter. Participants' responses are to be marked on the Likert scale by the experimenter. Experimenter should document open-ended comments and ask participants to verify their accuracy and completeness.

The task you learned was comprised of several different dimensions. You goals included:. Starting the movement with as little delay as possible. Meeting timing goals for each of the three segments (200-400-300). Meeting the overall timing goal (900ms).

The next series of questions are organized by these three goals. For each goal, I will ask you about trials on which you thought your performance was good and then about trials on which you thought your performance was bad.

[redacted]

Before you began practicing, you were instructed to request feedback only when you felt you needed it to learn the task. In general, how often did you ask for feedback when you needed it?

Never Seldom Occasionally Often Always

Follow-up: Did you have a specific reason for this choice?
____
____

How often did you ask for feedback when you thought your performance was good in terms of starting your movement with little delay?

Never Seldom Occasionally Often Always

Follow-up: Did you have a specific reason for this choice?
____
____

How often did you ask for feedback when you thought your performance was bad in terms of starting your movement with little delay?

Never Seldom Occasionally Often Always

Follow-up: Did you have a specific reason for this choice?
____
____

How often did you ask for feedback when you thought your performance was good in terms of meeting each individual segment time?

Never Seldom Occasionally Often Always

Follow-up: Did you have a specific reason for this choice?
____
____

How often did you ask for feedback when you thought your performance was bad in terms of meeting each individual segment time?

Never Seldom Occasionally Often Always

Follow-up: Did you have a specific reason for this choice?

How often did you ask for feedback when you thought your performance was good in terms of meeting the overall timing goal?

Never Seldom Occasionally Often Always

Follow-up: Did you have a specific reason for this choice?

How often did you ask for feedback when you thought your performance was bad in terms of meeting the overall timing goal?

Never Seldom Occasionally Often Always

Follow-up: Did you have a specific reason for this choice?

When you asked for feedback you might have used it in different ways. The following three questions pertain to how you used feedback

How often did you use the feedback you requested for error correction?

Never Seldom Occasionally Often Always

How often did you use the feedback you requested to confirm success?

Never Seldom Occasionally Often Always

How often did you use the feedback you requested for other purposes?

Never Seldom Occasionally Often Always

Please explain your uses of feedback for other purposes:

You were asked to manage the administration of feedback by requesting it only when you needed it. The next two questions are about how that responsibility affected your ability to focus on learning the task.

How often did being responsible for deciding to receive feedback make you concentrate more on learning the task?

Never Seldom Occasionally Often Always

How often did being responsible for deciding to receive feedback make you concentrate less on learning the task?

Never Seldom Occasionally Often Always

Is there anything else you think I should know about your experience today?
____
____

Appendix D
YK Questionnaire (Day 1)

Each question is to be read by experimenter. Participants' responses are to marked on the Likert scale by the experimenter. Experimenter should document open-ended comments and ask participant to verify their accuracy and completeness.

Before you began practicing, you were told that you would receive feedback after some trials but not others. In general, how often did you feedback when you needed it?

Never Seldom Occasionally Often Always

The task you learned was comprised of several different dimensions. You goals included:. Starting the movement with as little delay as possible. Meeting timing goals for each of the three segments (200-400-300). Meeting the overall timing goal (900ms).

The next series of questions are organized by these three goals. For each goal, I will ask you about trials on which you thought your performance was good and then about trials on which you thought your performance was bad.

[redacted]

How often did you receive feedback when your performance was good in terms of starting your movement with little delay?

Never Seldom Occasionally Often Always

How often would you have preferred to receive feedback when your performance was good in terms of starting your movement with little delay?

Never Seldom Occasionally Often Always

How often did you receive feedback when your performance was bad in terms of starting your movement with little delay?

Never Seldom Occasionally Often Always

How often would you have preferred to receive feedback when your performance was bad in terms of starting your movement with little delay?

Never Seldom Occasionally Often Always

How often did you receive feedback when your performance was good in terms of meeting the segment times?

Never Seldom Occasionally Often Always

How often would you have preferred to receive feedback when your performance was good in terms of meeting the segment times?

Never Seldom Occasionally Often Always

How often did you receive feedback when your performance was bad in terms of meeting the segment times?

Never Seldom Occasionally Often Always

How often would you have preferred to receive feedback when your performance was bad in terms of meeting the segment times?

Never Seldom Occasionally Often Always

How often did you receive feedback when your performance was good in terms of meeting the overall timing goal?

Never Seldom Occasionally Often Always

How often would you have preferred to receive feedback when your performance was good in terms of meeting the overall timing goal?

Never Seldom Occasionally Often Always

How often did you receive feedback when your performance was bad in terms of meeting the overall timing goal?

Never Seldom Occasionally Often Always

How often would you have preferred to receive feedback when your performance was bad in terms of meeting the overall timing goal?

Never Seldom Occasionally Often Always

When you received feedback you might have used it in different ways. The following three questions pertain to how you used feedback

How often did you use the feedback you received for error correction?

Never Seldom Occasionally Often Always

How often did you use the feedback you received to confirm success?

Never Seldom Occasionally Often Always

How often did you use the feedback you received for other purposes?

Never Seldom Occasionally Often Always

Please explain your uses of feedback for other purposes:

[redacted]

The next two questions are about how receiving feedback after only some trials affected your ability to focus on learning the task.

How often did not knowing when you would receive feedback make you concentrate more on learning the task?

Never Seldom Occasionally Often Always

How often did not knowing when you would receive feedback make you concentrate less on learning the task?

Never Seldom Occasionally Often Always

Is there anything else you think I should know about your experience today?
____
____

Appendix E
SC & YK Questionnaire (Day 2)

I would like to ask you a few open-ended questions about your learning experience.

Did you use and/or develop any particular strategies while learning the task? If so, what kind of strategies did you use? Did those strategies change as you practiced?

____
____

Did you use set any particular goals while learning the task? If so, what were those goals? Did they change as you continued to practice?

____
____

What did you think about the quality of feedback that was available to you while you learned?

____
____

Is there anything else that I have forgotten to ask that you think is important?

____
____

VITA

Andrew Duvier Bass was born in College Grove, TN on March 25, 1989. He attended and graduated from Battleground Academy in Franklin, TN in the spring of 2007. After high school he enrolled at Davidson College in Davidson, NC where he was a 4-year letter winner in baseball. Upon completion of his undergraduate degree, with a major in psychology and a minor in philosophy, he was selected in the 18^{th} round of the 2011 Major League Baseball draft. He spent two years playing professional baseball in the Tampa Bay Rays and Chicago White Sox organizations, respectively. Following his release from professional baseball, he completed his master's degree in kinesiology with a concentration in Sport Psychology and Motor Behavior from the University of Tennessee- Knoxville in 2015 and was admitted to the PhD program in Kinesiology at the University of Tennessee-Knoxville.