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An examination of feedback request strategies when learning a multi-dimensional motor task under self-controlled and yoked conditions

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I am submitting herewith a dissertation written by Arya Alami entitled "An examination of feedback request strategies when learning a multi-dimensional motor task under self-controlled and yoked conditions." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Kinesiology and Sport Studies.

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An examination of feedback request strategies when learning a multi-dimensional motor task
under self-controlled and yoked conditions

A Dissertation Presented for the
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Degree
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ABSTRACT

Recent research investigating how learners benefit from having control over some aspect of their practice environment has led to numerous potential explanations for its beneficial effects (Janelle et al., 1997; Chiviacowsky & Wulf, 2002). These explanations, however, are vague and difficult to directly measure. Current research suggests that learners in a self-controlled setting prefer feedback after relatively good performances. More recently, Aiken and colleagues (2012) have provided evidence suggesting that when learners control their feedback schedule while learning a task with multiple dimensions of performance, they prefer and request feedback after both “good” and “poor trials” equally. The purpose of this study was to directly address how learners in self-controlled and yoked conditions learn a task with two conflicting elements of performance in a laboratory setting. Participants (n=22) learned a discrete aiming task for which they had to move from a starting zone around a barrier to a target with a handheld stylus in their non-dominant hand in 600 ms. Success was determined on two criteria: temporal and spatial accuracy. Participants completed motivation scales assessing intrinsic motivation, perceptions of choice and competence, and fulfillment of basic psychological needs. A post-training questionnaire was used to examine learner preferences for feedback. Results indicated the self-control group outperformed the yoked group in spatial accuracy during transfer tests. Further, analysis of performance and questionnaire data revealed that the self-control group requested feedback equally on their best performance as on their worst performances. The findings of this study support the notion that learners request and benefit from feedback differently dependent on task complexity. Future research should consider using semi-structured interviews to better understand how learners use and develop strategies related to feedback requests.

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CHAPTER 1

Introduction

A major goal of motor behavior research has been to investigate and explain the different ways one can facilitate the learning of motor skills. Recently, researchers have focused their efforts on understanding the role of learner autonomy in motor skill acquisition (for a review see Sanli, Patterson, Bray, & Lee, 2013). Often termed “self-control” in the motor domain, the idea of allowing learners control over some aspect of their learning environment (e.g., feedback administration) is rooted in self-regulation research in social cognitive psychology. According to self-regulation research, learners who are allowed to regulate their learning environment by establishing goals, using strategies, and monitoring and evaluating one’s performances exhibit higher aptitude in educational settings (Cleary & Zimmerman, 2001; Zimmerman, 2002; Schunk & Zimmerman, 2006). As a result, learners demonstrate higher aptitude and higher motivation associated with the learned task. Likewise, the beneficial effects of affording individuals autonomy over some aspect of their learning environment have also been demonstrated and replicated while learning motor skills.

The notion that autonomy, even in novices, leads to better learning has been supported by motor learning research providing control over performance-related feedback (Janelle, Kim, & Singer, 1995; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997), outcome-related feedback, or knowledge of results (KR), (Chen, Hendricks, & Lidor, 2002; Patterson & Carter, 2010), physical guidance (Wulf, Clauss, Shea, & Whitacre, 2001; Wulf & Toole, 1999), practice schedule (Keetch & Lee, 2007; Post, Fairbrother, & Barros, 2011), and the presentation of video demonstration (Wulf, Raupach, & Pfeiffer, 2005) and video feedback (Aiken, Fairbrother, & Post, 2012; Ste-Marie, Vertes, Law, & Rymal, 2013) while practicing a wide range of motor

skills (e.g., overhand and underhand throwing tasks, table tennis serves, sequential key pressing). This so-called self-control effect (Fairbrother, 2010) has also been demonstrated in children (Chiviacowsky, Wulf, de Medeiros, Kaefer, & Tani, 2008; Kolovelonis, Goudas, & Dermitzaki, 2010), active and less active individuals (Fairbrother, Laughlin, & Nguyen, 2012), people with Parkinson's disease (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012) and children with spastic hemiplegic cerebral palsy (Hemayattalab, Arabameri, Pourazar, & Ardakani, 2013). In such studies, performance of one group of participants given control over some aspect of their learning environment (self-controlled) is compared to that of a "yoked" group of participants, whose learning environment is structured to mirror that of a self-control counterpart. For example, a self-controlled group would receive performance feedback whenever requested, while the yoked group would receive feedback based on the schedule selected by their self-controlled counterpart.

In the early research on self-controlled motor learning, a few studies forwarded potential explanations for the observed beneficial effects. These explanations included the use of more effective learning strategies, triggering deeper cognitive processing, increasing learner motivation, and fulfilling learner-specific needs and preferences. Citing earlier work by Watkins (1984), Janelle et al. (1997) proposed that the self-control effect might be a product of the development of more effective learning strategies and deeper information processing, and as a result increased confidence in their performance. Further, Janelle et al. also suggested that having an active role in planning the learning environment forces the learner to assume responsibility for learning the skill and thus increases motivation in performing well. Additionally, Chiviacowsky and Wulf (2002) proposed that self-controlled learners might also benefit from being able to

tailor the practice environment to their specific needs and preferences, such as using feedback to confirm successful performances, to learn where they need to make adjustments, or when they feel uncertain about their performance. However, these proposed explanations are assumptions of how learners may benefit from the self-control effect. Published empirical research directly investigating the validity of these early explanations is lacking. Chiviacowsky and Wulf (2002) acknowledged this gap in the literature, suggesting the vague nature of the proposed explanations makes it difficult to directly investigate any underlying mechanism responsible for the self-control effect. Instead, recent research has taken an indirect approach.

In order to better understand the underlying mechanisms behind the self-control effect, Chiviacowsky and Wulf (2002) investigated whether learners utilize feedback for error correction or for confirmation of success when given control over feedback schedule. While learning a sequential key-pressing task, where timing accuracy was the primary goal, self-control participants were allowed to request feedback whenever they “needed it,” while yoked participants received feedback according to the schedule set by their self-control counterpart. At the end of the experiment, participants were given questionnaires addressing their preferences for feedback. Self-control participants were asked whether they requested feedback after mostly “good trials,” “bad trials,” after both equally, or randomly. Similarly, yoked participants were asked if they received feedback “after the right trials” and, if no, when they would have preferred feedback: primarily after “good trials,” “bad trials,” didn’t matter, or none of the above. Results revealed that the majority of learners in the self-control group preferred feedback after relatively good trials. When asked when they requested feedback, 66% of self-controlled participants reported they requested feedback mostly on trials that they thought they “had a good trial”; no

self-control participant reported to have requested feedback on trials that they thought they “had a bad trial.” Of the yoked participants, 73% reported they did not receive feedback “after the right trial,” 63% of which reported a preference for feedback “after good trials.” Additionally, a comparison of performance on trials that feedback was and was not administered indicated that the self-control group performed with better accuracy on trials that they asked for feedback than on trials that they did not ask for feedback. The yoked group, on the other hand, performed worse on feedback trials than on no-feedback trials. Though not overwhelming, the findings suggested that learners benefit from self-control because they can tailor the feedback schedule to their preference for feedback that confirms successful performance. However, it still was not clear whether the beneficial effect of self-controlled learning was due to learner’s utilizing the afforded autonomy to tailor the learning environment to better fit their specific needs, their preferences for feedback after relatively good trials, or simply the provision of control over feedback schedule.

Follow-up studies investigating the provision of feedback after “good trials” have confirmed its beneficial effects on learning. Chiviacowsky and Wulf (2007) observed that learners who receive feedback on their better performances learn a motor skill better than learners who receive feedback on their poorer performances. Bademi, Vaez Mousavi, Wulf, and Namazizadeh (2011) further investigated this phenomenon while also measuring learner motivation via the Intrinsic Motivation Inventory (IMI; McAuley, Duncan, & Tammen, 1989). Results indicated that learners who received feedback after “good trials” reported higher perceived competence and intrinsic motivation in performing the task than learners who received feedback after “poor trials.” Likewise, Saemi, Porter, Ghotbi-Varzaneh, Zarghami, and Maleki

(2012) reported increases in both motor learning and self-efficacy (Bandura, 2006) when presenting learners with feedback after relatively good trials versus relatively bad trials. According to self-determination theory (SDT), perceived competence and self-efficacy are synonymous (Ryan & Deci, 2000). Thus, rather than utilizing feedback for error corrective purposes, the findings of Chiviacowsky and Wulf (2002) and the research highlighting the learning benefit of receiving feedback after “good trials” suggest that learners use self-control feedback to confirm good performances as well as increase their feelings of competence or efficacy.

Recent research investigating self-control over video feedback, however, indicates that learner needs and preferences may change based on the nature of the task. In Aiken, Fairbrother, and Post (2012), learners given self-control over the administration of video feedback demonstrated superior learning of a basketball set shot compared to their yoked counterparts. However, the self-controlled learners did not exhibit the same tendency to request for feedback after “good’ trials,” as reported by Chiviacowsky and Wulf (2002). Instead, performers in both self-controlled and yoked groups had similar form scores and accuracy scores on feedback and no-feedback trials. Further, results from a post-training questionnaire indicated that self-controlled learners reported requesting feedback occasionally after both “good” and “poor trials.” While the procedures were similar to previous self-control research, the basketball set shot task used by Aiken et al. had more elements of performance than the key-pressing task used by Chiviacowsky and Wulf. Presumably, tasks with multiple performance related dimensions (e.g., accuracy and various features constituting proper form) can place the learner in a dilemma if his or her goal is to seek feedback only after so-called “good” trials. Any given trial is likely to have

included features that were good as well as some that were “poor.” Aiken et al.’s results suggest that when learning such tasks, learners actually use feedback to address both correction for poor features and confirmation for good features. The richness of information provided by video feedback lends itself well to such an endeavor and participants could in fact use the same video clip to alternately focus on different features of the task. In most self-control feedback studies, on the other hand, feedback has focused on only a single aspect of the task, requiring participants to simply decide if they would receive it or not. This comparison illustrates that the nature of learners’ self-controlled feedback preferences requires a more comprehensive examination to determine if tasks with multiple performance-related dimensions alter the way learners use and benefit from self-control.

One way to directly address the issue of preferences for good- or poor-trial feedback is to examine self-control requests for a task that directly pits the successful performance of one aspect against that of another. In a discrete aiming task that requires both timing and spatial accuracy (e.g., Schmidt et al., 1979), learners use augmented feedback to monitor and evaluate performance of each aspect. Although improvements in both speed and spatial accuracy are needed to increase proficiency, the nature of such tasks introduces a speed-accuracy trade-off (Fitts, 1954). Specifically, gains in performance on one aspect of the task are offset by sacrificing performance on the other aspect. The simple nature of such a task allows for a more convenient and controlled way to test self-controlled participants’ preferences for feedback in a laboratory setting. Giving self-controlled learners the freedom to choose when to receive feedback and on which aspect of the task they receive feedback (i.e., either movement time or spatial accuracy)

allows an examination of how learners use the autonomy afforded by self-controlled learning when asked to learn a motor skill.

An examination of how learners use self-control to learn a motor skill, however, would be incomplete without also addressing changes in learner motivation and perceptions of competence or efficacy. As illustrated by the work of Chivacowsky and Wulf (2002), Badami et al. (2011) and Saemi et al. (2012), requesting feedback primarily after relatively good trials can illicit positive effects on learner motivation and feelings of competence. Bund and Weimeyer (2004) reported that self-control over different learning modalities, regardless of learner preference, increased feelings of efficacy and led to better motor learning than yoked conditions. In their study, self-controlled learners were allowed to have control over one of two aspects of the learning environment: practice schedule (more preferred among self-control participants) or the administration of a video model (less preferred among self-control participants). Results indicated that, regardless of preference, participants with self-control over either learning modality exhibited higher movement form scores and reported higher self-efficacy than their yoked counterparts during retention tests. Further, Ste-Marie, Vertes, Law, and Rymal (2013) measured learner motivation in children learning a trampoline routine with and without control over video feedback schedule. Results indicated that self-controlled learners reported greater increases in self-efficacy during the acquisition phase and performed with better form scores and reported higher intrinsic motivation and perceptions of choice in retention tests than their yoked counterparts. However, measuring motivation and perceptions of competence or efficacy with scales from separate motivational theories, with distinct conceptualizations of motivation, is problematic. Ste-Marie et al. (2013) used an adapted version of Bandura's (2006) self-efficacy

scale, based on his self-efficacy theory (Bandura, 1977), to measure feelings of competency and efficacy and the IMI, based on self-determination theory (SDT; Deci & Ryan, 1985), to measure perceptions of choice and intrinsic motivation. Additionally, the beneficial effects to perceived competence and self-efficacy exhibited by Badami et al. (2012) and Saemi et al. (2013) also used two different motivational scales, the IMI and Bandura's (2006) self-efficacy scale, respectively.

Instead, using measurement scales from one theoretical framework, such as SDT, provides a more fluid understanding of the role motivation plays in the self-control effect. SDT provides such a framework to examine learner motivation and need fulfillment in self-controlled learning. The idea of giving learners control over their learning environment fits SDT's view on basic psychological need fulfillment (Deci & Ryan, 1985). SDT describes motivational needs as innate organismic necessities, inherent in all humans; the on-going fulfillment of which leads to healthy development, well-being and optimal functioning (Deci & Ryan, 2000). Further, SDT suggests that people will pursue goals, actions, or behaviors that allow or support the satisfaction of their basic psychological needs: autonomy, competence, and relatedness (Deci & Ryan, 2000). The need for autonomy refers to volition and an individual's desire to self-organize experiences and behaviors (Ryan & Deci, 2000). The need for competence refers to feelings that result from effective functioning (Deci & Ryan, 1985). The need for relatedness refers to a person's desire to feel connected to others (Deci & Ryan, 2000). According to SDT, the self-control effect may be partially explained by fulfillment of the basic psychological need for autonomy. Further, based on the findings of Chiviacowsky and Wulf (2002), it can be argued that learners then use the autonomy afforded to them by self-control to also fulfill a second basic psychological need for competence by requesting feedback after good performances rather than poor performances.

Therefore, a possible explanation to the self-control effect could be provided by fulfillment of the basic psychological need for autonomy, the basic psychological need for competence, or a combination of the two.

In summary, self-controlled feedback allows learners to request feedback when they prefer it. Research has shown that learners prefer feedback after relatively good performances when learning basic motor skills. Additionally, these preferences are associated with increases in intrinsic motivation and perceptions of competence. When learning a motor task with multiple elements of performance, however, learners exhibit a preference for video feedback after both relatively good and poor performances. The richness of information presented via video feedback puts learners in a situation where they can use the same video clip to focus on both well and poorly performed aspects of a task. Investigating the self-control effect with a simple task incorporating multiple elements of performance while measuring learner motivation under the framework of one motivational theory provides an opportunity to better understand how learners utilize self-control for motor learning. If learners use the autonomy afforded by an experimental self-control provision to fulfill the basic psychological need for competence (Deci & Ryan, 1985), it would be expected that feedback requests would be tied to the feature of task performance that is performed accurately. For example, requests for temporal accuracy feedback should follow movements that are temporally accurate and spatial accuracy feedback requests should follow movements that are spatially accurate. In order to examine these possibilities, performance data were analyzed across feedback requests (feedback and no-feedback) and self-control condition (self-controlled and yoked groups) for both temporal and spatial accuracy.

Changes in motivation, perceived competence, and need fulfillment were assessed using the IMI and basic psychological needs scale (BPNS; Ryan & Deci, 2000), respectively.

Statement of the Problem

Present understanding of the self-control effect and its underlying mechanisms is limited, largely due to the vague nature of the currently proposed explanations and the narrow scope of the existing literature. In order to better explain how self-control works, a more in depth investigation of how learners behave when given control over feedback administration while learning a task with multiple dimensions of performance is warranted.

Purpose of the Study

The purpose of this study is to examine how learners in self-controlled and yoked conditions behave when learning a task with two conflicting dimensions of performance. Specifically, this study was designed to examine how learners use the autonomy afforded to them in a self-control protocol to learn a novel skill incorporating a speed-accuracy trade-off. Special attention was given to resulting effects on perceived competence, the fulfillment of basic psychological needs, the development of and use of any strategies during learning, and differences in performance and learning between the self-controlled and yoked conditions.

Hypotheses

Based on the existing literature, the following hypotheses were tested:

1. Participants will ask for temporal accuracy feedback more often than spatial accuracy feedback.
2. Self-control participants will perform with better temporal accuracy and better spatial accuracy than their yoked counterparts in retention and transfer tests.

3. Self-control participants will perform with equal temporal accuracy and spatial accuracy on feedback versus no-feedback trials.
4. Self-control participants will report higher levels of interest and enjoyment than their yoked counterparts.
5. Self-control participants will report higher levels of perceived choice than their yoked counterparts.
6. Self-control participants will report higher levels of perceived competence than their yoked counterparts.
7. Self-control participants will report higher levels of satisfaction for the basic psychological needs of autonomy and competence than their yoked counterparts.

Assumptions

1. Participants performed to the best of their abilities throughout the course of the study.
2. Participants were honest in their responses to all questionnaires.
3. Participants had no prior experience with the experimental task

Delimitations

1. Participation was voluntary.
2. Participants were naïve to the purpose of the study.
3. The study was conducted in a laboratory setting.

Limitations

1. The data collector was not blind to the study.
2. The task was a simple motor task with multiple dimensions of performance.

3. The measures for basic psychological need fulfillment and intrinsic motivation level are self-reported instruments.

Definition of Terms

Acquisition. The initial phase of a motor learning study during which the participant practices the motor task (Janelle, Kim, & Singer, 1995).

Augmented feedback. Information about a movement that is provided to the learner from an outside source (Fairbrother, 2010).

Autonomy. An individual's experience of choice in their ability to regulate themselves in pursuit of self-selected goals (Deci & Ryan, 1985).

Basic psychological needs (BPN). The needs for autonomy, competence, and relatedness that specify innate psychological nutrients, essential for ongoing psychological growth, integrity, and well-being (Deci & Ryan, 1985).

Competence. The basic psychological need to feel efficacious with respect to a performed activity, analogous to self-efficacy (Ryan & Deci, 2000).

Feedback. Sensory information in regards to a movement (Magill, 2007).

Floor effect. When performance in a task has reached an asymptote and further improvement and lower performance is no longer possible (Schmidt & Lee, 2011)

Intrinsic motivation. A non-drive-based form of motivation, where the energy to act and/or behave is intrinsic to the nature of the organism (Deci & Ryan, 19985).

Knowledge of performance (KP). Augmented feedback about the nature of a movement (Fairbrother, 2010).

Knowledge of results (KR). Augmented feedback about the outcome of a movement (Fairbrother, 2010).

Motor learning. “The changes, associated with practice or experience that determine a person’s capability for producing a motor skill” (Schmidt & Wrisberg, 2008, p. 191).

Motor skills. Activities or tasks that require voluntary head, body, and/or limb movement to achieve a goal (Magill, 2007).

Movement time (MT). The interval of time between the initiation of a movement and the completion of the movement (Magill, 2007).

Perceived competence. An individual’s assessment of their ability or skill level at a task or activity (Deci & Ryan, 1985).

Performance. The behavioral act of executing a skill at a specific time and in a specific situation (Magill, 2007).

Rapid, discrete aiming task. A movement where performers attempt to make a single movement with a handheld stylus from a starting position to a target (Schmidt & Wrisberg, 2008).

Relatedness. The basic psychological need to feel connected to other human beings (Ryan & Deci, 2000).

Retention test. A test of a practiced skill that a learner performs to assess learning following an interval of time after practice has ceased (Magill, 2007).

Self-control. Giving a learner some degree of control over the learning environment (Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997).

Self-efficacy. A form of self-confidence that refers to beliefs about one's capability to plan and execute the behaviors needed for successful production of the outcomes (Bandura, 1997).

Self-regulation. The degree that individuals are metacognitively, motivationally, and behaviorally active participants in their own learning process (Zimmerman, 1989).

Spatial accuracy. The type of accuracy for which spatial position of the movement's end point is important for successful performance (Schmidt & Wrisberg, 2008).

Transfer test. A test in which a person performs a skill that is similar yet different from the skill that he or she has practiced (Magill, 2007).

Yoked. A control group that is matched to a self-control group with respect to the schedule and type of feedback requested (Janelle, Kim, & Singer, 1995).

CHAPTER 2

Review of Literature

The purpose of this literature review is to provide background information related to self-control research in motor learning and a brief review of self-regulation research from which it emerged. Additionally, this chapter presents a background on *Self-Determination Theory*, highlighting the three basic psychological needs of autonomy, competence, and relatedness. Finally, a brief description and overview of critical issues related to the use of a task requiring a speed-accuracy trade-off will be discussed.

Origins of Self-Control

In the late 1980's, researchers in social-cognitive psychology began examining the idea of giving students more autonomy in the classroom. Specifically, researchers were interested in how learners initiate, adjust, and continue the pursuit of knowledge autonomously in unconstrained educational settings (Zimmerman, 1986). Such so-called *self-regulated learning* was thought to explain the self-generated thoughts, feelings, and behaviors that students employ toward the achievement of specific learning goals.

According to Zimmerman (1986), students are considered to be self-regulated to the degree to which they are metacognitively, motivationally, and behaviorally active participants in the acquisition of knowledge. In this definition, metacognition refers to the awareness of and knowledge about one's own thoughts. Learners who plan, organize, self-instruct, self-monitor, and self-evaluate are said to be self-regulated. Similarly, motivation refers to a state in which students are free to and capable of choosing whether and how much to study (i.e., intrinsically motivated) and perceive themselves as competent and autonomous. The behavioral aspect of

self-regulation is a manifestation of metacognition, referring to situations in which a learner proactively engages in the processes of learning, such as selecting, structuring, and creating environments that optimize learning. For example, learners are regarded as behaviorally self-regulated to the degree to which they choose, modify, and adapt their responses to available feedback (Zimmerman, 1998). On average, learners who utilize self-regulation learning techniques score higher on aptitude tests (Zimmerman & Martinez-Pons, 1986; 1988) and perceptions of efficacy (Zimmerman, Bandura, & Martinez-Pons, 1992). Investigating the effectiveness of this learning strategy in a motor learning setting was a natural progression.

Self-Control

Chen and Singer (1992) first applied the idea of actively involving the learner in the learning process to the acquisition of motor skills. The authors argued that an ideal motor learning environment is one in which learners are able to control the use of learning strategies as they see fit. Later calling it a “self-controlled situation,” Janelle et al. (1995) gave learners control over the schedule of performance related feedback (knowledge of performance; KP) while learning an underhand ball toss. The main objective of the task was to toss balls as accurately as possible toward a circular target (10 cm in diameter), 183 cm away. Five conditions with different feedback schedules were tested: a subject-controlled condition (received feedback whenever they requested), a yoked condition (received feedback based the schedule of a matched subject-controlled counterpart), a performance summary condition (received feedback after every five trials), a fifty-percent condition (received feedback after every other trial), and a control condition (no feedback). Results indicated that participants in the subject-control group had significantly better target scores than participants in the other four groups during retention tests.

Additionally, learners in the self-control group requested feedback on less than 10% of the acquisition trials. The authors speculated that giving learner's control over feedback schedule led to more efficient information processing and more effective learning. Citing work by Watkins (1984) illustrating that individuals who are confident in their control of the learning environment also exhibit deeper information processing, the authors assumed that learners' confidence in their control led to confidence in their ability to perform the task, which in turn facilitated learning. However, no empirical evidence was provided to support learners were indeed confident in their control or if the exhibited learning benefit was a product of such perceptions.

A follow-up study by Janelle et al. (1997) further examined the generalizability of giving learners control of their learning environment with a more complex task, involving more elements of performance, by utilizing a task that required dynamic control of multiple degrees-of-freedom: an overhand throw with the non-dominant arm. During a two-day acquisition phase, participants learned how to correctly throw a standard tennis ball with their non-dominant arm. Participants were told that the primary goal was to improve their throwing form as they performed 200 total throws toward a circular target, from nine meters away. The experimental conditions in this study consisted of a self-controlled KP group, a yoked KP group, a summary KP group (that received feedback on throwing form after every five trials), and a KR (knowledge of results) only group (that only received observable feedback of ball destination and no feedback on throwing form). Results provided further evidence for the beneficial effects of learning under self-controlled feedback schedules compared to other types of feedback schedules. During the retention phase, the self-controlled group had significantly higher form scores than the other groups, while the KR group exhibited significantly higher throwing speeds.

As in Janelle et al. (1995), the authors speculated that self-controlled learners were able to process information more effectively due to their confidence in controlling the learning environment and they may have developed more effective learning strategies. Additionally, the authors suggested that self-controlled learners may have developed more effective learning strategies and that being actively involved in planning the learning environment increased learner motivation to perform well because they have assumed responsibility for acquiring proficiency. These explanations, however, are based on anecdotal assumptions instead of empirical evidence as no assessments of learner strategies or measurements of learner motivation were collected.

Initially, the effects of giving learners control over the schedule of feedback were only thought to be observable with performance related feedback or KP (Janelle et al., 1995; 1997). Subsequent studies have provided evidence that this self-control effect (Fairbrother, 2010) is prevalent with outcome related feedback (KR) as well. Chen, Hendrick, and Lidor (2002) examined how participants learned a sequential key-pressing task when given the freedom to request for KR feedback whenever they wanted compared to yoked counterparts. Additionally, the authors included an “experimenter-induced KR” condition, where learners were reminded that they could ask for KR feedback whenever they wanted. Results indicated that the two self-control groups (with and without reminders of control over feedback) had lower error scores than their yoked counterparts on both immediate and delayed retention tests. Building from Janelle and colleagues (1995; 1997), the authors concluded that a learning environment in which learners have control over the schedule of either type of feedback (KP or KR) is more conducive to learning a motor skill than not having control over feedback schedule. Further, the authors presume that self-controlled learning may have implicitly enhanced learner intrinsic motivation.

Citing self-regulation research, the authors suggested that self-controlled learners are more motivated to acquire new skills. Finally, the author suggested that self-controlled learning facilitates the development of more effective feedback-schedule related strategies. As in previous self-control studies, however, no measurement of motivation or strategy use is utilized nor any empirical evidence is provided to support the proposed explanations for the beneficial effects of self-controlled learning.

Janelle and colleagues (1995; 1997) as well as Chen and Singer (2002) all suggested that research toward empirically investigating the specific underlying mechanisms of the self-control effect is warranted. Chiviawsky and Wulf (2002) acknowledged the difficulty in examining such mechanisms, however, due to the vague nature of the previously proposed explanations. Instead, investigating how learners use control over feedback by comparing how learners perform on trials that they request and do not request feedback provides a potential method in examining how and why learners benefit from having control over their learning environment. So, Chiviawsky and Wulf (2002) examined learner behaviors while learning a sequential key-pressing task. Learners in this experiment were instructed to press a series of computer keys in a specified order and in a specified movement time. Feedback on their absolute and relative timing errors based on either a self-control or a yoked feedback schedule. Of particular interest to this study was how learners utilize the autonomy afforded by self-controlled feedback scheduling. Specifically, whether learners use control over feedback for error correction or for confirmation of success. At the end of the experiment, participants were given questionnaires addressing their preferences for feedback. Self-control participants were asked whether they requested feedback after mostly “good trials,” “bad trials,” after both equally, or randomly. Similarly, yoked

participants were asked if they received feedback “after the right trials” and, if no, when they would have preferred feedback: primarily after “good trials,” “bad trials,” didn’t matter, or none of the above. Further, the researchers compared learner performances on trials after which feedback was presented (feedback trials) and on trials after which feedback was not presented (no-feedback trials).

The authors hypothesized that if self-controlled learners utilize control over feedback for confirmation of success, they would have lower error scores on feedback trials than on no-feedback trials. If learners utilize control over feedback for error correction, they would have higher error scores on feedback trials than on no-feedback trials. Results revealed that the majority of learners in the self-control group preferred feedback after relatively good trials. When asked when they requested feedback, 66% of self-controlled participants reported they requested feedback mostly on trials that they thought they “had a good trial”; no self-control participant reported to have requested feedback on trials that they thought they “had a bad trial.” Of the yoked participants, 73% reported they did not receive feedback “after the right trial,” 63% of which reported a preference for feedback “after good trials.” Additionally, the comparison of performance on trials that feedback was and was not administered indicated that the self-control group did in fact perform with better accuracy on trials that they asked for feedback than on trials that they did not ask for feedback. The yoked group, on the other hand, performed worse on feedback trials than on no-feedback trials. Based on these findings, the authors concluded that self-control learners were able to use a feedback request strategy to tailor the feedback schedule to their preference for feedback confirming successful performances. While yoked learners also reported a preference for feedback after relatively good trials, their feedback schedule did not

match their preference. Thus, they were not able to benefit from such a schedule and their performance and learning suffered. Additionally, the authors suggested that requesting feedback after relatively good trials could have motivated learners to try harder to reproduce the successful response. However, it still is not clear whether the beneficial effect of self-controlled learning was due to learner's utilizing the afforded autonomy to tailor the learning environment to better fit their actual needs, or their preference for feedback after relatively good trials, or simply the provision of control over feedback schedule. Also, since motivation was not directly measured, any suggestion of the role motivation plays in the self-control effect is purely speculative.

Follow-up studies addressing learner preferences for “good” feedback suggested that self-control learners do, in fact, adopt a strategy for feedback requests. Badami et al. (2011) compared learners who were given feedback on only their better attempts to learners who were given feedback on only their poorer attempts. Novices practiced a golf-putting task 60 times. After every six trials, one group of participants received feedback on their three best trials (KR good) and the other group received feedback on their three worst trials (KR bad). Neither group was aware of the manipulation. After performing 60 trials, both groups completed the intrinsic motivation inventory (IMI; McAuley, Duncan, & Tammen, 1989). The IMI is a motivational scale comprised of several different sub-scales that assess intrinsic motivation in performing a task. The IMI used in this study included subscales for interest and enjoyment, perceived competence, and effort and importance. Each sub-scale had three statements. Additionally, participants were asked they would like to practice the skill more at the end of the experiment (a self-report of intrinsic motivation). There were no retention or transfer tests nor were performance data analyzed. Results showed that the KR good group reported higher levels of all

three sub-scales. The only differences, however, were for perceived competence and the self-report for intrinsic motivation. Though this study provided evidence that learners given feedback on their better performances report higher perceived competence and are more intrinsically motivated to perform the task, it was still unclear how feedback on better performances affected motor learning and the role learner preferences play.

Saemi et al. (2012) addressed giving learners feedback after only their better performances while also comparing differences in motor performance. For this manipulation, learners performed a blinded underhand ball toss at a target three meters away. Participants wore opaque goggles and performed the task 60 total times in acquisition. Feedback procedures were similar to those of Badami et al. (2011), however, participants returned approximately 24 hours later to complete a retention test. Further, this manipulation created a measure for self-efficacy using Bandura's (2006) model, which consisted of 10 statements addressing learner's confidence in their tossing ability (e.g., "How confident were you in your ability to score 100"). The scale was rated on a Likert scale from 0 (not confident at all) to 100 (completely confident), in increments of 10. The self-efficacy scale was completed after every six trials and again at the end of the retention test. Results indicated that the KR good group significantly improved their performance during acquisition, while the KR bad group did not improve. Additionally, the KR good group outperformed the KR bad group in the retention test. Finally, the self-efficacy of the KR good group significantly increased, while that of the KR bad group decreased throughout the study. Thus, rather than utilizing feedback for error corrective purposes, the findings of Chiviacowsky and Wulf (2002) and the research highlighting the learning benefit of receiving

feedback after “good trials” suggest that learners use self-control feedback to confirm good performances as well as increase their feelings of competence or efficacy.

Patterson and Carter (2010) further investigated learner preferences in a self-controlled learning environment while learning multiple motor tasks. Similar to the task used by Chiviacowsky and Wulf (2002), participants in this study learned three different key-pressing tasks (sequences A, B, and C) under self-control and yoked feedback conditions. Again, learners in the self-control group were instructed to request feedback when they needed it. Consistent with previous self-control studies, participants in the self-control group had significantly lower error and variability scores than those in the yoked group. Similar to the findings of Chiviacowsky and Wulf (2002), 67% of the participants in the self-control group also reported to have asked for feedback after relatively good trials while performing sequences A and C, and 58% of participants reported to have requested feedback after relatively good trials while performing sequence B. Also similar to Chiviacowsky and Wulf (2002), participants in the self-control group performed with lower timing error on feedback trials compared to no-feedback trials. Based on these findings, the authors concluded that learners given control over their feedback schedule are able to adapt to and meet the additional challenges presented when asked to learn multiple motor tasks simultaneously. The authors also speculate that asking for feedback after more successful trials puts self-controlled learners in a position to effectively decrease the amount of effort and possibly increase motivation in performing the task successfully. However, the authors do suggest that further research providing empirical evidence that replicating a correct motor response increases learner motivation and decreases required

effort is required to better understand how and why self-controlled learners use this strategy of requesting feedback after relatively good trials to their benefit.

Recent research investigating self-control over video feedback, however, indicates that learner needs and preferences may change based on the nature of the motor task. Aiken, Fairbrother, & Post (2012) examined the self-control effect when giving learners control over the provision of video feedback when learning the basketball set shot. All participants were given a video demonstration of proper technique when performing the set shot, highlighting seven instructional features associated with proper form. Participants were instructed to focus on improving their shooting form and to not prioritize shot accuracy at the expense of form. The seven instructional cues were posted on a chalkboard and available to all participants during the acquisition phase. The self-control was allowed to control when they were shown video replay of their shot, while the yoked group were shown video replay of their shot based on the schedule set by a self-control counterpart. Of particular interest in this study was how often learners requested feedback after “good” versus “poor trials.” Questions on the post-training questionnaire addressing feedback preferences were modified from the ones used by Chiviackowsky and Wulf (2002) to utilize a five-point Likert scale so that frequency of feedback requests/preferences could be measured (one representing “rarely,” three representing “occasionally” and five representing “frequently”). Additionally, open-ended questions were utilized to further understand any specific reasons self-controlled participants did or did not request feedback.

Results indicated that, while neither group performed with significantly better shooting accuracy on retention or transfer tests, the self-control group significantly outperformed the yoked group on form score during transfer tests. Since improving one’s form was the primary

focus for participants, this finding was consistent with previous self-control research highlighting its beneficial effects. Comparisons between performance on feedback and no-feedback trials revealed that the self-controlled group had similar form scores and accuracy scores on feedback trials compared to no-feedback trials. Further, the responses to the questionnaires mirrored this finding, showing that the self-control group reported to have asked for feedback occasionally after both “good” ($M = 2.93$ on the Likert scale) and “poor trials” ($M = 3.07$). These findings, however, were not consistent with previous self-control research suggesting self-controlled learners prefer feedback after relatively good trials. Further, questionnaire responses from yoked participants also suggested that their preferences also differed from findings of previous self-control research. Participants in the yoked group reported to have occasionally received feedback when they needed it ($M = 3.50$), as well as occasionally after “good” ($M = 3.21$) and “poor trials” ($M = 3.29$). Additionally, the yoked group was split on their preference for feedback as almost half reported a preference for feedback after good trials while the others reported a preference for feedback after poor trials.

The authors concluded that, although the self-control group was able to use control over feedback to their benefit, as evidenced by their superior form score performance in transfer tests, tasks with multiple elements of performance, such as the basketball set shot, can change how learners use feedback. The stark contrasts in feedback preferences and behaviors when compared to previous literature can be attributed to differences in task complexity. The basketball set shot has more elements of performance (e.g., accuracy and various features constituting proper form) than key-pressing. As such, any given basketball set shot attempt is likely to include features that were “good” as well as some that were “poor.” Therefore, it’s possible learners actually used

feedback to confirm “good” features and correct “poor” features on the same trial. Naturally, the richness of information provided by video feedback lends itself well to such an endeavor.

Additionally, questionnaire responses from yoked participants regarding their feedback preferences further suggest that when learning a task with multiple elements of performance, a preference for feedback after both “good” and “poor trials” exists. However, it’s not clear if self-controlled learners alter their feedback request strategy when learning a task with multiple elements of performance because of the added difficulty the task or because the amount of information available in video feedback. In other words, is it the feedback modality or the nature of a multi-dimensional task that changes feedback request preferences? Thus, a more comprehensive investigation to determine if motor tasks with multiple performance-related dimensions alter the way learners use and benefit from self-control is warranted.

Self-Control and Speed-Accuracy Trade-Offs. One way to directly address the issue of feedback preferences when learning a multi-dimensional task is to examine self-control requests for a task that directly pits the successful performance of one aspect against that of another. Previous self-control studies have predominantly used one-dimensional tasks, where the objective and motor elements are quite simple (e.g., sequential key-pressing, underhand beanbag toss). Recent research using tasks with multiple elements of performance have indicated that self-controlled learners may behave differently dependent on the nature of the task. Real-world motor tasks, such as the basketball set shot, however, can introduce multiple sources of error. Instead, laboratory tasks tend to offer a more controllable environment in which measurement of the learning manipulation is less likely to be contaminated by random error. A rapid, discrete aiming task similar to the one used by Schmidt, Zelaznik, Hawkins, Frank, & Quinn (1979)

provides such a task. The simple nature of such a task allows for a more convenient and controlled way to test self-controlled participants' preferences for feedback in a laboratory setting.

In a discrete aiming task, both temporal accuracy and spatial accuracy are requisites for success. Previous research by Fitts (1954) established empirical evidence for an inverse relationship between speed and accuracy of rapid reciprocal movements (e.g., repeatedly tapping a pencil in alternating circles). Schmidt et al. (1979) further investigated this relationship between speed and accuracy with single-aiming movements. For their study, participants moved a stylus pen rapidly from a starting zone to a target at varying distances and target times: 7.5 to 60 cm and 200 to 500 ms. Regardless of movement distance or target time, the researchers observed an inverse relationship between speed and accuracy. That is, as movement speed increased, movement accuracy decreased. Therefore, a rapid, discrete aiming task that posits a temporal accuracy demand as well as a spatial accuracy should hold true to the principles of the speed-accuracy trade-off in that success at temporal accuracy will come at the performance cost of spatial accuracy, and vice versa. Having participants learn a task where successful performance of one element will result in poorer performance in the other provides more insight into how they use control over feedback schedules to learn a multi-dimensional task.

Self-Control and Motivation. The role motivation plays in the beneficial effects of self-controlled learning has garnered relatively little empirical attention. Although Janelle et al. (1997) and Chiviakowsky and Wulf (2002), and more recently Patterson and Carter (2010), all suggested that self-controlled practice could enhance learner motivation, there is very little research that directly measures differences in motivation when learning under self-control and

yoked conditions. A complete investigation of the underlying mechanisms behind self-controlled learning should include a direct empirical measure of motivation.

Bund and Weimeyer (2004) were the first to include motivation as a dependent measure when they examined giving learners control over their most preferred and least-preferred practice condition. In this study, participants learned how to return a table tennis shot using the topspin shot method. First, the self-control groups were asked to rank the degree to which they'd prefer to control different types of practice conditions. Based on the results, two groups of participants were given control of either how often they saw video instructions of the table tennis topspin shot (preferred) or how often they saw a video replay highlighting the trajectory of each ball as it approached them (not-preferred). Two more groups were yoked to the aforementioned self-control groups. Participants performed a pre-test before completed 100 acquisition trials of the topspin shot. Five minutes and 24 hours after acquisition, participants took immediate and delayed retention tests, respectively. Throughout the study, participants in all four groups completed a self-efficacy questionnaire: prior to a pretest, after the pretest, mid-way through acquisition, and before the immediate and delayed retention tests. The authors designed the self-efficacy scale to assess how competent the participants felt about their capability to hit the shot accurately: "I am sure that I can hit at least...1 out of 10 balls into the target." There were 10 total statements that were rated on a Likert scale from 1 (very uncertain) to 10 (very certain). The aggregated score from all of the statements was used for comparisons between the four groups.

Results from the study showed a self-control effect: both self-control groups, regardless of learner preference, scored higher form scores than their yoked counterparts. Further, all participants became more efficacious throughout the study, however, mean self-efficacy scores

decreased after completing of the first half of acquisition and the before taking the delayed retention test. Statistical analysis revealed that both self-control groups reported significantly higher self-efficacy after the first half of acquisition and before both retention tests than both yoked groups. That is, the self-control groups reported higher self-efficacy than the yoked groups before taking the immediate retention and the yoked groups reported a greater decrease in their self-efficacy after completing 50 acquisition trials and upon arriving for the delayed retention test than did the self-control groups. The authors concluded that, regardless of preference, giving learners control over their practice schedule is more effective when learning a motor skill than not having control. Additionally, the authors suggested that not only do self-controlled learners increase their self-efficacy more than yoked learners, their self-efficacy also decreases following poor attempts to a lesser extent than that of yoked learners. In other words, learners allowed to control some aspect of their learning environment were able to maintain their perceptions of efficacy better than their yoked counterparts. According to the authors, however, their study was an initial investigation into the role motivation plays in self-controlled learning. Further self-control research measuring changes in motivation is still warranted to better understand how motivational processes interact with learner needs and preferences in explaining the self-control effect.

Ste-Marie et al. (2013) introduced self-determination theory (SDT) as a way to measure the difference in choice between self-controlled and yoked learners. In this study, children learned a trampoline routine with and without control over their video feedback schedule. Learner performance was assessed on 10 performance criteria and rated by a former national level trampolinist. The experiment consisted of 60 trials across two days of acquisition followed

by a 24 hour delayed retention test. A self-efficacy questionnaire was developed based on Bandura's (2006) guidelines, specific to this study. The questionnaire consisted of seven statements assessing how confident learners felt about their capability to successfully perform a sequence of the routine and was rated on a Likert scale from 1 (cannot do at all) to 100 (highly certain can do), in increments of 10. All participants completed the self-efficacy questionnaire before performing the trials on all three days of the study. Further, two subscales from the IMI were used to measure learner interest and enjoyment (e.g., "I enjoyed doing the double mini activities very much") and perceived choice (e.g., "I believe I had a choice about doing the double mini activities") in performing the task. The two subscales, consisting of seven items each, were rated on a Likert scale from 1 (not at all true) to 7 (very much true) and were administered at the end of each day of the experiment.

Results indicated that the self-control group learned the skill better and reported higher self-efficacy, intrinsic motivation, and perceived choice than the yoked group. The self-control group performed with significantly better form scores than the yoked group during the delayed retention test. The self-reported self-efficacy scores of the self-control group increased from the first day of acquisition to the second day of acquisition while that of the yoked group did not change, however this change only approached significance. Additionally, a comparison of self-efficacy between the two groups was not reported and there were no differences in self-efficacy during retention. Finally, the self-control group reported higher intrinsic motivation and perceived choice than the yoked group throughout the experiment, achieving significance in both at the conclusion of the retention test. While these findings suggest that young learners become more intrinsically motivated to a greater degree when given control over their feedback schedule, they

don't provide a clear understanding of how the provision of control over feedback changes perceptions of efficacy.

Further, measuring motivation and perceptions of competence or efficacy with scales from separate motivational theories, with distinct conceptualizations of motivation, is problematic and may lead to inconsistent findings. Ste-Marie et al. (2013) used an adapted version of Bandura's (2006) self-efficacy scale, based on his self-efficacy theory (Bandura, 1977), to measure feelings of competency and efficacy and the IMI, based on self-determination theory (SDT; Deci & Ryan, 1985), to measure perceptions of choice and intrinsic motivation. Additionally, the beneficial effects to perceived competence and self-efficacy when receiving feedback after relatively good trials shown by Badami et al. (2012) and Saemi et al. (2013) also used two different motivational scales, the IMI and Bandura's (2006) self-efficacy scale, respectively. According to Deci and Ryan (2000), Bandura's view on motivation and self-efficacy and that of SDT are in sharp contrast of each other. Therefore, an investigation of changes in motivation and perceptions of competence as a result of self-controlled and yoked learning may be more consistent and comprehensive if it is based on the same motivational theory. Further, in a review of current self-control research, Sanli et al. (2013) propose that specific and valid measures of motivation addressing how the fulfillment of learner needs changes behavior in self-controlled settings needs more attention and should be the focus of future research. Thus, the use of measurement scales from one theoretical framework allows for a more comprehensive, more fluid way to address this hole in the existing self-control literature.

Self-Determination Theory

Self-determination theory (SDT) provides a framework through which the behavioral and motivational effects of self-controlled learning can be better understood. First, SDT's conceptualization of motivation and the energy behind actions and behaviors provide a clear and organized way to measure and understand changes in motivation when learning in self-controlled and yoked environment. Second, SDT's view on human's basic psychological needs and the fulfillment of which can be directly applied to the suggestions from self-controlled research that learner use self-control to tailor the learning environment to their needs and preferences. The following section includes a brief description the basic tenets of SDT, followed by explanations of its view on intrinsic motivation and the three basic psychological needs.

SDT's foundation is based on an organismic perspective of human behavior. This organismic perspective describes that behavior is regulated by internal structures and that humans are active by nature, always acting toward something (Deci & Ryan, 1985). Self-determination, then, is defined as a quality of human functioning that arises from the experience of an internal locus of causality (Deci & Ryan, 1985). In other words, being self-determined involves having the experience of choice and self-determination can be thought of as the capacity to choose and to have said choices be the determinants of one's actions, rather than reinforced behaviors or drives (Deci & Ryan, 1985). As such, an adequate theory of motivation should take into account innate, organismic needs that are a product of an individual's central locus of causality. According to Deci and Ryan (1985) motivation describes the energy and direction behind human behavior. In this definition of motivation, energy is a product of need fulfillment. The more an individual fulfills their organismic needs, the more energized they become.

Likewise, direction explains the processes and structures put in place toward the satisfaction of specific needs; in other words, direction represents which needs are being satisfied. Research stemming from SDT examines how the processes and structures of reward, feedback, and praise facilitate or hinder self-motivated behaviors and outcomes that are crucial to both intrinsically motivated and some extrinsically motivated behaviors (Ryan & Deci, 2008).

The differences between SDT and other motivational theories is SDT's view on the locus of causality. The SDT perspective suggests that not all behaviors can be explained by traditional drive-based theories because not all behaviors are necessarily functions of external control. Traditionally, drive-based theories of motivation explain that deficits in innate physiological needs (e.g., food, water, safety) give rise to drives states that push an organism into action (Hull, 1943). Instead, based on the organismic perspective, SDT explains that human behavior is regulated by internal structures that strive for ongoing fulfillment of basic organismic needs, such as competence or autonomy, regardless if a deficit exists because the ongoing fulfillment of these needs leads to healthy development, well-being and optimal functioning (Deci & Ryan, 2000). Principles of SDT have been applied to psychotherapy (Ryan & Deci, 2008; Ryan, Lynch, Vansteenkiste, & Deci, 2011), physical activity and sport settings (Ryan, Patrick, Deci, & Williams, 2008; Ryan, Williams, Patrick, & Deci, 2009), personal relationships (La Guardia & Patrick, 2008), and education (Ryan & Brown, 2005; Ryan & Deci, 2009). The following subsections further explain intrinsic motivation and the basic psychological needs theory (BPNT), as understood according to the SDT paradigm.

Intrinsic Motivation. According to Ryan and Deci (2000), motivation is at the core of behavioral regulation. Cognitive processes and their resulting behaviors are rooted in the energy

and direction of daily human actions. Specific to SDT, intrinsic motivation is based on an organism's needs to be competent and self-determining and is defined as the life force or energy for the healthy activity and development of organic human behavior (Deci & Ryan, 1985). Further, intrinsically motivated behaviors are those that are freely engaged out of interest, without the necessity of secondary consequences (Deci & Ryan, 2000). Therefore, intrinsic motivation energizes a wide variety of behaviors and psychological processes for which the primary rewards are the experiences of efficacy and autonomy (Deci & Ryan, 1985). A person is said to be intrinsically motivated to the extent that they perform or exhibit a behavior in the absence of a reward or a control.

Intrinsic needs, like drives (Hull, 1943), are innate to humans and function as an important energizer of behavior (Deci & Ryan, 1985). They are, however, different in that primary drives are based on deficits in the organism, while intrinsic needs are not. For example, drives explain actions in response to a depletion of competence or autonomy, while intrinsic needs explain actions in response to the ongoing strive for fulfillment of competence or autonomy. According to SDT, then, intrinsic motivation is based on the ongoing search for and triumph over optimal challenges. As a result from overcoming said challenges, one experiences inherently driven pleasures and satisfaction (Ryan, Williams, Patrick, & Deci, 2009). These feelings of pleasure and satisfaction, in turn, further drive intrinsically motivated behaviors. Intrinsic motivation is directly tied to feelings of interest and enjoyment, competency and self-determining, and an internal locus of causality, for which pressure and tension are antitheses. Intrinsic motivation has also been linked to greater creativity, (Amabile, 1983), flexibility (McGraw & McCullers, 1979), and spontaneity (Koestner, Ryan, Bernieri, & Holt, 1984).

Naturally, it can be understood that creativity, flexibility, and spontaneity are important if one is charged with regulating and controlling one's learning environment.

Basic Psychological Needs Theory. In an attempt to better explain the primary drive behind intrinsic motivation and the pursuit and attainment of goals within the self-determination paradigm, Deci and Ryan (2000) developed the basic psychological needs theory (BPNT). As such, the BPNT describes the process of attaining and the maintenance of intrinsically motivated behaviors. Natural processes such as intrinsic motivation, integration of extrinsically regulated behavior, and constant movement toward well-being are theorized to only operate optimally to the extent that three basic psychological needs are fulfilled, or to the extent that the individual has sufficient inner resources to find or construct said necessary needs (Deci & Ryan, 2000). These needs are the needs for autonomy, competence, and relatedness. The need for autonomy refers one's need to be self-determining in their actions. The need for competence refers to one's need to feel efficacious in their actions, decision-making, and behaviors. The need for relatedness refers to one's need to be connected to others.

The primary assumption of this theory is that intrinsic motivation is facilitated by conditions that are conducive toward fulfillment of the three basic psychological needs, while conditions that tend to thwart said needs undermine intrinsic motivation. Unlike the physiological needs (e.g. food, water, sex) presented by Hull's drive theory (1943), the BPNT states that needs are innate life processes and satisfaction of said needs, which should occur organically, facilitates natural growth processes and optimal development (Deci & Ryan, 2000). Another important postulation of the BPNT is that in order for optimal, healthy development to progress, all three needs must be attended to. Neglecting just one need can have harmful effects

on an individual's intrinsic motivation, self-efficacy, and well-being. Finally, Deci and Ryan (2000) state that fulfillment of the three basic psychological needs is the path to optimal development and the most effective functioning. The following sub-sections further explain the basic psychological needs for autonomy, competence, and relatedness.

Autonomy. The need for autonomy is fundamental to SDT's primary hypothesis that individuals strive to be self-determining. To be self-determining, one must experience an internal locus of causality. Autonomous behavior, then, is described to be intentional, self-organized and self-endorsed (Deci & Ryan, 1985). Simply put, autonomy refers to behavioral regulation of the self and the experience of choice. Even in the presence of rewards, behaviors can be autonomous if they are deliberately executed in order to meet specific, self-appointed goals. In other words, autonomy refers to how an individual chooses behavior in anticipation of achieving self-related goals (Deci & Ryan, 1985). The experience of autonomy cannot be forced, however, and must organically come to fruition. One can only encourage and support autonomy supportive environments.

As such, autonomy supportive environments are crucial to fulfillment of the basic psychological need for autonomy. According to SDT, an autonomy supportive environment is one that allows for an individual's motivation to develop and emerge from volitional and internally focused sources (Reeve & Jang, 2006). Further, autonomy supportive environments help people develop a sense of congruency between a learner's environment, their behavior, and their inner motivational resources. From previous literature, Reeve and Jang (2006) have identified eleven instructor behaviors that help facilitate an autonomy supportive environment. Such behaviors include listening to and asking about student needs as well as allowing students

to work in their own way and providing praise as informational feedback. As a result, learners become more comfortable with the learning environment and employ learning materials and tools more often.

Competence. In addition to the need for autonomy, the need for competence provides an energy source that motivates learning. According to SDT, in order to act spontaneously and from internally regulated processes, a person needs to experience some level of effectiveness and confidence in said act (Ryan, Williams, Patrick, & Deci, 2009). Feelings of competency are predicated on the assumption that the obstacle be slightly beyond one's current level of competency. Therefore, challenging, yet attainable goals are crucial to fulfillment of the need for competency. Again, different from the idea of fulfilling deficits proposed by drive theories (Hull, 1943), the need for competence or efficacy is always present and ongoing (Deci & Ryan, 1985). Behaviors toward fulfilling the need for competency don't arise from a deficit. People will always seek to fill their need for competency, as it is a basic organismic need. The result of effective functioning is that an individual is rewarded with inherent feelings of competence (Deci & Ryan, 1985).

Further, the necessary needs for competence can be related to aspects in a person's social environment, such as parents, peers, or coaches. By providing feedback directed toward one's competency and providing structure to learning activities, an instructor can facilitate fulfillment of the need for competence. Structure, in this case, helps implement an autonomy supportive environment by promoting the use of goals and strategies while still placing realistic limits to the learning environment (Ryan & Deci, 2008). Similar to the need for autonomy, feelings of competency cannot be forced. Fulfilling the need for competency is predicated on learners

feeling responsible for the competent performance. Naturally, the learner must be able to directly connect their performance or actions with the successful outcome in order to feel competent.

Relatedness. While the impact of autonomy and competence on intrinsic motivation are much more prominent than relatedness, an individual's need to feel connected with another plays an important role in the maintenance of intrinsic motivation (especially with young children). According to Deci and Ryan's (1985) organismic integration theory, people will internalize extrinsically motivating behaviors that are deemed valuable to social interaction, so that they are internally regulated. The BPNT proposes that it is an individual's innate need for relatedness that drives the internalization and integration process. Because people inherently want to be connected to one another, when given the autonomy to, people will willingly integrate externally controlled and socially desired behaviors to a degree of acceptable competence, thus fulfilling the need for relatedness.

While it's important for people to be intrinsically motivated in their day-to-day lives, not all behaviors suitable for effective inclusion in society are inherently enjoyable, especially for children or young adults. For example, saying, "please" and "thank you," for example, are not necessarily intrinsically enjoyable behaviors. However, we learn that these 'magic words' as important for daily social interaction. Therefore, integration of such socially necessary behaviors from an external locus of causality to an internal locus of causality is essential and facilitated by fulfillment of the need for relatedness. According to SDT, behaviors that are prompted, modeled, or valued by significant others to whom an individual feels attached or related to are more likely to be integrated (Ryan & Deci, 2000). In this study, however, the integration of externally motivated behaviors is not of primary interest. Because the two groups will not be interacting

with each other and the social interaction involved in this study will be with the same experimenter, the basic psychological need for relatedness is not expected to be different between the two manipulation groups.

The notion that providing an environment that encourages learners to be autonomous is beneficial to learning, as suggested by SDT, is consistent with self-control literature that suggests giving learners control over learning environment is beneficial to motor learning. Additionally, research examining the feedback request tendencies of self-controlled learners suggests that learners might be strategically requesting feedback after their better performances also fits SDT theory of a need for competency. Further, SDT posits that not all of the basic psychological needs will be met all the time (Deci & Ryan, 2000). As is the case with the need for relatedness, fulfillment of one need can overcome that of another, to a certain extent. However, SDT's view on intrinsic motivation and the sub-scales it utilizes to measure its different components, in addition to SDT's theory on basic psychological needs provide a sound framework to investigate the role motivation, needs and preferences play in understanding the underlying mechanisms of self-controlled motor learning.

In summary, current motor learning research has highlighted the beneficial learning effects of giving learners control over their learning environment. Additionally, there is evidence that learners preferences for feedback after relatively good performances are associated with increases in intrinsic motivation and perceptions of efficacy. However, further research investigating the underlying mechanisms behind self-controlled learning is warranted. The proposed explanations of the self-control effect are vague and lack direct empirical evidence. Further, when learning a motor task with multiple elements of performance, learners exhibit a

preference for video feedback after both relatively good and poor performances. Investigating how learners use control over feedback by comparing how they perform on trials that they request and do not request feedback while learning a simple task incorporating multiple elements of performance provides a potentially useful method in understanding how and why learners benefit from having control over their learning environment. Additionally, measuring changes in learner motivation provides further insight in the underlying mechanisms behind the self-control effect. Utilizing a motivational theory that also allows for assessment of learner feelings of autonomy, perceptions of choice, and feelings of efficacy allows for a consistent and comprehensive understanding.

CHAPTER 3

Method

Participants

Twenty-four participants were recruited to take part in the study. All participants were right-hand dominant, according to the Edinburgh Handedness Inventory (Oldfield, 1971) and naïve to the purposes of the study. None had any prior experience with the experimental tasks. Before taking part in the study, each participant provided voluntary informed consent (Appendix A), by signing a written form approved by the University of Tennessee Institutional Review Board.

Task and Apparatus

The experimental task was a discrete aiming task adapted from Fitts and Peterson (1964). The objective was to move a stylus from the starting location, maneuver it around a rectangular barrier, and then hit a circular target. Participants were instructed to finish the movement in a pre-determined goal time and with the stylus within the target (i.e., they were not allowed to move through the target). The starting location and the barrier were visible throughout the movement. Participants used their left hand to move the stylus around the left side of the barrier and to the center of the target. The task included two equally important goals: a) to move the stylus as close to the center of the target as possible; and b) to complete the movement in a criterion time of 600 ms



Figure 1. *The Wacom Intuos 4 XL digitizing tablet with the stylus, starting zone, barrier, and target (picture is not to scale).*

The task was completed on the *Intuos 4 XL* digitizing tablet (Wacom; Vancouver, WA). For each trial, the target was initially projected onto the tablet using a laser pointer positioned above the tablet, but removed once the movement was initiated. The target was 20 cm below the starting zone (0.5 cm x 0.5 cm). The barrier (6 cm x 1 cm) was equally spaced between the starting zone and the target. A representation of the tablet surface with the starting location, barrier, and target was presented on a computer monitor connected to a Dell PC. After each trial, the display showed the trajectory of the movement. The monitor was oriented so that participants could not see it unless the experimenter rotated it for the purpose of feedback administration.

Each participant sat at a desk and faced the digitizing tablet, which was placed directly in front of him or her. The computer monitor was located to the participant's left.

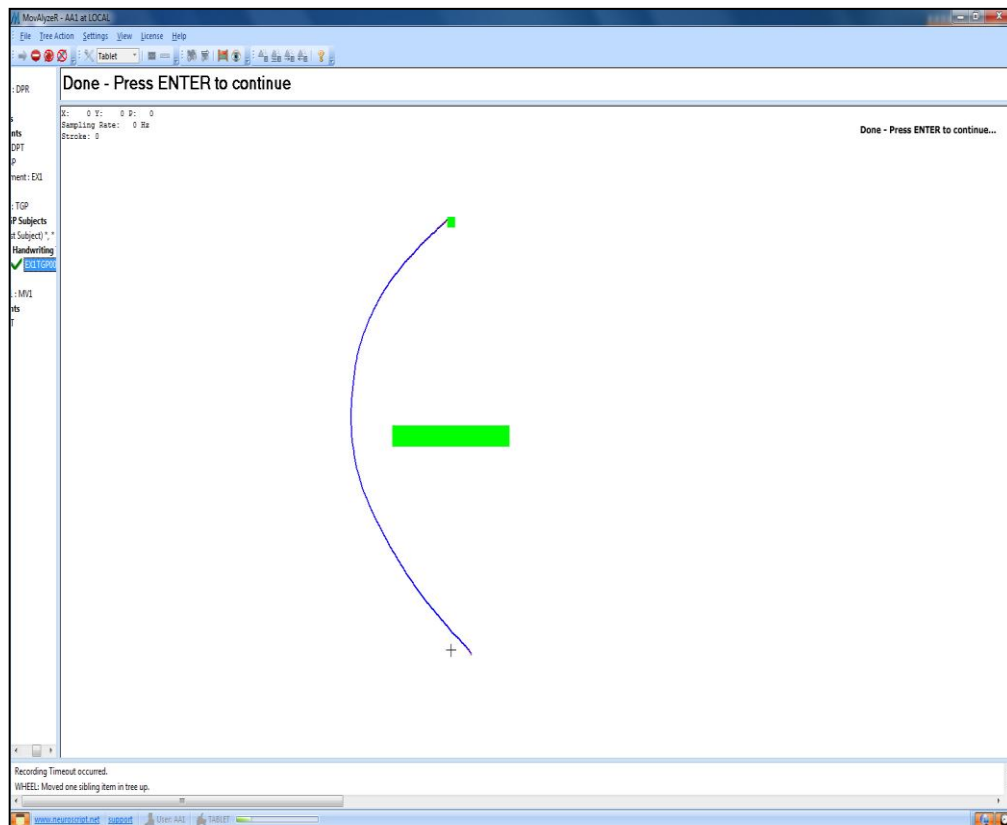


Figure 2. *Screenshot of Movalyzer® software displaying spatial accuracy feedback with starting zone, barrier, movement trajectory, and target (cross).*

Instruments

Intrinsic Motivation Inventory. The Intrinsic Motivation Inventory (IMI) scale was comprised of four sub-scales, addressing one's interest and enjoyment, perceived competence, perceived choice, and pressure and tension while performing the task (Ryan, 1982; Ryan, Mims & Koestner, 1983; Plant & Ryan, 1985). The interest and enjoyment sub-scale consisted of six

statements and measured how intrinsically motivated learners were in performing the task. The perceived competence sub-scale consisted of six statements and measured how competent or efficacious learners felt about their movements. The perceived choice sub-scale consisted of five statements and measured whether learners felt they had a choice in performing the task. The pressure and tension sub-scale consisted of five statements and measured how pressured learners felt in performing the task. There were 22 total statements in the complete scale. Participants rated each of the statements on a seven-point Likert scale. Responses to the statements ranged from “not true at all” (1) to “somewhat true” (4) to “very true” (7) and were averaged for each subscale. A sample of the IMI is provided in Appendix C.

Basic Psychological Needs Scale. The Basic Psychological Needs Scale (BPNS) used in this study was adapted from the Basic Needs Satisfaction at Work Scale (Deci, Ryan, Gagné, Leone, Usunov, & Kornazheva, 2001; Ilardi, Leone, Kasser, & Ryan, 1993; Kasser, Davey, & Ryan, 1992). The wording was modified to be relevant in an experimental setting addressing motor learning (e.g., “I do not feel very competent when I am at work” became “I do not feel very competent while performing this task”). The adapted version used in this study included 21 total statements (seven statements per sub-category). The sub-categories addressed the perceived fulfillment of the three basic psychological needs. The autonomy sub-category measured if an individual’s need to be autonomous in their actions has been satisfied. The competence sub-category measured if an individual’s need to be competent in their actions has been satisfied. The relatedness sub-category measured if an individual’s need to be connected with others has been satisfied. Participants rated each of the statements on a seven-point Likert scale. Responses to the

statements ranged from “not true at all” (1) to “somewhat true” (4) to “very true” (7) and were averaged for each subscale. A sample of the adapted BPNS is provided in Appendix D.

Post-training questionnaire. The post-training questionnaire (PTQ) addressed participants’ thoughts and feelings about the task, the feedback, and possible learning strategies. For the self-control group, the PTQ included a questionnaire asking learners to rate how often they asked for feedback after trials on which they felt their performance was relatively “good” or relatively “poor” with respect to each of the two movement goals (i.e., spatial accuracy & timing accuracy). For the yoked group, the questionnaire asked when participants would have *preferred* to receive feedback had they been given the choice. Participants in both groups were also asked to discuss their reasons for requesting feedback, their preferences for receiving feedback, their use of strategies, and anything else that stood out about their experience. A sample of the PTQ is provided in Appendix B.

Procedure

Upon arriving in the laboratory, participants were asked to fill out the Edinburgh Handedness Inventory and provide voluntary informed consent. Participants were then randomly assigned to either a self-control group or a yoked group. As part of the yoking procedure, participants in the yoked group were matched to the same gender as their self-control counterpart (i.e., men to men and women to women). After group assignment, participants were seated in front of the apparatus. The experimenter then explained the experimental task and procedures. Participants in the self-control group were instructed to request feedback only when they needed it and that each request could be for feedback on either their movement time or spatial accuracy, but not both. Participants in the yoked group were informed that they would sometimes receive

feedback on either their movement time or spatial accuracy. All participants were informed that they would be required to perform the task without feedback during the retention and transfer tests. Participants were then given a demonstration of the task and feedback administration procedures. After the demonstration, participants in both groups completed both the IMI and the BPNS.

During acquisition, participants completed 60 trials with a 20 second inter-trial interval. A 5-min break was provided between Trials 30 and 31. At the completion of Trial 60, participants again completed the IMI and the BPNS. All participants also completed the post-training interview. At the beginning of acquisition, all participants were reminded of the objectives of the task. For each trial, participants were instructed to place the pen in the starting zone and to move when ready. Data was recorded from the initiation of movement until the pen stopped moving or until the movement changed direction. At the conclusion of each trial, self-control participants could ask for feedback on either their temporal accuracy or their spatial accuracy. On feedback trials, the experimenter rotated the computer monitor presenting either movement speed feedback via a dialogue box indicating the total duration of the movement or movement accuracy feedback via a digital representation of the entire movement. Feedback was presented for approximately five seconds. Approximately 24 hours after acquisition, participants returned to the lab to complete retention and transfer tests. Participants again completed the IMI and BPNS before the retention and transfer tests. The retention test consisted of six no-KR trials of the acquisition task. The transfer test consisted of six no-KR trials on the same task, but participants were required to move in the opposite direction around the barrier. All other procedures were similar to those used during acquisition.

Data Treatment & Analysis

Temporal and spatial accuracy. Data were collected using a customized program written with Movalyzer® software (Neuroscript, copyright 1999-2012). Movement time was defined as the time elapsed from the initiation of movement until the pen stopped moving, was lifted from the tablet, or when the movement changed direction. Movement time data was calculated by the Movalyzer® software and exported into an Excel spreadsheet for further processing. Spatial position of the cursor was sampled via the Movalyzer® software at 100 Hz in both the x- and y-axes. End point coordinates in both axes (x- and y-coordinates) were transferred from the Movalyzer® software into an Excel spreadsheet for further processing.

Temporal accuracy was analyzed by calculating the average temporal error or constant error (CE; $[x_i - T]$). CE measures the average magnitude and direction of the difference between the movement time (x_i) and the target time (T ; Schmidt & Wrisberg, 2005). Temporal accuracy was also analyzed by calculating the average overall error or absolute error (AE; $|x_i - T|$). AE measures the average absolute deviation, without regard to direction, between the movement time (x_i) and the target time (T ; Schmidt & Wrisberg, 2005). Finally, variability in temporal accuracy was analyzed by calculating variable error (VE; $\sqrt{\{[x_i - M]^2\}}$). VE measures the inconsistency or variability between movement time (x_i) and a subject's average movement time (M ; Schmidt & Wrisberg, 2005). Spatial accuracy was analyzed by calculating radial error (RE; $\sqrt{\{[x_i - x_T]^2 + [y_i - y_T]^2\}}$). RE measures the average distance between the final movement point (end-point; x_i, y_i) and the center of the target (x_T, y_T), via x- and y-coordinates (Emanuel, Jarus, & Bart, 2008). Variability in spatial accuracy was analyzed by calculating variable radial error

(VRE; $\sqrt{\{[x_i - x_M]^2 + [y_i - y_M]^2\}}$). VRE measures the inconsistency or variability between the end-point (x_i, y_i) and the average end-point (x_M, y_M) ; Emanuel, Jarus, & Bart, 2008).

For the purposes of data analysis, acquisition trials were divided into ten blocks of six trials. All performance data (CE, AE, VE, RE and VRE) were averaged by trial block and statistically analyzed with separate 2 (group) x 6 (trial block) analyses of variance (ANOVA). Retention and transfer data were analyzed with separate univariate ANOVAs for all performance data. To assess performance on feedback versus non-feedback trials, performance data was averaged and analyzed via separate 2 (group) x 2 (trial type; feedback, no-feedback) and 2 (group) x 3 (trial type; timing feedback, spatial feedback, no-feedback) ANOVAs for timing CE, AE, and RE. Alpha was set at 0.05 and Sidak post-hoc analyses were used whenever significance was reached. All data were screened for outliers. Individual data scores for all variables were eliminated if they were more than 2.58 standard deviations away from the mean. Greenhouse-Geiser adjustments were used whenever sphericity was violated.

Additional analyses were made upon review of the results. Because findings were not consistent with previous literature, further comparisons of feedback requests were made. To get a better understanding of self-control feedback request strategies, comparisons of feedback requests based on temporal and spatial accuracy performance were made. First, acquisition trials for each participant were ranked from least error to most error for both AE and RE (for this analysis, outliers were re-introduced to the data set). The total number of feedback requests were then calculated for the top, middle, and bottom third of acquisition trials per feedback type (temporal accuracy, spatial accuracy, and no-feedback) for each dependent variable individually. Finally, feedback requests for all feedback types were aggregated over the two dependent

performance measures. Comparisons of the total number of feedback versus no-feedback requests for both AE and RE combined, the total number of spatial accuracy versus temporal accuracy feedback requests for both AE and RE combined, and the total number of spatial accuracy versus temporal accuracy feedback requests for AE and RE separately were made.

IMI, BPNS, and PTQ. The individual responses from the IMI, the BPNS, and the PTQ were transferred into an Excel spreadsheet for analysis. Responses from each statement were averaged across sub-scale for the IMI and across sub-category for the BPNS and averaged for each group for the PTQ. Group differences for the IMI were analyzed with separate 2 (group) x 3 (administration: pre-training, post-training, pre-test) x 4 (sub-scale) ANOVAs. Group differences for the BPNS were analyzed with separate 2 (group) x 3 (administration: pre-training, post-training, pre-test) x 3 (sub-category) ANOVAs. Alpha was set at 0.05 and Sidak post-hoc analyses were used whenever significance was reached. Greenhouse-Geiser adjustments were used whenever sphericity was violated. No statistical analysis was run on the results from the PTQ. Group differences were reported for comparison. Results from the open-ended questions of the PTQ were reviewed for any emerging themes. Responses from all questions were summarized for clarity before recurring themes were identified. Summarized responses were then categorized into the themes. Additionally, total responses in each theme were compared with performance and feedback request data.

CHAPTER 4

Results

Results of the present study are discussed in this chapter. Performance measures data, including data on timing and spatial accuracy, as well as comparisons between performance on feedback and no-feedback trials are reported. Additionally, data from motivational and need fulfillment scales and training questionnaires are reported. Only summary data and group comparisons are reported in this chapter. Complete summary tables for all statistical analyses are included in Appendix E.

Performance measures

Timing accuracy was measured by calculating the constant error and absolute error of each attempt. Constant error (CE) provided information about the total deviation from the target time of 600 msec with respect to direction (faster or slower than the target time), while absolute error (AE) provided information about the absolute deviation from the target time without regard to direction. Variability in timing accuracy performance was measured by calculating the variability of each attempt (variable error; VE). Spatial accuracy was measured by calculating the radial error (RE) or the straight-line distance from the final movement (end-point) to the center of the target via x and y coordinates. Variability in radial error (variable radial error; VRE) was measured in a similar fashion as that of timing error variability. All performance data were averaged by trial block for statistical analyses.

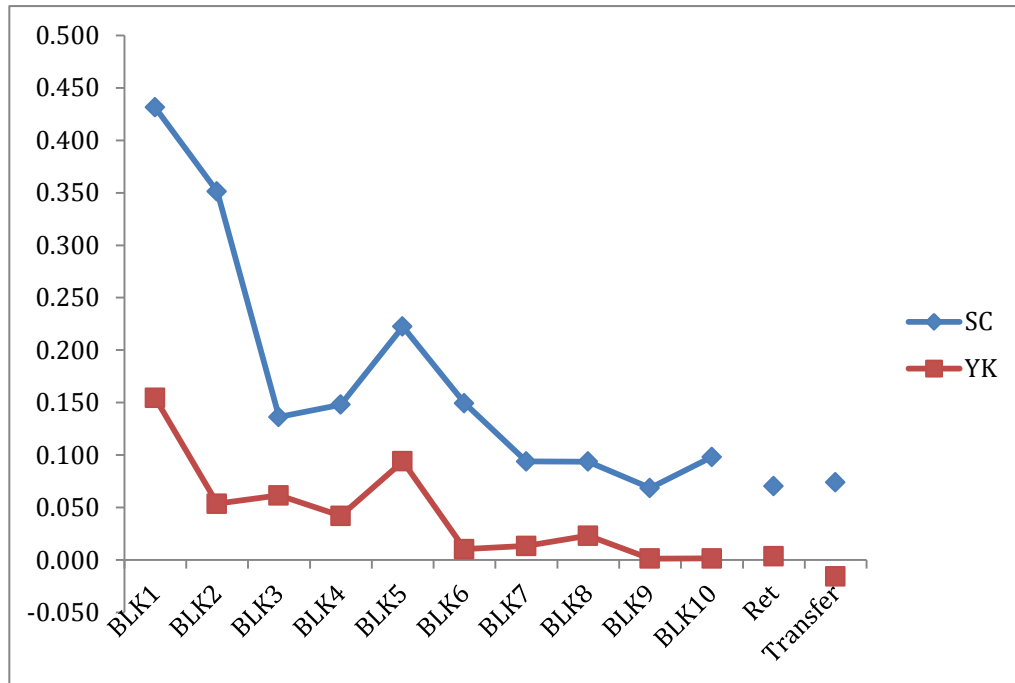


Figure 3. *Mean CE scores for self-control and yoked groups during acquisition, retention, and transfer phases (msec).*

Acquisition. Performance data from the acquisition phase were analyzed via separate 2 (group) x 6 (trial block) analyses of variance (ANOVA). During acquisition, there were group differences in timing accuracy. Analysis of CE revealed a significant group effect ($p = .025$, $F(1, 20) = 5.832$, $\eta^2 = .226$) and a significant block effect ($p < .001$, $F(1, 20) = 8.472$, $\eta^2 = .298$), but not a significant group x block interaction. On average, the yoked group performed with significantly lower CE (0.046 msec) than the self-control group (0.179 msec). Both groups, on average, performed slower than the 600 msec goal time. Analysis of AE revealed a significant group effect ($p = .014$, $F(1, 20) = 7.253$, $\eta^2 = .266$) and block effect ($p = .001$, $F(1, 20) = 6.505$, $\eta^2 = .245$), as well as a significant group x block interaction ($p = .049$, $F(1, 20) = 2.791$, $\eta^2 =$

.122). On average, the yoked group (0.107 msec) out performed the self-control group (0.228 msec), moving with significantly less absolute timing error during the acquisition phase.

Analysis of VE revealed a similar trend as seen with CE and AE (yoked group=0.097 msec, self-control group=0.146 msec), however, the difference did not reach significance ($p = .079$, $F(1, 20) = 3.427$, $\eta^2 = .146$). Finally, data describing spatial accuracy of the movement did not reveal significant differences between the groups. Analysis of RE did not reveal a significant group effect nor did the analysis of VRE. Although not significant, the self-control group (0.871 cm) did perform the task with lower spatial error than the yoked group (0.915 cm).

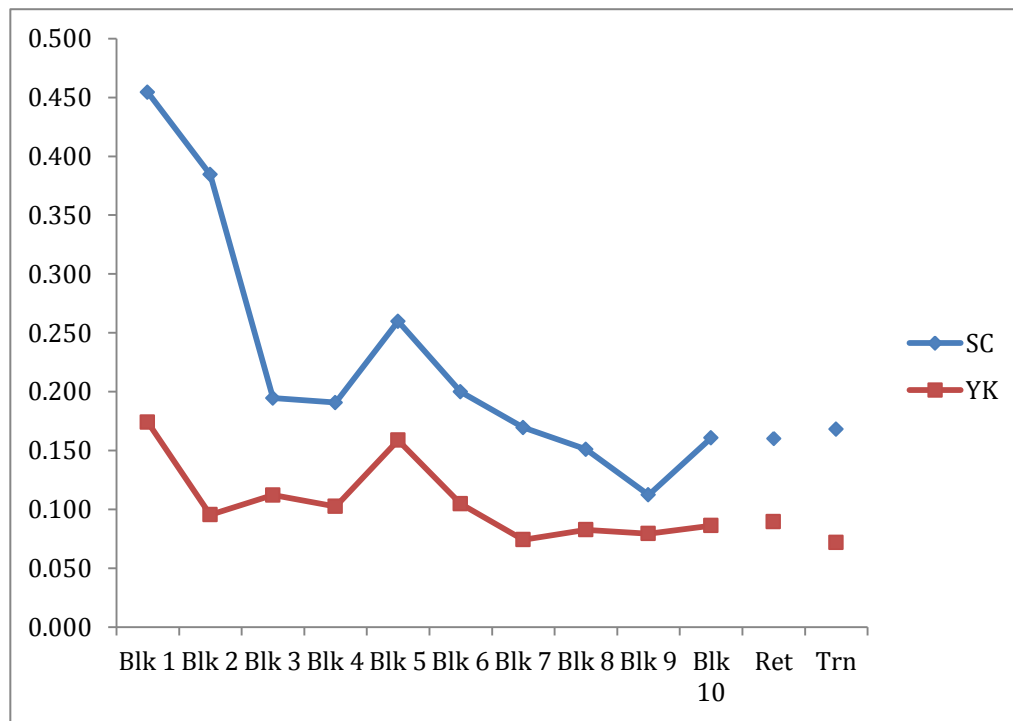


Figure 4. *Mean AE scores for self-control and yoked groups during acquisition, retention, and transfer phases (msec).*

Retention. Performance data from the retention tests were analyzed via separate one-way ANOVAs for each dependent performance measure. The difference in CE performance between the self-control (0.070 msec) and yoked (0.004 msec) groups during retention was not significantly different, however, the difference in AE performance between the two groups (self-control=0.160 msec; yoked=0.090 msec) was significantly different. The yoked group performed with significantly lower AE than the self-control group ($p = .037$, $F(1, 20) = 5.017$, $\eta^2 = .201$). However, when the first block of acquisition was used as a covariate, the significant difference between the two groups disappeared. Performance differences between the two groups on VE, RE, and VRE were not significantly different.

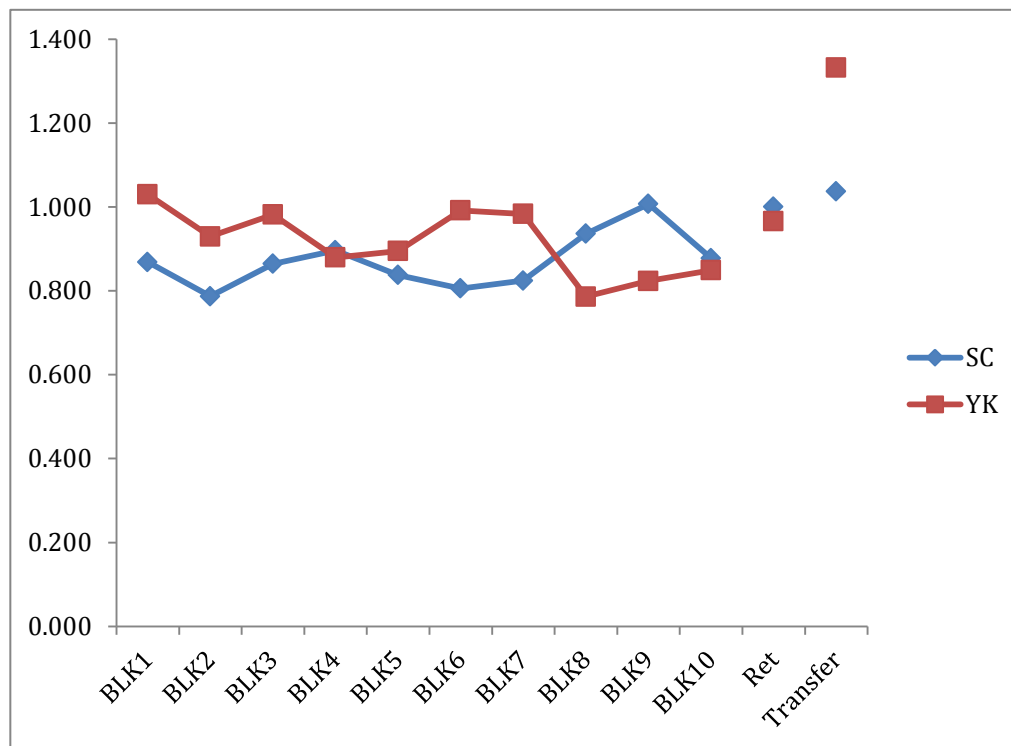


Figure 5. *Mean RE scores for self-control and yoked groups during acquisition, retention, and transfer phases (cm).*

Transfer. Performance data from the transfer test were also analyzed via separate one-way ANOVAs for each dependent performance measure. As seen in the retention test, the performance difference between the self-control and yoked groups was not significantly different for CE or VE. Again, the yoked group (0.072 msec) performed with significantly lower absolute timing error (AE) than the self-control group (0.168 msec) during the transfer test ($p = .029$, $F(1, 20) = 5.498$, $\eta^2 = .216$). Again, however, when the first block of acquisition was used as a covariate, the significant difference between the two groups disappeared. The self-control group performed with significantly lower spatial error in the transfer test. Radial error for the self-control group (1.037 cm) was significantly lower ($p = .048$, $F(1, 20) = 4.446$, $\eta^2 = .182$) than that of the yoked group (1.332 cm). The self-control group (0.474 cm) also performed with lower VRE than the yoked group (0.698 cm), but this difference did not reach significance ($p = .078$, $F(1, 20) = 3.439$, $\eta^2 = .147$).

Feedback vs. no-feedback. Performance on feedback versus no-feedback trials was analyzed for CE, AE, and RE during the acquisition phase. Analysis of CE performance on feedback versus no-feedback trials showed that the self-control group performed with slightly worse CE on trials that they asked for feedback (0.192 ms) than trials that they did not ask for feedback (0.189 ms). The yoked group, on the other hand, performed equally on feedback trials as they did on no-feedback trials (0.055 ms). Statistical analysis of a 2 (group) x 2 (feedback, no-feedback) ANOVA revealed a main effect for group ($p = .001$, $F(1, 20) = 15.775$, $\eta^2 = .441$). The yoked group performed with significantly better CE on both feedback trials ($p = .020$, $F(1, 20) = 6.367$, $\eta^2 = .241$) and on no-feedback trials ($p = .032$, $F(1, 20) = 5.294$, $\eta^2 = .209$) than the

self-control group. However, there was no main effect for feedback type or a significant group x feedback type interaction.

Analysis of AE performance on feedback versus no-feedback trials showed that the self-control group performed with slightly better AE on trials that they asked for feedback (0.240 ms) than trials that they did not ask for feedback (0.250 ms). The yoked group showed a similar performance behavior (feedback trials=0.101 ms; no-feedback trials=0.123 ms). The 2 (group) x 2 (feedback, no-feedback) ANOVA for AE also revealed a main effect for group ($p = .008$, $F(1, 20) = 8.565$, $\eta^2 = .300$). The yoked group performed with significantly better AE on both feedback trials ($p = .012$, $F(1, 20) = 7.585$, $\eta^2 = .275$) and no-feedback trials ($p = .024$, $F(1, 20) = 5.978$, $\eta^2 = .230$) than the self-control group. Again, there was no main effect for feedback type or a significant group x feedback type interaction.

The analysis of RE performance on feedback versus no-feedback trials showed that the self-control group performed with better RE on trials that they asked for feedback (0.828 cm) than on trials they did not ask for feedback (0.918 cm). The yoked group, on the other hand, performed with slightly worse RE on trials that they received feedback (0.906 cm) than on trials they did not receive feedback (0.876 cm). The 2 (group) x 2 (feedback, no-feedback) ANOVA for RE, however, revealed no significant main effect for group, no significant main for feedback type, and no group x feedback type interaction.

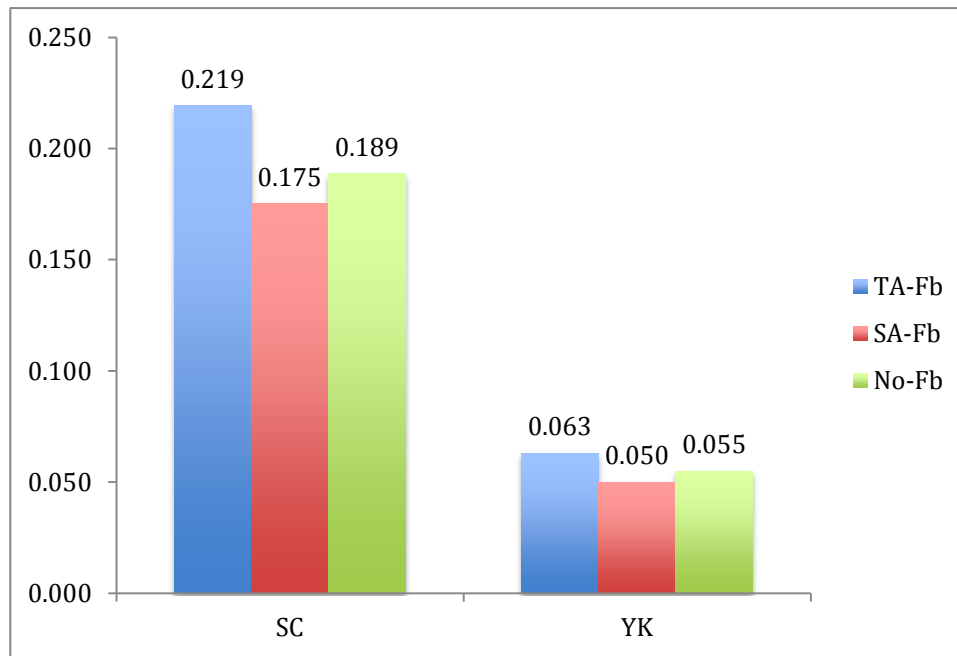


Figure 6. *Mean CE scores on trials after which temporal accuracy feedback, spatial accuracy feedback, and no feedback was requested during acquisition (ms).*

The comparison between feedback and no-feedback performance was further analyzed by specifically comparing performance temporal accuracy feedback, spatial accuracy feedback, or no-feedback trials. Analysis of CE data revealed that the self-control group asked for spatial accuracy feedback when they performed the task with their best CE (0.175 ms) and asked for temporal accuracy feedback when performed the task with their worst CE (0.219 ms). The yoked group showed a similar trend, but with smaller differences (spatial accuracy feedback=0.050 ms; timing accuracy feedback=0.063). A 2 (group) x 3 (timing feedback, spatial feedback, no-feedback) ANOVA revealed a main effect for group ($p = .001$, $F(1, 20) = 13.787$, $\eta^2 = .408$) indicating that the yoked group performed with significantly lower CE on trials after which they

received feedback on timing accuracy ($p = .024$, $F(1, 20) = 5.972$, $\eta^2 = .230$) than the self-control group. The two groups did not perform differently on trials after which they received spatial feedback or no-feedback. Again, there was no main effect for feedback type or a significant group x feedback type interaction.

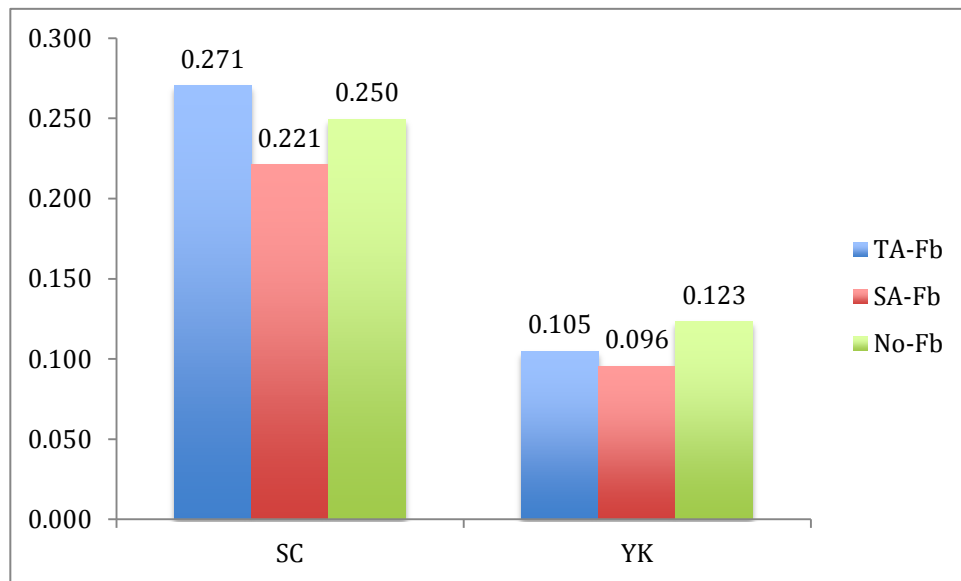


Figure 7. Mean AE scores on trials after which temporal accuracy feedback, spatial accuracy feedback, and no feedback was requested during acquisition (ms).

Likewise, analysis of AE data showed that the self-control group asked for spatial accuracy feedback when they performed with their best AE (0.221 ms) and asked for timing accuracy feedback when they performed with their worst AE (0.271 ms). Similarly, the yoked group performed with their best AE when they received feedback on spatial accuracy (0.096 ms). However, the yoked group performed with their worst AE when they did not receive feedback

(0.123 ms), while their performance on trials after which they received feedback on timing accuracy was in between (0.105 ms). Statistical analysis revealed a main effect for group ($p = .008$, $F(1, 20) = 8.629$, $\eta^2 = .301$) indicating that the yoked group performed with significantly lower AE than the self-control group on trials after which they received feedback on timing accuracy ($p = .023$, $F(1, 20) = 6.043$, $\eta^2 = .232$) and spatial accuracy ($p = .035$, $F(1, 20) = 5.113$, $\eta^2 = .204$). The two groups did not perform differently on trials after which they received no-feedback. Again, there was no significant main effect for feedback type or a significant group x feedback type interaction.

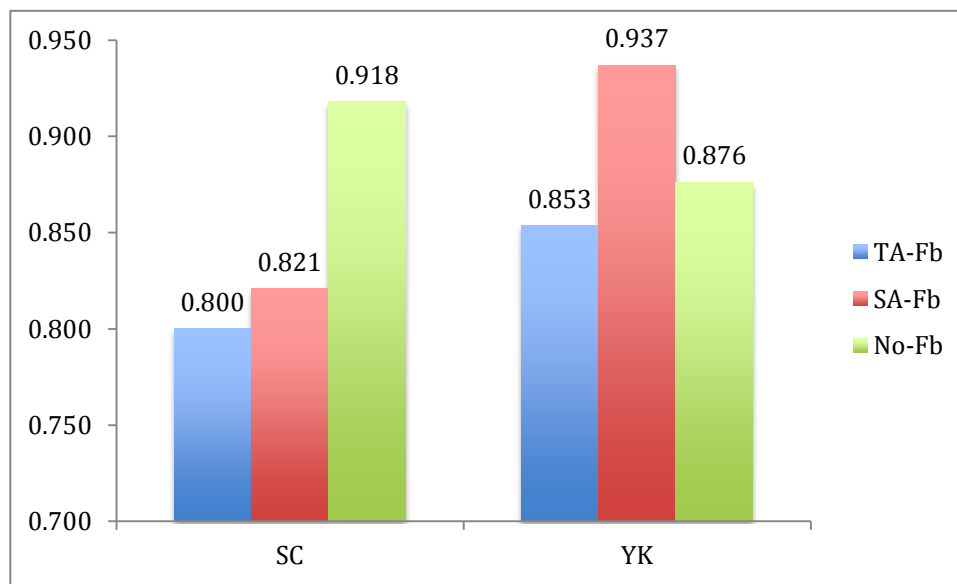


Figure 8. *Mean RE scores on trials after which temporal accuracy feedback, spatial accuracy feedback, and no feedback was requested during acquisition (cm).*

Finally, the analysis of RE data showed that the self-control group performed with their best RE when they asked for timing feedback (0.800 cm) and spatial feedback (0.821 cm). The yoked group, however, received feedback on spatial accuracy when they performed with their worst RE (0.937 cm) and received feedback on timing accuracy when they performed with their best RE (0.853 cm). Statistical analysis revealed no main effects for group or feedback type and no significant group x feedback type interaction.

Feedback requests. The total number of requests for temporal accuracy feedback, spatial accuracy feedback, and no-feedback were calculated. Results indicated that the self-control group made a total of 239 requests for temporal accuracy feedback and 152 requests for spatial accuracy, while not requesting feedback 269 times. Additionally, comparisons of self-controlled feedback requests, organized by most successful (top third) to least successful (bottom third), were made for feedback versus no-feedback trials as well as for spatial accuracy feedback versus temporal accuracy feedback trials for both AE and RE combined and individually. First, the comparison of feedback versus no-feedback trials for AE and RE combined revealed that the self-control group requested feedback equally on their best performances as on their worst performances, as seen in Figure 7. Across both AE and RE performances, the self-control group requested feedback 261 times during their top third performances and 258 times during their bottom third performances. Further, they did not ask for feedback on 179 trials during their top third performances and 182 times during their bottom third performances. The self-control group asked for feedback 44% more often than they did not ask for feedback.

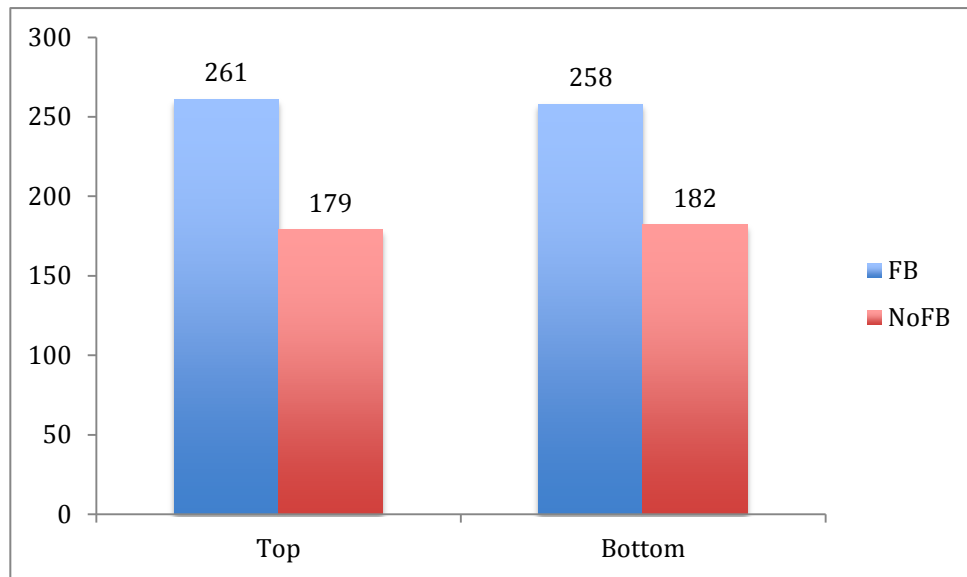


Figure 9. *Total number of feedback and no-feedback requests from the top and bottom tertiles of AE and RE performances combined.*

The comparison of feedback requests between spatial accuracy feedback and temporal accuracy feedback for AE and RE combined reveal a similar pattern. The self-control group requested spatial accuracy feedback 112 times during their top third performances and 98 times during their bottom third performances, a difference of only 15%. The self-control group requested temporal accuracy feedback 149 times during their top third performances and 160 during their bottom third performances, a difference of only 7%. However, the self-control group asked for temporal accuracy feedback 47% more often than they asked for spatial accuracy feedback.

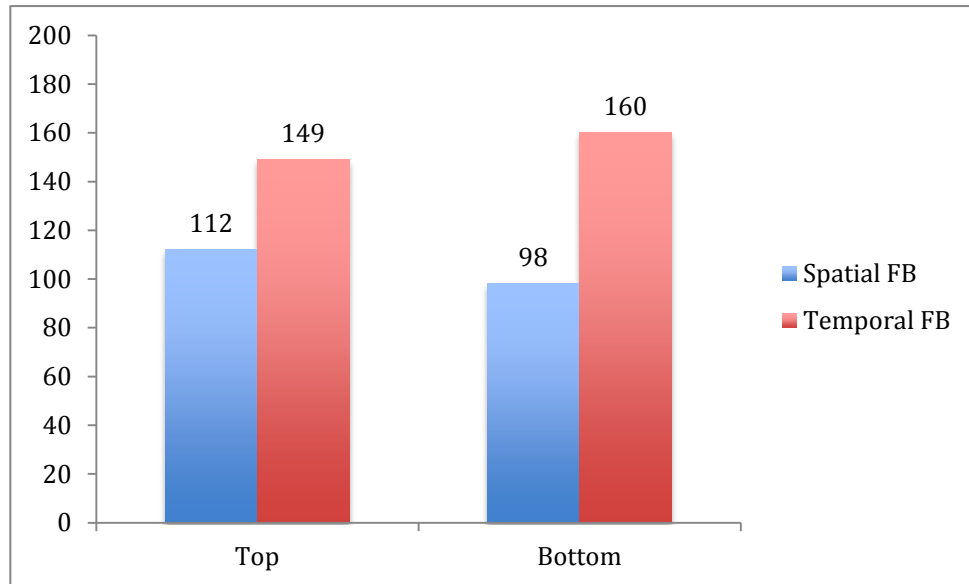


Figure 10. *Total number of spatial accuracy feedback and temporal accuracy feedback requests from the top and bottom tertiles of AE and RE performances combined.*

The comparison of feedback requests between spatial accuracy feedback and temporal accuracy feedback for RE revealed a slight difference in feedback requests between the top third and bottom third of performances. The self-control group requested spatial accuracy feedback 42% more often when their RE was most accurate than when their RE was least accurate (i.e., 64 times during their top third performances and 45 times during their bottom third performances). However, their feedback requests for temporal accuracy feedback were equal whether they performed with the best or the worst spatial accuracy.

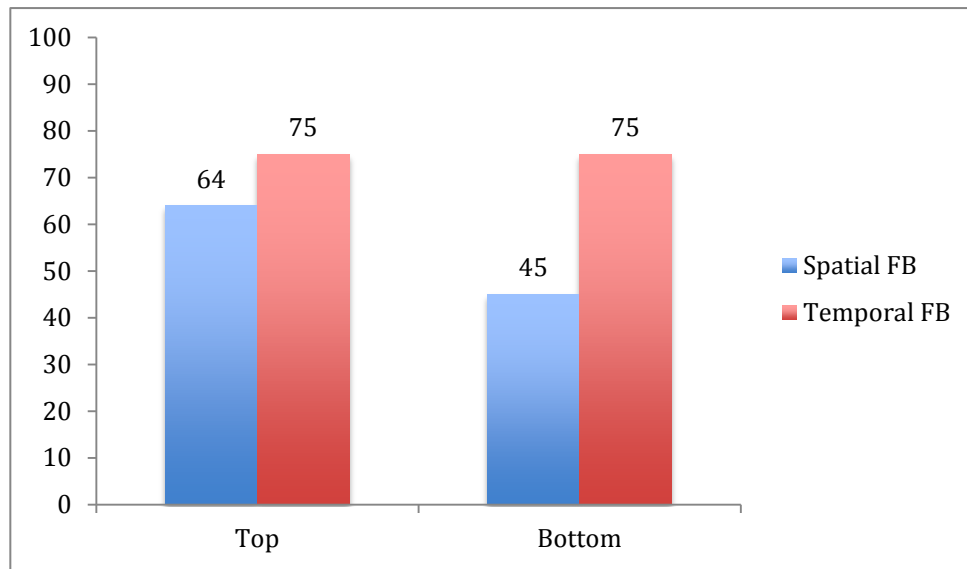


Figure 11. *Total number of spatial accuracy feedback and temporal accuracy feedback requests from the top and bottom tertiles of RE performance.*

The comparison of feedback requests between spatial accuracy feedback and temporal accuracy feedback for AE revealed a virtually no difference in feedback requests between the top third and bottom third of performances. The self-control group requested spatial accuracy feedback 48 times on their best AE trials and 53 times during their worst AE trials. Additionally, the self-control group requested temporal accuracy feedback 74 times on their best AE trials and 85 on their worst AE trials, an increase of only 15%.

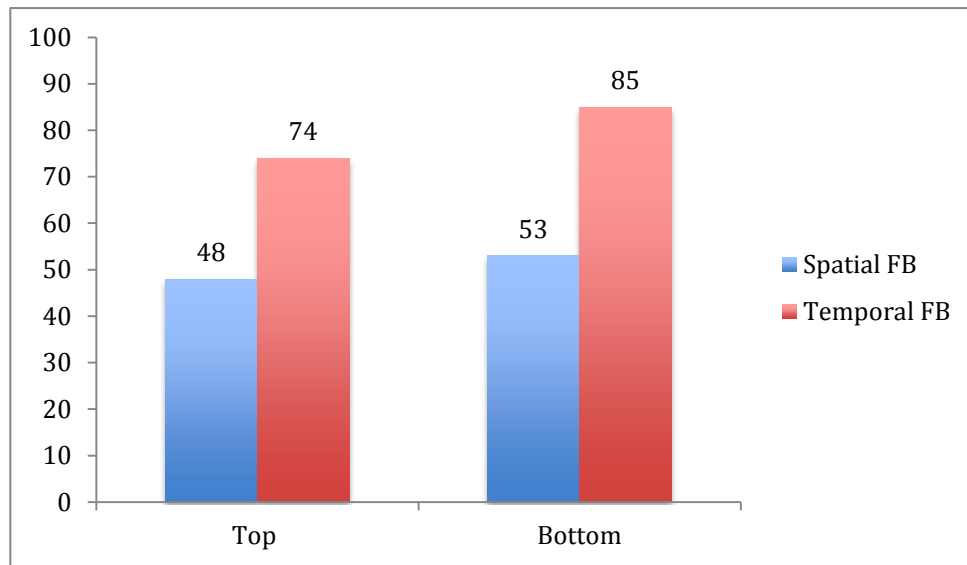


Figure 12. *Total number of spatial accuracy feedback and temporal accuracy feedback requests from the top and bottom tertiles of RE performance.*

Motivation and Need Fulfillment Scales

IMI. The Intrinsic Motivation Inventory is comprised of four sub-scales that assess a learner's interest and enjoyment, perceived competence, pressure and tension, and perceived choice while performing the task. Together, the scores from the sub-scales provide an estimate of intrinsic motivation while learning the task (e.g. Ryan, 1982; Ryan, Mims & Koestner, 1983; Plant & Ryan, 1985). The adapted version used in this study had four statements per sub-category (16 total statements) and were rated on a seven-point Likert scale.

Results from the analysis of the IMI revealed small difference in motivation between the two groups. The yoked group reported higher interest and enjoyment than the self-control group pre-training (yoked=5.14, self-control=4.45), post-training (yoked=5.21, self-control=4.89), and pre-test (yoked=5.00, self-control=4.67). The yoked group also reported higher perceived

competence than the self-control group at performing the task pre-training (yoked=4.53, self-control=4.00), post-training (yoked=4.45, self-control=4.06), and pre-test (yoked=4.67, self-control=4.24). The yoked group reported to feel higher pressure and tension than the self-control group pre-training (yoked=5.08, self-control=4.50), post-training (yoked=4.85, self-control=4.47), and pre-test (yoked=4.83, self-control=4.41). Finally, the yoked group reported higher perceived choice than the self-control group pre-training (yoked=4.76, self-control=3.85), post-training (yoked=4.64, self-control=4.29), and pre-test (yoked=4.69, self-control=4.24).

Table 1. *Mean scores from Intrinsic Motivation Inventory for self-control and yoked groups pre-training, post-training, and pre-test.*

Sub-category	Group	Pre-train	Post-train	Pre-test
Interest & enjoyment	SC	4.45	4.89	4.67
	YK	5.14	5.21	5.00
Perceived competence	SC	4.00	4.06	4.24
	YK	4.53	4.45	4.67
Pressure/tension	SC	4.50	4.47	4.41
	YK	5.08	4.85	4.83
Perceived choice	SC	3.85	4.29	4.22
	YK	4.76	4.64	4.69

Note: 1 = not true at all, 4 = somewhat true, 7 = very true.

A 2 (group) x 3 (time) x 4 (sub-scale) ANOVA revealed two significant group x time x sub-scale interactions. The yoked group reported statistically higher perceived competence than

the self-control group post-training ($p = .038$, $F(1, 20) = 4.935$, $\eta^2 = .199$). Differences for perceived competence approached significance pre-training ($p = .051$, $F(1, 20) = 4.297$, $\eta^2 = .177$), as well. Additionally, the yoked group also reported statistically higher perceived choice than the self-control group pre-training ($p = .010$, $F(1, 20) = 8.122$, $\eta^2 = .289$).

BPNS. The Basic Psychological Needs Scale is comprised of three sub-categories that measure an individual's level of need fulfillment of each of the three basic psychological needs (Deci & Ryan, 2000): autonomy, competence, and relatedness. The adapted version used in this study included seven statements per sub-category to assess need fulfillment (21 total components) and were rated based on a seven-point Likert scale, seven indicating "very true" and one indicating "not true at all."

Table 2. *Mean scores from Basic Psychological Needs Scale for self-control and yoked groups pre-training, post-training, and pre-test.*

Sub-category	Group	Pre-train	Post-train	Pre-test
Autonomy	SC	4.48	4.62	4.82
	YK	4.91	4.69	4.48
Competence	SC	5.30	5.32	5.36
	YK	5.70	5.87	5.78
Relatedness	SC	5.05	5.23	5.23
	YK	5.56	5.51	5.40

Note: 1 = not true at all, 4 = somewhat true, 7 = very true.

Results from the analysis of the BPNS revealed small differences in need fulfillment between the two groups over the course of the study. The yoked group reported to have slightly higher fulfillment of their need for autonomy than the self-control group pre-training (yoked=4.91, self-control=4.48) and post-training (yoked=4.69, self-control=4.62). Just before the retention and transfer tests (pre-test), the self-control group (4.82) reported higher autonomy fulfillment than the yoked group (4.78). For the need for competency, the yoked group reported slightly higher scores than the self-control group pre-training (yoked=5.70, self-control=5.30), post-training (yoked=5.87, self-control=5.32), and pre-test (yoked=5.78, self-control=5.36). Finally, the yoked group reported to have slightly higher fulfillment of their need for relatedness than the self-control group pre-training (yoked=5.56, self-control=5.05), post-training (yoked=5.51, self-control=5.23), and pre-test (yoked=5.40, self-control=5.23). A 2 (group) x 3 (time) x 3 (sub-category) ANOVA revealed that none of the aforementioned group differences were statistically significant.

Post-Training Questionnaire

Likert-scale questions. The self-control and yoked groups were given two separate post-training questionnaires, to be answered using a five-point Likert scale: five indicating “always”, four indicating “often”, three indicating “occasionally”, two indicating “seldom”, and one indicating “never.” The self-control group was asked how often they asked for feedback when they thought they did a good job of hitting the target time, when they thought they did not do a good job of hitting the target time, when they thought they did a good job of hitting the center of the target, and they thought they did not do a good job of hitting the center of the target. Participants in the self-control group reported that they asked for feedback occasionally when

they thought they did a good job of hitting the target time (3.09), when they did not do a good job of hitting the target time (3.18), when they thought they did a good job of hitting the center of the target (2.95), and when they thought they did not do a good job of hitting the center of the target (2.91).

Table 3. *Mean scores on the Likert-scale questions from the Post-Training Questionnaire for the self-control group.*

Question	Mean
How often did you ask for feedback about your timing accuracy when you thought you did a good job of achieving the goal time of 600 ms?	3.09
How often did you ask for feedback about your timing accuracy when you thought you <u>didn't</u> do a good job of achieving the goal time of 600 ms?	3.18
How often did you ask for feedback about your spatial accuracy when you thought you did a good job of hitting the center of the target?	2.95
How often did you ask for feedback about your spatial accuracy when you thought you <u>didn't</u> do a good job of hitting the center of the target?	2.91
Note: 1 = never, 2 = seldom, 3 = occasionally, 4 = often, 5 = always.	

The yoked group was asked how often they received feedback when they need it, how often they received timing accuracy feedback when they thought they did and didn't do a good job of hitting the target time, how often they received spatial accuracy feedback when they thought they did and did not do a good job of hitting the center of the target, and how often they would have preferred to receive feedback in the four aforementioned scenarios. Again, a response of four indicated "often", a response of three indicated "occasionally", and a response of two indicated "seldom". Participants in the yoked group on average reported that they received

feedback when they needed it (3.64). They also reported that they received feedback about occasionally when they thought they did (3.24) and did not (2.91) do a good job of hitting the target time, and less than occasionally when they thought they did (2.55) and did not (2.55) do a good job of hitting the center of the target. Additionally, the yoked group reported that they would have preferred to receive feedback occasionally when they did a good job of hitting the target time (3.09), more than occasionally when they did not do a good job of hitting the target time (3.45), about often when they thought they did a good job of hitting the center of the target (3.85) and more than occasionally when they thought they did not do a good job of hitting the center of the target (3.64).

Table 4. *Mean scores on the Likert-scale questions from the Post-Training**Questionnaire for the yoked group.*

Schedule	Question	Mean
Actual	How often did you receive feedback when you needed it?	3.64
	How often did you receive feedback about your timing accuracy when you thought you did a good job of achieving the goal time of 600 ms?	3.27
	How often did you receive feedback about your timing accuracy when you thought you <u>didn't</u> do a good job of achieving the goal time of 600 ms?	2.91
	How often did you receive feedback about your spatial accuracy when you thought you did a good job of hitting the center of the target?	2.55
	How often did you receive feedback about your spatial accuracy when you thought you <u>didn't</u> do a good job of hitting the center of the target?	2.55
Preferred	How often would you have preferred to receive feedback when you thought you did a good job of achieving the goal time of 600 ms?	3.09
	How often would you have preferred to receive feedback when you thought you <u>didn't</u> do a good job of achieving the goal time of 600 ms?	3.45
	How often would you have preferred to receive feedback when you thought you did a good job of hitting the center of the target?	3.82
	How often would you have preferred to receive feedback when you thought you <u>didn't</u> do a good job of hitting the center of the target?	3.64

Note: 1 = never, 2 = seldom, 3 = occasionally, 4 = often, 5 = always.

Open-ended questions. Additionally, both groups were asked open-ended questions geared toward providing insight into how feedback was utilized and describing any strategies they used. The self-control group was asked four open-ended questions about their feedback requests: why they chose one feedback type over the other (timing feedback or spatial feedback), their specific reasons for asking for feedback on timing accuracy and spatial accuracy, respectively, and if they developed any strategies related toward feedback requests. The yoked group was asked if they developed any strategies that helped them learn. Responses from the open-ended questions were summarized and categorized in themes. All participants responded to all of the open-ended questions. Initial inspection of the responses to question 5 ("What were your reasons for choosing one feedback type over the other?") revealed vague and general reasons for requesting feedback. However, summarizing the self-control group's responses to questions 5a ("Specifically, tell me why you asked for timing accuracy feedback when you did") and 5b ("Specifically, tell me why you asked for spatial accuracy feedback when you did") revealed seven recurring themes: requesting feedback when temporal performance was good, when spatial performance was good, when temporal performance was poor, when spatial performance was poor, to confirm performance regardless of success, and if the other aspect was performed well or if the other aspect was performed poorly. Responses to the two questions were then categorized into the seven themes; some responses fit into multiple themes. From the two questions, the self-control group reported to have requested feedback equally on good (4 responses) and poor (4) temporal performance, good (5) and poor (4) spatial performance, and to confirm performance regardless of success (4). Further, the self-control group requested

feedback when the other aspect was performed well (6) much more often than when the other aspect was not performed well (1).

Table 5. Themes revealed about how self-control participants requested feedback and number of responses from Q5a and Q5b.

Theme	Responses
When temporal performance was good	4
When temporal performance was poor	4
When spatial performance was good	5
When spatial performance was poor	4
To confirm performance regardless of success	4
If the other aspect was performed well	6
If the other aspect was performed poorly	1

Review of the responses to questions 6 and 6a regarding strategies that were used and/or developed related to feedback request (self-control group) or to help learn the task (yoked group) did not reveal any consistent themes. Interestingly, only one self-control participant reported using a strategy related to feedback request; all other self-control strategies involved performance strategies. Responses to question 7 ("When you think about your experience today, what else stands out for you?") for both the self-control and yoked groups also did not reveal any consistent themes. A complete list of responses to the open-ended questions of the post-training questionnaire is provided in Tables 5–11 of Appendix F.

CHAPTER 5

Discussion

Recently, the investigation of learner-controlled practice environments has garnered a lot of attention in motor behavior research. Specifically, investigating how learners benefit from having control over the administration of feedback schedules, practice schedules, and the utilization of physical assistance devices has led to numerous potential explanations for its beneficial effects. These explanations include the development of deeper cognitive processing, increased confidence and motivation, the development of more effective learning strategies (Janelle, et al., 1995; 1997), and fulfilling learner-specific needs by self-tailoring the practice environment to learning specific needs and preferences (Chiviacowsky & Wulf, 2002). Current research suggests that learners' preference for feedback after relatively good performances are associated with higher motor learning, increases in intrinsic motivation, and perceptions of competence. More recently, Aiken and colleagues (2012) have provided evidence suggesting that when learners control their feedback schedule while learning a task with multiple dimensions of performance (the basketball set shot), they prefer and request feedback after both "good" and "poor trials" equally. In their study, the self-control group performed with better form scores (primary objective), while both groups had statistically similar performance scores (secondary objective). Further, learners in the self-control group reported to have requested feedback "occasionally" on both good and poor trials. Comparisons of form scores and performance scores on feedback and no-feedback trials revealed no differences across the two groups.

It was proposed that tasks with multiple dimensions of performance, such as the basketball set shot, place the learner in a dilemma over which aspect of the task to request

feedback on and may alter the way learners use self-controlled feedback. The purpose of this study was to directly address this dilemma and further understand how people use control over feedback schedules to learn a motor skill by examining how learners in self-controlled and yoked conditions behave when learning a task with two conflicting dimensions of performance: a discrete aiming task (Schmidt et al., 1979). Of particular interest to this study are the changes and differences in learner motivation and fulfillment of basic psychological needs.

Summary of Procedures

Upon arriving at the Motor Behavior Laboratory, participants were given a brief explanation of the task and study, and were asked to fill out the EHI (handedness scale) and the informed consent form. Participants were then randomly assigned to either a self-control group (SC) or a yoked group (YK). After group assignment, participants were seated in front of the apparatus and the experimenter explained the experimental task and procedures. Participants in the SC group were instructed to request feedback when they need it and that they may request feedback on either their movement speed or accuracy, but not both on any given trial. Participants in the YK group were informed that they would sometimes receive feedback on either their movement speed or accuracy. All participants were informed that they would perform the task without feedback during the retention and transfer tests. Participants were then given a demonstration of how to complete the task and how the feedback would be presented. After the demonstration, participants in both groups completed both the IMI and the BPNS. During acquisition, participants completed 60 trials with a 20 second inter-trial interval. Half way through acquisition (30 trials), participants were given a 5 min break. At the completion of

acquisition, participants again completed the IMI and the BPNS. All participants also took part in the post-training interview at the end of acquisition.

At the beginning of acquisition, all participants were reminded of the objectives of the task. For each trial, participants were instructed to place the pen in the starting zone and to move when ready. Data was recorded from the initiation of movement until the pen stopped moving or until the movement changed direction. At the conclusion of each trial, SC participants had the chance to request feedback. On feedback trials, the experimenter rotated the computer monitor presenting either movement speed feedback via a dialogue box indicating the total duration of the movement or movement accuracy feedback via a digital representation of the entire movement. Feedback was presented for approximately five seconds. Approximately 24 hours after acquisition, participants returned to the lab to complete retention and transfer tests. Participants again completed the IMI and BPNS before the retention and transfer tests. The retention test consisted of six no-KR trials of the acquisition task. The transfer test consisted of six no-KR trials on the same task, but participants were required to move in the opposite direction around the barrier. All other procedures were similar to those used during acquisition.

Summary of Findings

Hypotheses

1. Participants will ask for temporal accuracy feedback more often than spatial accuracy feedback.

This hypothesis was supported. The self-control group requested temporal accuracy feedback 239 times and spatial accuracy feedback 152 times during acquisition.

2. Self-control participants will perform with more temporal accuracy and more spatial accuracy than their yoked counterparts in retention and transfer tests.

This hypothesis was partially supported. The self-control group performed with more spatial accuracy (lower RE) than the yoked group during the transfer test ($p = 0.048$). There were no significant differences between the two groups in temporal accuracy performance (CE or AE).

3. Self-control participants will perform with equal temporal accuracy and spatial accuracy on feedback versus no-feedback trials.

This hypothesis was supported. The differences between the self-control group and the yoked group CE, AE, and RE performance on feedback versus no-feedback trials were marginal and not significantly different.

4. Self-control participants will report higher levels of interest and enjoyment than their yoked counterparts.

This hypothesis was not supported.

5. Self-control participants will report higher levels of perceived choice than their yoked participants.

This hypothesis was not supported. The yoked group reported statistically higher perceived choice than the self-control group at the beginning of the experiment ($p = .010$).

6. Self-control participants will report higher levels of perceived competence than their yoked counterparts at the end of the study.

This hypothesis was not supported. The yoked group reported significantly higher perceived competence scores than the self-control group at the end of acquisition ($p = .038$).

7. Self-control participants will report higher levels of satisfaction for the basic psychological needs of autonomy and competence than their yoked counterparts at the end of the study.

This hypothesis was not supported.

Additional findings

1. The self-control group requested feedback as often during their most accurate (261) and least accurate (258) trials.
2. The self-control group requested spatial accuracy feedback roughly as often during their most accurate (112) and least accurate (98) trials.
3. The self-control group requested temporal accuracy feedback roughly as often during their most accurate (149) and least accurate (160) trials.

Discussion and Conclusions

The primary aim of the present study was to better understand how learners utilize control over their feedback schedule while learning a task with multiple elements of performance. Based on current self-control research, it was expected that the self-control group would outperform the yoked group in both temporal accuracy and spatial accuracy in retention and transfer tests. We did not, however, see this in their temporal accuracy performance. Instead, the yoked group performed with significantly lower absolute timing error during retention and transfer. However, the performance curves of the two groups during acquisition suggested that the yoked group might have been superior to the self-control group in temporal accuracy before the study took place (Figures 3 and 4). The self-control group improved their temporal accuracy (both CE and AE) over the course of acquisition, while the yoked group's improvement was not

as noticeable. A group x block interaction of both CE and AE revealed that while the self-control group performed better on trial blocks 7–10 compared to the first trial block, the yoked group did not perform significantly different on any trial blocks during acquisition. So, AE scores for retention and transfer were re-analyzed with the first trial block of acquisition as a covariate. Results indicated that the previously observed differences in AE during retention and transfer were attributable to performance at the beginning of the study. The results of the spatial accuracy performance indicated that the self-control group did perform with significantly lower radial error during transfer than did the yoked group. Although the two groups did not exhibit a learning curve with RE similar to the one observed in CE and AE, the self-control group was able to maintain their spatial accuracy during transfer (Figure 5). The yoked group, however, performed noticeably worse when asked to perform the task in the opposite direction. Relative stability in performance during transfer tests has often been used as an indicator of superior learning (Chiviacowsky & Wulf, 2002). As such, the current study provides evidence for a self-control effect when learning a simple motor task with competing elements of performance.

The comparisons of learner performances on feedback versus no-feedback trials revealed some interesting results. While the data showed that the self-control group's feedback requests came when their RE performance was relatively good, their CE and AE performance was relatively the same on feedback and no-feedback trials. Closer examination revealed that when the self-control group asked for temporal accuracy feedback, they performed with the best spatial accuracy, and when they asked for spatial accuracy feedback, they performed with their best temporal accuracy. Therefore, it is possible that the self-control group adopted a feedback strategy to request spatial accuracy feedback whenever they felt they performed with good

temporal accuracy and request temporal accuracy feedback whenever they felt they performed with good spatial accuracy. However, these differences were not significant, indicating any differences in performance on trials that feedback was or was not provided, regardless of feedback type, were negligible. Additionally, the trends observed and reported by Chiviacowsky and Wulf and Patterson and Carter (2010) also failed to reach significance. It is possible that such comparisons only provide insight into the behavioral trends of self-controlled learners in regard to feedback requests. Without evidence of significant differences between temporal or spatial accuracy performances on feedback versus no-feedback trials, any explanations for the beneficial effects of self-controlled learning based on such comparisons may be painting a picture that does not exist. A more in-depth, semi-structured post-training interview could provide enough evidence to suggest these trends are not random.

The main purpose of this study was to gain a better understanding of how learners use control over feedback schedule to learn a multi-dimensional task. Since the comparisons of performance on feedback and no-feedback trials revealed no significant differences, analyses examining feedback request tendencies based on self-controlled learners' best and worst performance were also used. Performance scores during acquisition for AE and RE were ordered from most accurate to least accurate and the total number of feedback requests by feedback type were tabulated and compared. The results revealed that the self-control group requested feedback 44% more often than not. Additionally, the self-control group requested feedback on temporal accuracy 47% more often than they requested feedback on spatial accuracy. However, they requested feedback as often on their most accurate trials (261) as their least accurate trials (258). Contrary to Chiviacowsky and Wulf, the probability of their feedback versus no-feedback

requests in the top and bottom thirds of their performance being virtually the same suggests self-controlled learners did not solely request feedback after relatively good attempts. If self-controlled learners request feedback after their most accurate attempts, we would expect to see an influx of no-feedback requests in the bottom third of performance. However, the feedback request pattern in the bottom third of performance matched that in the top third of performance, indicating that the self-control group requested feedback equally after good and poor performances, which is consistent with the findings of Aiken et al (2012). Therefore, the findings of this study further suggest that when learning a multi-dimensional task learners prefer feedback after both good and bad trials.

Further, comparisons of feedback requests between spatial accuracy feedback and timing accuracy feedback during the most and least accurate trials revealed little difference. The self-control group requested spatial accuracy feedback almost as often after their most accurate trials (112) than during their least accurate trials (98) and temporal accuracy feedback just as often after their most accurate trials (149) than their least accurate trials (160). Comparisons of feedback tendencies with respect to AE and RE separately, however, reveal a noticeable difference in feedback behavior. Self-control feedback requests in their top tertile of AE performance compared to their bottom tertile were similar for spatial accuracy feedback requests (48 and 53, respectively) and temporal accuracy feedback requests (74 and 85, respectively). However, the self-control group requested spatial accuracy feedback 42% more often during their top tertile of RE performance (64) than during the bottom tertile (45), while feedback requests for temporal accuracy were the exact same during their top and bottom tertiles of RE performance (75). Such a difference suggests that the self-control group actively requested

spatial accuracy feedback more often when they were the most spatially accurate. These findings suggest that task complexity might in fact alter the feedback request behavior of learners in a self-controlled environment. Again, the main difference between Chiviacowsky and Wulf and Aiken et al. was the complexity of the motor task.

According to Wulf and Shea (2002), complex tasks can be defined as those that involve “different components that have to be coordinated to produce skilled performance” (p. 194). The task used in this study, though simple in nature, presented two competing components of performance requiring a coordinated movement for successful performance. Studies by Wulf and colleagues (Wulf, Shea, & Matschiner, 1998; Wulf, Horger, & Shea, 1999) have suggested that task complexity can change the effects of feedback administration on performance. Specifically, learning complex motor tasks benefited from more frequent feedback than the learning simple motor tasks. Similar to the findings of Wulf and colleagues, the feedback request patterns exhibited by the self-control group in this study (i.e., requesting feedback after both the best and worst performances equally) suggests that learners benefit from a different feedback schedule when learning a complex motor task than when learning a simple motor task (i.e., requesting feedback after primarily good trials, as seen in Chiviacowsky and Wulf). Further, as evidenced by the self-control group's stable spatial accuracy performance throughout the study and their feedback request pattern for spatial accuracy feedback after their best performances, it's possible that learners prefer to receive feedback after primarily good trials once proficiency for a complex motor task has been established.

Recent research supports the notion that once proficiency for a motor task is established, learners prefer and request for feedback for successful confirmation. The results from Laughlin

(2012) investigating how self-controlled learners request feedback as they progress through the stages of learning a complex motor task demonstrated that learners who become increasingly proficient begin to request KR feedback more and descriptive KP feedback less. Further, self-control participants reported that they requested KP feedback after both good and bad attempts to identify and correct mistakes. This suggests that as proficiency is gained, learners utilize information regarding the quality of their performance and prefer confirmatory information about their performances. Therefore, the findings of this study suggest that while exploring the movement space of more complex tasks learners prefer and benefit from feedback after both good and bad trials, but when proficiency is established or when the task is relatively less complex, learners prefer to receive feedback primarily after good trials. However, this conclusion is predicated on the assumption that proficiency in spatial accuracy was already established and had already hit a floor effect, in which performance in the task had reached an asymptote and further improvement was no longer possible. This also suggests that the yoked group would have preferred feedback on both their temporal accuracy and spatial accuracy performance after more accurate trials. However, this was not supported by the findings from the PTQ.

Consistent with the findings of Aiken and colleagues (2012), the self-control group reported to have asked for feedback after both relatively “good” and “poor” performances occasionally. One-dimensional motor tasks, such as sequential key pressing, present the learner with few sources of error and confirming successful attempts may be enough to effectively learn the skill. When learning more complex motor tasks, however, simple confirmation of successful performances may not be sufficient. With such motor tasks, having the opportunity to compare

estimated performance outcomes with actual performance outcomes at a self-controlled schedule, regardless of success, may be preferred. As part of Schmidt's Schema Theory, the refinement of parameterization is dependent on feedback, regardless of outcome (Schmidt, 1975). Accordingly, unsuccessful attempts are just as important as successful attempts while a learner is refining the general motor program for a specific task. Therefore, learners with control over their feedback schedule while learning more complex tasks may be utilizing their feedback requests as such. When performance is already at a relatively high proficiency, though, a preference for feedback after good trials might emerge, as seen with one-dimensional tasks. However, self-reports on feedback preferences from this study don't fully support this conclusion.

Results from the open-ended questions of the PTQ suggest that self-controlled learners might be comparing estimated performance outcomes with actual performance outcomes. All of the participants in the self-control group reported that they engaged in a process of estimating performance on one or both aspects before asking for feedback. Further, many of the open-ended responses centered around the apparent trade-off between being temporally accurate and spatially accurate, and the desire to know how they performed, both on successful and unsuccessful trials. Consistent with feedback request patterns based on performance and PTQ responses on feedback preference, the open-ended questions revealed that learners asked for feedback equally when both their temporal and spatial performances were good and poor. Still, responses to questions addressing the use of strategies varied from participant to participant and were often vague and general, making it difficult to summarize common themes. To date, self-control research has not employed a semi-structured interview addressing learner experiences in

self-controlled and yoked conditions. Therefore, a comprehensive post-training interview with a structured thematization of responses could provide further insight about the specific strategies used and the possible underlying mechanisms behind self-controlled learning.

The findings from the IMI and BPNS revealed little difference between the two groups' feelings of intrinsic motivation, perceived choice, perceived competence, and fulfillment of needs for autonomy and competence while learning the task. The only observed differences were with perceptions of choice and competence. The yoked group reported significantly higher feelings of perceived choice prior to the acquisition phase (4.76) than the self-control group (3.85). At the end of acquisition, however, the yoked group's perception of choice decreased, while that of the self-control group increased. Additionally, the yoked group reported near significantly and significantly greater feelings of perceived competence than the self-control group prior to the acquisition phase (YK = 4.53; SC = 4.00) and at the end of the acquisition phase (YK = 4.45; SC = 4.06), respectively. This difference was not significant prior to the retention and transfer tests. These findings suggest that the yoked group began the study with higher feelings of choice and competence than the self-control group. This difference, however, disappeared by the end of the experiment. It can be assumed, then, that providing learners with control over their feedback schedule does in fact increase perceptions of choice and competence. Therefore, results from the current study suggest that any feelings of perceived choice or perceived competence about participating in a self-control study prior to the experiment are erased when control over feedback schedule is withheld from the learner.

It is also important to note that the statements of the IMI and the BPNS were directed toward feelings about participation in the study not feelings about the learning environment.

Therefore, the observed findings that the two groups reported similar fulfillment of the needs for autonomy and competence can be understood as such. When it came to feelings related to their overall participation in the experiment, learners in both the self-control and yoked group felt their need for autonomy and competence equally met. To better understand how the self-control effect changes feelings of autonomy and competence, future studies should re-structure statements in the BPNS to directly address feelings about self-control manipulation.

Additionally, while the task used in this study provided a useful way to examine how learners prefer and request for feedback when learning a multi-dimensional task, it also provided the yoked group with a choice of what aspect to focus during practice: temporal accuracy or spatial accuracy. This provision of choice could have positively affected perceptions of choice, feelings of autonomy, and performance and learning beyond those experienced by yoked participants in previous studies. Further, while yoked participants in this study received a lot of feedback, the schedule and type of feedback presented was inconsistent. According to Guthrie (1952), proficiency in a motor skill is characterized by the ability to produce a movement with maximum certainty. Without being able to rely on feedback to foster perceptions of certainty, it is possible the yoked group was forced to develop their own sense of certainty on their own, independent of feedback, thus facilitating learning. However, the findings of this study do not provide enough evidence to support this possibility. More in-depth post-training interviews addressing learner perceptions of choice, perceptions of certainty, and possible strategies used to achieve certainty in their movement is warranted.

In conclusion, the present findings provide further evidence suggesting that our previous understanding of how learners use self-control to learn a motor skill is not complete. It seems

that control over feedback schedule is utilized differently when learning a motor task with multiple elements of performance, than when learning a one-dimensional motor task. This conclusion is evidenced by the self-control group's tendency to request feedback equally after their good and bad performances, with a preference for feedback on temporal accuracy. Their self-reported preference for feedback after both good and bad trials also supports this conclusion. Additionally, while the self-control group requested spatial accuracy feedback 42% more often on their best RE trials than on their worst RE trials, the fact that they did not exhibit any other tendencies between top and bottom thirds of performance suggests that their feedback requests might have been random or based on some other criteria other than performance. Further research examining how learners request feedback when learning a multi-dimensional task is warranted. Considering the learning curve exhibited by the self-control group for CE and AE in acquisition and the fact that they didn't seem to get any better at their spatial accuracy, it can be hypothesized that the self-control group utilized control over feedback schedule to improve their temporal accuracy than their spatial accuracy. This, however, indicates a strategy, not for feedback schedule, but for practice schedule in general. Previous research, such as Bund and Weimeyer (2004), has shown the self-control effect with practice schedule. Finally, the findings from this study provide some practical application to real-world settings. In sport skill training, athletes often face an inherent trade-off between speed and accuracy in their movements. Based on the findings of this study, self-controlled learning can be used to facilitate learning even with complex skills that present the learner with conflicting elements of performance. Additionally, the implications of this study are relevant for people working with machinery and/or on assembly lines, where temporal and spatial accuracy are important elements of successful performance.

Thus, sport coaches and factory foremen should feel comfortable giving novice athletes and workers control over their feedback schedule.

Recommendations for Future Research

1. IMI and BPNS scales should be modified to address feelings about learning the task under the specified conditions.
2. A semi-structured post-training interview asking learners to describe their experiences controlling (self-control) and not controlling (yoked) their learning environment would provide further insight into any similarities and differences in the experiences of self-controlled and yoked learners.

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APPENDICES

APPENDIX A

An experiment to examine the performance and learning of a simple motor skill

The purpose of this study is to investigate how participants use information when learning a new motor skill. During the study, you will participate in two separate data collection sessions held on two consecutive days. The first session will last approximately 45 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 asked to learn will require you to use your non-preferred hand to move a stylus-pen on a digitizing tablet from a starting box to a target, without view of the target. You will not be able to rest your arm on the tablet while moving, but can rest in between trials. During the first session, you will complete 60 trials of the task. Throughout the first session, you will complete questionnaires about your experiences during practice. During the second session, you will complete two 6-trial tests to assess your learning. At the end of the second session, you will again be asked to complete a questionnaire about your experiences during the experiment. Will have the opportunity to learn more about the research project at this time.

If you volunteered for this experiment through the Human Participation in Research (HPR) website in exchange for course credit, 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.

If you have questions at any time about the study or the procedures, you may contact Arya Alami 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) 974-3466.

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.

Participant's name (please print): _____

Participant's signature: _____ Date: _____

Investigator's signature: _____ Date: _____

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APPENDIX B

POST-TRAINING QUESTIONNAIRE

1	2	3	4	5
Never	Seldom	Occasionally	Often	Always
SC Group				

1. How often did you ask for feedback about your timing accuracy when you thought you did a good job of achieving the goal time of 600 ms?
2. How often did you ask for feedback about your timing accuracy when you thought you **didn't** do a good job of achieving the goal time of 600 ms?
3. How often did you ask for feedback about your spatial accuracy when you thought you did a good job of hitting the center of the target?
4. How often did you ask for feedback about your spatial accuracy when you thought you **didn't** do a good job of hitting the center of the target?
5. What were your reasons for choosing one feedback type over the other?
 - a. Specifically, tell me why you asked for timing accuracy feedback when you did.
 - b. Specifically, tell me why you asked for spatial accuracy feedback when you did.
6. As you practiced, did you use and/or develop any particular strategies related to your feedback requests? Please tell me about them.
 - a. Did those strategies change as you practiced?
7. When you think about your experience today, what else stands out for you?

POST-TRAINING QUESTIONNAIRE

YK Group

1 Never	2 Seldom	3 Occasionally	4 Often	5 Always
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1. How often did you receive feedback when you needed it?
2. How often did you receive feedback about your timing accuracy when you thought you did a good job of achieving the goal time of 600 ms?
 - a. How often would you have preferred to receive feedback in this situation?
3. How often did you receive feedback about your timing accuracy when you thought you **didn't** do a good job of achieving the goal time of 600 ms?
 - a. How often would you have preferred to receive feedback in this situation?
4. How often did you receive feedback about your spatial accuracy when you thought you did a good job of hitting the center of the target?
 - a. How often would you have preferred to receive feedback in this situation?
5. How often did you receive feedback about your spatial accuracy when you thought you **didn't** do a good job of hitting the center of the target?
 - a. How often would you have preferred to receive feedback in this situation?
6. As you practiced, did you use and/or develop any particular strategies to help you learn? Please tell me about them.
 - a. Did those strategies change as you practiced?
7. When you think about your experience today, what else stands out for you?

APPENDIX C

INTRINSIC MOTIVATION INDEX (IMI)

Using the following scale, please answer each of the following questions as honestly as possible:

1	2	3	4	5	6	7
Not at all true			Somewhat true			Very true

1. This task did not hold my attention at all. ()
2. I did not feel nervous while performing this task. ()
3. I performed this task because I wanted to. ()
4. I think I am pretty good at this task. ()
5. I felt tense while performing this task. ()
6. I think I did pretty well at this task, compared to other people. ()
7. Doing this task was fun. ()
8. I felt relaxed while performing this task. ()
9. I enjoyed performing this task very much. ()
10. I didn't feel like I was doing what I wanted to do while performing this task. ()
11. I am satisfied with my performance at this task. ()
12. I was anxious while performing this task. ()
13. I thought this task was very boring. ()
14. I believe I had some choice while performing this task. ()
15. I feel pretty skilled at this task. ()
16. I would describe this task as very interesting. ()
17. I felt pressure while performing this task. ()
18. This was a task that I couldn't do very well. ()
19. I felt like I had to do this task. ()
20. I thought this task was quite enjoyable. ()
21. I performed this task because I had no choice. ()
22. After performing this task for a while, I feel pretty competent. ()

APPENDIX D

BASIC PSYCHOLOGICAL NEEDS SCALE (BPNS)

Using the following scale, please answer each of the following questions as honestly as possible:

1	2	3	4	5	6	7
Not at all true			Somewhat true			Very true

1. I feel like I can make a lot of inputs to deciding how to perform this task. ()
2. I really like the researcher I interact with. ()
3. I do not feel very competent while performing this task. ()
4. I feel pressured while performing this task. ()
5. The have a feeling I am good at this task. ()
6. I get along with the researcher. ()
7. I pretty much keep to myself while performing this task. ()
8. I am free to express my ideas and opinions while performing this task. ()
9. I consider the researcher to be on my side. ()
10. I have been able to learn interesting new skills while performing this task. ()
11. While performing this task, I have to do what I am told. ()
12. The researcher cares if I do well or not. ()
13. I feel a sense of accomplishment from performing this task. ()
14. My feelings are taken into consideration while I am performing this task. ()
15. While performing this task, I do not get much of a chance to show how capable I am. ()
16. I do not feel comfortable with the researcher. ()
17. I feel like I can pretty much be myself while performing this task. ()
18. The researcher does not seem to want me to do well. ()
19. While performing this task, I do not feel very capable. ()
20. There is not much opportunity for me to decide for myself how to perform this task. ()
21. The researcher is generally pretty friendly towards me. ()
22. I don't think I am any good at this task. ()

APPENDIX E

EDINBURGH HANDEDNESS INVENTORY

Please indicate your preferences in the use of hands in the following activities *by putting a check in the appropriate column*. Where the preference is so strong that you would never try to use the other hand, unless absolutely forced to, *put 2 checks*. If in any case you are really indifferent, *put a check in both columns*. Please try and answer all of the questions, and only leave a blank if you have no experience at all with the object or task.

Which hand do you prefer to use when:

		Left	Right
1	Writing		
2	Drawing		
3	Throwing		
4	Using scissors		
5	Using a toothbrush		
6	Eating with a spoon		
7	Striking a match		
8	Holding a computer mouse		
9	Holding a hammer		
10	Using a broom (upper hand)		

*Adapted from Oldfield, R.C. (1971) The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia* 9(1), 97-113.

APPENDIX F

Table 6. *Responses to Q5 of the PTQ for self-control participants.*

ID	Response
102	I usually (asked for) spatial when I thought I went slower, but I did temporal when I thought I was going a little faster than I had before.
103	I just chose what I did badly on.
104	Whenever I (focused on) time, I wanted to see if my (spatial) was lacking. If I was focusing on (spatial), I wanted to see if my timing was lacking.
105	If I asked for time, I felt like the (spatial) accuracy was close, so I didn't think I did very good on the timing.
106	I think my accuracy was better than my speed, so I would choose my speed over my accuracy.
107	Depending on what I thought I did well. If I thought I hit the target right, then I wanted the feedback about that.
108	Towards the last 30 trials, I felt that I pretty much had the spatial accuracy down. I decided to focus on the time more. I was concerned with figuring out where the target is first, then trying to fix my speed.
109	Depending on what I felt like. If I felt like I missed the circle, then I would ask for speed, spatial, if I was not sure. But, if I was positive I missed, I didn't ask. Then on the timing, if I felt like I went more slowly than before I would ask for it.
110	I felt like I could detect my spatial accuracy, but I had no idea what the time was. That made me ask for timing probably more.
111	In the beginning, I would choose temporal because I wanted to figure out the timing first off, and then I figured, I could later on adjust my spatial. For some reason, I thought that was the most important thing to get down first, and then I wanted to hit that last as well.
112	Well, the dot was always in the same spot, so I felt like after a while I kind of knew what I was aiming for, whereas timing I was just everywhere.

Table 7. Responses to Q5a of the PTQ for self-control participants.

ID	Response
102	I asked for it when I thought it went really fast or when I thought I got around 600 milliseconds.
103	N/A
104	It's because I thought that my (spatial) was pretty nice, but I had a feeling that my timing was lacking. I wanted to confirm that.
105	When I thought my spatial accuracy was good. When I was trying to beat 0.8, but I don't think I ever beat it.
106	Because the previous ones I asked, took a little longer than I expected I guess. I wanted to speed it up.
107	If I thought I made it in time, I wanted to know.
108	I wanted to see how far off I was from 600 milliseconds.
109	Because I thought I was going slower than 600 milliseconds.
110	If I thought I went really fast, I wanted timing. If I knew that I hit the target or hit it close, I wanted timing also, to see where I stood with the accuracy part.
111	I would ask for (temporal) feedback when I felt I was either way off the time, or if I was really close to it. I couldn't physically see my time, but I could see where I was on the (tablet).
112	I liked to guess around how fast or slow I was. I wanted to see how accurate I was just so maybe in the future I could speed up if I needed to, which was usually always what it was actually.

Table 8. *Responses to Q5b of the PTQ for self-control participants.*

ID	Response
102	I asked for it because when I thought I was really slow, or when I thought I got dead on the center.
103	N/A
104	Yeah, it's just the reverse (i.e., timing accuracy was good, but spatial accuracy was bad)
105	Because I thought I (hit the target)
106	Because I thought I was off the mark.
107	If I thought I hit the target right, then I wanted the feedback about that.
108	I wanted to try and get a feel for where the target was. There would be some trials where I felt like, "I got it." Then I look at it, and it's like, "Oh, I didn't get it." Then there were times where I felt that I didn't get it. Then I looked at the spatial, and I did have it. Then, with the (last) 30 trials, I felt like I knew where I was going. That's why I stopped asking about spatial.
109	I would ask for that if I was not sure how I did, if I didn't know if I missed it or hit it.
110	To see how close I was to the target. When I asked for spatial accuracy, I either thought I was really close, or I thought I went really fast. If I went really fast, I wanted to see how close I was to the target.
111	I asked for (spatial) feedback when I thought I was really close to the target. If I felt that I was not close to the target, I wouldn't ask.
112	(On) a couple, it was because I thought I did really bad. Then, usually, it was just because I'd asked for timing so much, I thought I should maybe check out spatial occasionally.

Table 9. *Responses to Q6 & Q6a of the PTQ for self-control participants.*

ID	Response
102	To cut the time I'd try to decrease the distance instead of making a lead, I'd try to get more straight forward, like a line to the center.
103	No
104	I tried holding the pen differently, holding it closer to the tip or holding it closer to the end to see if that would help me any. I went back and forth.
105	I tried to know where the dot was going to be. I'd look there before.
106	I kept my eye on the red dot the whole time as I was drawing. After it went off, my eye just stayed on that part of the page (and) just that I tried to go faster when I saw that my times were not where they should be, over at the six.
107	None
108	I would try to have a feel for where the target was going to be when it came to the spatial. Then with the timing, I would just compare each trial, so if I did it faster, if I did it slower. If I need to slow down or speed up type of thing. At the beginning, I was trying to just visually find a cue of when to start, but I found that it was better for me to just go by hearing.
109	I attempted to alter my path around the barrier, sometimes trying to get closer, sometimes going further around it. If my timing was higher I tried to become closer to the barrier. If I hit the barrier I would try to go further away from the barrier.
110	I started looking at different places. I would watch my hands, and then I would be more accurate. Or I would just look at the target, and then I would be faster. At first, I didn't have a strategy. I was just trying to do it. Then, about 15 or 20 (trials) in, I started to focus. I focused on the target and didn't focus on my hand. When I didn't focus on my hand, I just made a quick movement. When I focused on my hand, it was more of a rounded movement. Towards the end, I was thinking of both speed and accuracy. I knew where the target was because it was 60 times. I knew where it was going. I was just going for speed, and the (spatial) accuracy came along with it
111	(Feedback strategy): For like the first five, I would do temporal. Then I do spatial, and then I guess kind of in the middle, I took a break from getting feedback I think, just to see how I'd do when I came back (from) ditching feedback. Then I'd kind of bounce between the two, just to make sure I was still on point. I feel like it (changed) towards the end. I feel like I was mostly just double checking. When it felt right, or if it didn't feel good, I would check and make sure I was either close with the timing or in the right area. . I didn't really know how to hold (the pen) at first. I went from using it right here, to more in this area, where I would with my right hand. So it steadied the pen more, if that makes sense
112	I tried to just go faster.

Table 10. *Responses to Q7 of the PTQ for self-control participants.*

ID	Response
102	(The task) was actually pretty hard for me to do, especially (because) I never use my left hand to write or anything. I thought I would be able to do it pretty good, and it was not that case.
103	I just think it's interesting. I don't know the practical use, though.
104	Like flashing the light. In my short-term memory, I could still see the light and then move the pen towards to it.
105	I didn't ask for much feedback because I didn't think I did very good.
106	I was surprised at how (well)my left hand did that, because I cannot write left-handed at all. (Also), I kept waiting on the red light to move.
107	(I wanted to know) what this is about. I was trying to figure out what parts of my responses are going to go into it.
108	I'm impressed with my left-handed abilities. I never do anything with this hand, and I guess I didn't think it was teachable. It's like trying to teach myself how to write with my left hand. I just feel like it can not happen.
109	It was definitely interesting to see how I reacted differently after asking for feedback. The feedback definitely helped for what I did the next time.
110	The feedback helped. I was not hardly even focused on the barrier.
111	I found it interesting that in the very beginning, I was real shaky and unsure of my left hand. As I continued to use it, continued throughout the trials, I felt more comfortable and more confident with it. As the trials progressed, I became more competitive with myself. I was trying to achieve my goals, like I wanted to hit, because I was invested in it, I guess.
112	(You wouldn't let) me see spatial and (timing) at the same time. I felt like whenever I was focused on timing, my spatial got crazy. Then when I was thinking about specifically spatial, I was slow. (I asked for feedback on every trial) because I will not be able to get it tomorrow, and it was kind of a fun little game to see if I was correct in guessing how fast I was.

Table 11. *Responses to Q6 & Q6a of the PTQ for yoked participants.*

ID	Response
202	When I felt like I was going slower, I tried to get closer to the barrier. That way, I would cut off time that my hand was not going towards the dot. I tried to get faster every time I saw. I tried to focus on the dot more instead of looking at the whole paper. I didn't start (my strategy) until I was like 25 trials in. Then I'm like, "I should probably try something else." Near the end I was really focusing on the dot, and not looking at where my hand was placed once I had it ready. I was just looking at the dot to try and get it closer.
203	My objective was to go from the starting point to roundabout the rectangle, as close as possible without breaking over the green part of the rectangle, to my ending point to make for the shortest distance possible in the quickest time. Sometimes it went a little too far inward. Sometimes it went a little too long because I was trying to make it quicker, so I'd go outside of my stopping point. For the next trial, I'd try remembering what I messed up on. I tried correcting a little bit of the time to where I could be repetitive with that action.
204	I realized that when you click that light on and off, I could still see for a split second when you click it off, so I just tried to use that spot. Then I started putting the bottom left hand corner too, because it's quicker. I developed them as I went, and just added on to those strategies.
205	At the end, I started staring more at the bottom of the paper. I tried to make a shorter path sometimes, but I kept going too far. I just tried to watch where the light was and keep my eyes there.
206	I felt like the closer I got to the barrier, the faster it was. Not necessarily spatially accurate. I would aim towards getting it close to that to get a better result. As I got feedback for not hitting the target or going too slow, I guess I would change it a little bit
207	Yeah. When you gave me feedback, I recognized it and thought either I need to go faster or move my pen closer to the mark. I think for the timing one, I recognized what that felt like better, as well as with the accuracy. I feel like when I saw the feedback, I was able to say, "OK, this is where I need to go. Right or left, up or down." I felt like I became a little more competent, at least with the timing one, as it went on.
208	Repeat (the movement) and I just tried to memorize. I did something here. I know the point that I got, and then I look at the screen. I figured out if I just got further or right, up or down. I just tried to figure out, how I could get to the right point. I really looked at that spot, the red spot. I just kept looking at here, and then when you said "Ready," and I just kept looking here and then just do the thing that I need to do.

Table 10. *Continued.*

ID	Response
209	Posture and I guess focusing on the area. After getting ready, focusing on the area where I thought the pointer would be, and then not taking my eyes off of it until I had gotten to that point with my hand. Instead of looking at the ready spot and then moving it towards that area, I just focused on the final area. Gradually to the point where, that's just what I did every time. I don't know if it made it better or not obviously, because I couldn't see the time or the...I didn't get feedback every time, so I don't know if it helped or not.
210	I focused on the point where my pen was first, and then as soon as the light was there, I'd switch my eyes really quick, and then just let my hands go where my eyes went. I would just focus on the point, whenever the light blinked out, if I'd look down and just pull my hand down that way. I just memorized the loop, that I wouldn't hit the bar in the middle.
211	None
212	the only thing I did was I realized that I was holding it weird, and I tried to hold it more like a pencil, like I would with my right hand. I felt like that might help being more accurate like my right hand is

Table 12. *Responses to Q7 of the PTQ for yoked participants.*

ID	Response
202	I thought it was going to be way easier than it was. I really did. I'm not sure I would be able to do that well with my right hand, either. I think just the process of doing it repeatedly made me realize that it's more than just which hand you are. It has a lot to do with how much attention you're paying and trying to weigh in am I going to go faster in order to hit it or am I going to try and take my time so I make sure I'm right in that area. Way more thought was put into this than I thought there would be. It was fun
203	I was trying to figure out the study.
204	I felt like the research will be interesting, I want to hear the results of this. As far as the test, I understand what it's for. I watch Sports Center so I understand what it's for. Other than that, I think nothing sticks out.
205	Nothing really.
206	Well, it's difficult using your left hand when you don't use it at all. No, it was a fun thing to do. It was cool to see how good I am using my left hand.
207	I felt like my left hand, it would stay fine, for the time. But then the next trial, I would feel like it was slower. For my right hand, it would just be interesting how accurate it would stay throughout the task and then just how little I use my left hand. It was already starting to get tired just from that because I don't write with my left hand. Overall, I was becoming more consistent.
208	I prefer the feedback when I did well. When I know that's the right thing to do, I can just practice and just keep doing the same thing, so that's good. For bad, if I got the feedback that I did a bad job, I need to know how I can just make that right. I prefer someone still like, "Oh, you're doing right." Then you just keep going. I got about half good, half bad.
209	I don't really like feel back. I'd rather try and figure it out in my head. As far as performing better, I definitely would have benefited had I received more feedback, I think. I don't know. I didn't feel like I needed it quite as much, especially the second time. After we took a little break and did the last 30, I didn't feel like I needed it at all. It was mostly towards the beginning where the feedback would have been more helpful
210	I'd like to see how I compare with my right hand. That would be interesting to see. I think I did learn how to approach it better in the end, kind of developed a strategy for it. At the beginning, I was just doing it
211	Felt more confident in my timing accuracy than my spatial accuracy.
212	I just noticed because there was so many (trials), I think sometimes I would, not stop paying attention, but I would just be like, "Oh, yeah, I'm doing this."

Vita

Arya Alami was born on July 3, 1984 in Oakland, California. Prior to attending the University of Tennessee for his doctorate degree, he earned a Bachelor of Science degree in Biological Sciences with an emphasis in Neurobiology, Physiology, and Behavior from the University of California at Davis and a Master of Science degree in Exercise Science and Health Promotion from the California Polytechnic State University at San Luis Obispo. In December 2013, he received his Doctor of Philosophy degree in Kinesiology and Sport Studies with a specialization in Sport Psychology and Motor Behavior.