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The effect of observation on motor learning in a self-controlled feedback protocol

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I am submitting herewith a dissertation written by Andrew Duvier Bass entitled "The effect of observation on motor learning in a self-controlled feedback protocol." 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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The effect of observation on motor learning in a self-controlled feedback protocol

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ABSTRACT

Research during the past few decades has demonstrated that allowing individuals to control some aspect of the instructional setting can facilitate motor learning. This facilitation has most commonly been referred to as the self-control effect. Self-control studies often include a yoked group. This group is meant to counterbalance the aspect of choice given to the self-control group. However, these groups pose a certain problem to the generalization of self-control—the procedure of yoking would never be utilized as a learning construct a real-world setting. Thus, there is a need to investigate the ecological validity of self-control in a more applied setting. Specifically, investigating the effect of implementing self-control in a setting where observation of other learners is inherently available (e.g. groups, teams). Participants were assigned based on when they volunteered for the study to one of five groups in order to learn a cup-stacking task. Four groups were crossing the two levels of the self-control factor, self-control (SC) and yoked (YK) with the two levels of observation factor, observation (O) and no observation (NO): SC-NO, YK-NO, SC-O, and YK-O. For each level of observation, the yoked participants were paired with self-control counterparts (e.g. SC-NO paired with YK-NO). A fifth group was created by pairing a second yoked group to the SC-NO and providing it with observation (e.g. YK2-O). Acquisition consisted of 30 practice trials. Approximately 24 hours later, participants returned to complete retention and transfer testing. Mean movement time (MT) scores during retention and transfer revealed that the YK-NO group was significantly slower than all other groups ($p < .05$). The results suggested that the application of self-control provisions to facilitate learning may be limited in group settings that afford the opportunity to observe other learners.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

Introduction

A growing body of research has demonstrated that allowing learners to control some aspect of the instructional setting can facilitate motor learning (Chiviacowsky & Wulf, 2002, Chiviacowsky & Wulf, 2007; Janelle, Kim, & Singer, 1995; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Post, Fairbrother, & Barros, 2012). Experiments on self-control effects have typically involved at least two groups. Participants in the self-control (SC) group are given control over an aspect of the instructional setting while participants in the yoked (YK) group are not. For example, a SC group might control when they receive feedback. Participants in the YK group, in contrast, would receive feedback according to a schedule determined by their counterpart in the SC group (hence, the term yoked). Because earlier studies (Janelle et al., 1995, 1997) focused on the effects of self-controlled feedback the yoking procedure was adopted to control for potentially confounding effects related to differences in feedback frequency. Since that time, however, yoking has become a standard procedure in self-control studies regardless of whether or not the control manipulation incorporates the administration of feedback.

The effects of self-control on motor learning have been examined using a variety of different types of instructional support, including knowledge of results (Chiviacowsky & Wulf, 2002; Chiviacowsky, de Medeiros, Kaefer, Wally, & Wulf, 2008; Janelle, Kim, & Singer, 1995;), knowledge of performance (Aiken, Fairbrother, & Post, 2012; Janelle et al., 1997) video demonstration (Wulf, Raupach, & Pfeiffer, 2005), amount of practice (Post, Fairbrother, & Barros, 2011), use of physical assistance devices (Wulf & Toole, 1999; Hartman, 2007), task difficulty (Andreiux, Bhoutin, & Thon, 2016). Some studies have even examined the effects of providing control over incidental features such as choice of color for a golf ball and the type of painting to be displayed during the task (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015). Research on self-control effects has also used a wide range of task demands, including sequential timing (Chiviacowsky & Wulf, 2002, 2005, 2007), a golf ball toss (Janelle et al., 1995, 1997), a basketball set shot (Aiken et al., 2012), dart throwing (Post, Fairbrother, & Barros, 2011), badminton serve (Wriserberg & Pein, 2002), balancing on a stabilometer (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012) and flight simulation (Huet, Jacobs, & Camach, 2009).

Despite the general finding that self-control facilitates motor learning studies have generate results not all studies have generated consistent results. For example, there has been a wide range in the reported frequencies of self-control requests across studies. Some studies have reported frequencies as low as 7% (Janelle, et al., 1995) while others have reported up to 35% (Chiviacowsky & Wulf, 2002) or even as high as 97% (Chen et al., 2002) The frequency of requests may depend on a variety of factors such as task demands, type of instructional support or instructions.

Another set of discrepant findings relate to the experimental phase during which observed self-control effects emerge. Often, the learning effects of self-control have been observed during transfer but not retention (Chiviacowsky & Wulf, 2002, 2005; Patterson, Carter, & Sanli; Fairborhter, Post, & Barros, 2012; Fairbrother, Laughlin, & Nguyen, 2012). Some researchers (Chiviacowsky & Wulf, 2002) argued that transfer tests may be a more sensitive assessment of learning due to the presentation of novel task demands. This argument, however, is not consistent with other studies that have shown self-control effects during retention only (Janelle et al., 1995; 1997; Wulf & Toole, 1999) as well as during both retention and transfer (Patterson & Carter, 2010; Patterson, Carter, & Sanli, 2011; Hemayattalab, Aramameri, Pourazar, Ardakani, & Kashefi, 2013). Additionally, there are even limited cases in which self-control effects have been observed during acquisition (Patterson & Carter, 2010; Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012).

The discrepancies of feedback frequency and emergence of the self-control effect demonstrate that certain idiosyncrasies (e.g. task demands, instruction, instructional format, etc.) within self-control protocols can influence not just individual behavior but also the overall beneficial learning effects. If such is the case it may prove beneficial to begin initial exploration of the practical application of self-control in real word settings where the idiosyncrasies of learning are inevitable. Investigation into the applied nature of self-control may not only illuminate what factors affect self-control, but also whether integrating self-control in certain real-world scenarios is even practical (Kamp, Duivienvoorde, Kok, & van Hilvoorde, 2015).

Exploring how, or why, self-control should be used in real world settings seems a pragmatic endeavor given that, if the effects of self-control are only present in the reductionist setting of the laboratory, and do not emerge in a practical scenario, there may exist little to no ecological validity for this construct. In particular, one criticism that has been leveled at the reductionist way in which self-control has been studies is that of the yoking procedure. The procedure was first implemented as a means of controlling feedback frequency differences between groups within the first self-control studies (Janelle et. al., 1995, 1997). And while the logic of yoking to control feedback frequencies is sound, the logic of yoking in a real-world setting is anything but. Yoking balances feedback schedules but it does not balance for the rationale of feedback provision. That is, a coach or instructor that does not allow self-control over feedback, the equivalent of yoking in the laboratory, still provides feedback based on their own intuitive knowledge of the skill. The same cannot be said for the yoking procedure. Feedback provision in a yoked condition is only provided based on the pre-determined schedule of the self-control condition and not on the actual performance or result of a specific trial. Thus, the findings concerning self-control could be attributed to a yoked detriment rather than a self-control benefit.

However, if this speculation is incorrect, and self-control does indeed facilitate motor learning, there exists the possibility of additive benefits if self-control were implemented in conjunction with another behavioral manipulation. In order to examine either of these speculations it would be necessary to introduce an aspect that may be inherent in real world scenarios to a self-control protocol. Moreover, to introduce an inherent behavioral manipulation that perhaps shares certain theoretical underpinning with self-control. Investigating this type of manipulation could provide further insight into whether the effects of self-control work together, or independent of, this other behavioral manipulation. Fortunately, a manipulation that is both inherent in many applied motor learning scenarios, as well one that has been posited to be driven by the same theoretical underpinnings as self-control, exists: observation.

The two most prominent explanations for the self-control benefit center on motivation and information processing. The motivation explanation posits self-control encourages more active participation in the learning environment that may lead to an increase in motivation (Wulf et. al., 2005). Active involvement due to self-control may also enhance the understanding of the learning process which then increases the perceived value of the learned skill thus increasing intrinsic motivation (Chen et. al., 2002). Researchers have also speculated that, aside from active engagement, the provision of control of an aspect of the learning environment may enhance motivation to engage in the task. Such speculation is driven by the concept of basic psychological need satisfaction found in self-determination theory (Deci & Ryan, 1985). Allowing an individual to control some aspect of the learning environment may enhance their perception of the basic psychological need for autonomy thereby increasing motivation to engage in the learning process (Sanli et. al., 2012). And although the purported explanation of increased motivation has found a foothold in the literature (Chiviacowsky & Wulf, 2002; Lewthwaite & Wulf, 2012), a number of studies exist that either contradict the connection between autonomy and the self-control benefit (Chiviacowsky & Wulf, 2005; Carter, Carlsen, & Ste-Marie, 2014), or provide an alternative explanation for the underlying mechanism.

The earliest studies examining self-control in a motor learning protocol by Janelle et al., (1995; 1997) proposed that the benefit could be related to an increase in information processing. Specifically, the SC participants processed information more efficiently and retained it more effectively than YK participants. Recent research has more closely examined the role of information processing in self-control. Post, Fairbrother, and Barros (2011) allowed for self-control of practice termination during dart throwing. Results revealed that SC participants may have been engaged in deeper task related processing than their YK counterparts prior to each throw. This proposition was demonstrated based on the recall accuracy and average preparation time (APT) of the SC participants. That is, participants in the SC group were more accurate in recalling how many trials they had performed during acquisition than the YK group, and also took longer between each throw (APT) than the YK group. Greater recall could be an indication that the SC participants may have created higher cognitive order structural aspects of the task during acquisition (i.e. enhanced recall) as well engaged in processes that may have benefited overall motor learning (i.e. APT).

In 2011, Aiken, Fairbrother, and Post conducted another study that indicated self-control may engage learners in certain beneficial cognitive processes. Tasking participants with learning a basketball shot, it was revealed that SC participants may have utilized more sources for task-related information than their YK counterparts. While SC participants were given control over video feedback during acquisition, individuals in both groups were allowed to access a written set of instructions describing the proper mechanics of a basketball set shot. Results revealed that SC participants chose to view these instructional cues more frequently during acquisition than YK participants. It is possible to theorize from findings that SC participants demonstrated deeper task engagement by utilizing facilitative information about the task than their YK participants.

The aforementioned studies (Aiken et al., 2011; Post et. al., 2012) describe means in which information processing may have been affected by the experimental protocol, but do not directly manipulate, or disrupt, information processing. However, Carter and Ste. Marie (2017) chose to investigate the theory of information processing in self-control by directly manipulating it. It is widely accepted that the knowledge of results (KR) delay interval, the time between movement completion and administration of feedback, is vital for information processing (Salmoni, Schmidt, & Walter, 1984). Presumably, this is the optimal time in which a learner can digest the intrinsic feedback of the movement as it allows for the learner to engage in error detection and correction mechanisms immediately following motor skill execution, but before external KR is provided (Del Rey, Wughalter, & Carnes, 1987). This interval can be eliminated altogether with the provision of instant KR (Swinnen, Schmidt, Nicholson, & Shapiro, 1990). That is, the cognitive processes associated with error detection and correction mechanisms would be unable to occur if KR were provided immediately following motoric execution, thus mitigating the possibility that the learner can utilize inherent feedback. This can be detrimental to learning as the individual would be unable to make optimal internal adjustments when the external KR was removed.

Moreover, the KR-delay interval can be interrupted as well. If an irrelevant cognitive task were introduced to the learner after motoric execution, but before administration of feedback (i.e. KR-delay interval), the learner would be unable to engage in error detection and correction mechanisms, thus interrupting optimal information processing. In an attempt to explore the theory that self-control engages the learner in deeper information processing, Carter and Ste-Martie (2017) introduced an interpolated event to one pair of SC and YK groups during the KR-delay interval to determine if it influenced the SC effect. One pair of SC and YK groups were required to perform and interpolated cognitive task prior to receiving feedback, while another pair of SC and YK groups were not required to perform the interpolated cognitive task. The results of the paired groups engaged in the interpolated event showed no SC effect. However, a SC effect did emerge in the traditional pairing where no interpolated event was present. The authors claimed that the interpolated activity disrupted information processing, which then eliminated the SC effect. This study provides compelling evidence for the role that information processing may play within self-control.

The role that information processing theoretically plays in self-control in the form of error detection and correction mechanisms could also be attributed to strategy exploration of those afforded self-control (Laughlin et al., 2015). Furthermore, self-regulation, in the form of self-control, is said to engage such motivational factors as goal setting and strategy choice (Zimmerman, 2002; Schunk & Zimmerman, 2009). If such is the case, integrating a measure of strategy exploration may prove insightful in backing these claims. In order to do so, the present study utilized statistical entropy, in particular Sample Entropy (SampEn), in an effort to quantify the movement strategies of the participants. Participants' movement during the task was captured with accelerometers, which was then analyzed using Sample Entropy. Entropy provides a measure of complexity and predictability across points in a time series. Thus, the complexity of each participants' movement can be quantified. If self-control engages greater strategy exploration then it would follow that the self-control groups (SC-NO, SC-O) would exhibit greater entropy than their yoked counterpart groups (YK-NO, YK-O, YK2-O) during acquisition, and perhaps lower entropy during retention and transfer.

Information processing serves as a potentially important point of intersection with a number of other research topics in motor learning. Of particular relevance for the purpose of the present study is the work on observational learning. Observational learning refers to situation in which a person learns by watching and imitating the behavior of others (Feltz, Landers, & Raeder, 1979; Martens, Burwitz, & Zuckerman, 1976). The study of observational learning in the motor domain has examined a range of modalities, including video modeling (Corbett, Blythe, & Abdullah, 2005), peer modeling (Smith, 2003); expert modeling (Boyer, Miltenberger, Batsche, Fogel, & LeBlanc, 2009), and dyad practice (Wulf, Clauss, Shea, & Whitacre, 2001). Observation has been shown to facilitate the learning of a wide range of task demands such as proper technique in kicking a soccer ball (Janelle, Champenoy, Coombes, & Mousseau, 2003), swimming (Weiss, McCullagh, Smith, & Berlant, 1998), dancing (Cross et al., 2009), archery (Kim et al., 2011), and basketball free throw shooting (Horn, Williams, & Scott, 2002).

It is through observation that may allow learners to create a mental blueprint from the model's movement and use it to evaluate their own movements (Bandura, 1986; Carrol & Bandura, 1987). Observational learning is thought to hinge up information processing because it is facilitated by attentional cueing that guide toward relevant aspects of the movement during the early stage of skill acquisition (Janelle, Champenoy, Coombes, & Mousseau, 2003; Woolfolk, 2007). This evidence is consistent with the notion that learning is facilitated when instructional manipulations promote particular mental processes, particularly the ability to anticipate certain motor outcomes based on symbolic representations (Bandura, 1977).

Observational learning is typically used in conjunction with physical practice (McCullagh, Weiss, & Ross, 1989). It is generally accepted that physical practice is the most efficient form of motor skill acquisition (Shea, Wright, Wulf, & Whitacre, 2000), but observational learning has been demonstrated to be significantly more effective than no physical practice at all (McCullagh, Weiss, & Ross, 1989). Moreover, the combination of observation and physical practice has been shown to facilitate learning more so than either factor alone (Cross et al., 2008; Shea, et al., 2000). The additive value may be due to the fact that observation affords certain insights that are not available during physical practice alone (Shea, et al., 2000). For example, observation allows a learner to witness kinematic features and compare them to their own kinesthetic and proprioceptive feedback created by their own movement. This comparison process is through to enhance error detection and correction mechanisms (Blandin & Proteau, 2000).

Research on observational learning has important implications for the potential practical application of self-control research. In many training settings such as those seen in sports, learners often have ample opportunity to observe others performing the same tasks and receiving feedback from instructor. If the beneficial effects of self-control are due to the processes that are overall prompted by observation, there is a need to determine whether or not the opportunity to observe will influence self-control effects. Current research on self-control benefits may lead some to logically conclude that it should recommended to practitioners as an effective way to enhance learning. As with any intervention, however, implementation will likely carry with it costs related to more complex practice logistics. There is, therefore, a need to determine if observation combined with a self-control manipulation produces additive effects, mitigates the benefits of self-control, or has no interaction.

One possibility is that self-control effects and observational learning operate independently of one another and might therefore produce an additive benefit. In contrast, independent processes resulting from observation and self-control might instead operate in parallel, producing no interaction. Another possibility is that observation and self-control invoke the same processes to facilitate learning. In this case, observation provided to a yoked control condition might eliminate the self-control benefit because both groups will engage in the same processes (albeit due to different manipulations). These scenarios are plausible because both phenomena have been attributed to similar processes (Carter & Ste-Marie, 2017; McCullagh, 1986; McCullagh, Ste-Marie, & Law, 2014; McCullagh & Weiss, 2002). For example, some researchers noted that both observation and self-controlled feedback are likely to operate on processes related to error detection and correction (Carter & Ste-Marie, 2017; McCullagh, 1986; McCullagh, Ste-Marie, & Law, 2014; McCullagh & Weiss, 2002).

Statement of the Problem

Because the opportunity for observation is inherent in group learning settings and the effect the effects of observational learning and self-control are thought to stem from similar information processing, there is a need to examine the combined and independent effects of these two manipulations. If the beneficial effects of observation and self-control are additive, incorporating self-control manipulations into group learning settings would be advisable. If observation provides the same advantages as self-control, however, there is little reason to advocate for the adoption of self-control in many practical settings.

Purpose of the Study

The purpose of the current study was to examine the combined and independent effects of observation and self-controlled feedback. This was accomplished by contrasting the performance and learning of two self-controlled feedback groups to their respective yoked control groups under conditions that provided observation and no observation. To test the proposition that observation might mitigate the self-control benefit, the traditional self-control group (without observation) was also compared to another yoked group that received observation.

Hypothesis

Based on the existing body of literature concerning self-control as well as observational learning, the following hypothesis will be tested:

If effect of self-control and observational learning are additive the following results will be expected:

1. The self-control without observation group (SC-NO) will produce significantly faster mean MT than the yoked without observation group (YK-NO) during retention.
2. The self-control without observation group (SC-NO) will produce significantly faster mean MT than the yoked without observation group (YK-NO) during transfer.
3. The self-control with observation group (SC-O) will produce significantly faster mean MT than the yoked only group (YK-O) during retention.
4. The self-control with observation group (SC-O) will produce significantly faster mean MT than the yoked only group (YK-O) during transfer.

5. The self-control without observation group (SC-NO) will produce significantly faster mean MT than the second yoked with observation group (YK2-O) during retention.
6. The self-control without observation (SC-NO) will produce significantly faster mean MT than the second yoked with observation group (YK2-O) during transfer.
7. The self-control without observation group (SC-NO) will produce significantly lower error rates than the yoked without observation group (YK-NO) during retention.
8. The self-control without observation group (SC-NO) will produce significantly lower error rates than the yoked without observation group (YK-NO) during transfer.
9. The self-control with observation group (SC-O) will produce significantly lower error rates than the yoked with observation group (YK-O) during retention.
10. The self-control with observation group (SC-O) will produce significantly lower error rates than the yoked with observation group (YK-O) during transfer.
11. The self-control without observation group (SC-NO) will produce significantly lower error rates than the second yoked with observation group (YK2-O) during retention.
12. The self-control without observation (SC-NO) will produce significantly lower error rates than the second yoked with observation group (YK2-O) during transfer.

13. The observation groups (SC-O, YK-O, and YK2-O) will produce significantly greater Sample Entropy scores than the two groups without observation (SC-NO, YK-NO) during acquisition.
14. The observation groups (SC-O, YK-O, and YK2-O) will produce significantly lower Sample Entropy scores than the two groups without observation (SC-NO, YK-NO) during retention.
15. The observation groups (SC-O, YK-O, and YK2-O) will produce significantly lower Sample Entropy scores than the two groups without observation (SC-NO, YK-NO) during transfer.

Assumptions

1. Participants will have no prior experience with the task.
2. Participants will perform to the fullest extent of their capabilities throughout the duration of the study.

Delimitations

1. Participation will be voluntary.
2. The study will be completed in a laboratory environment.

Limitations

1. Participant interaction with the experimenter, however indirect, may play a role in motivation.
2. Although all participants were deemed novices due to a pre-screening and self-reported acknowledgment, some participants may have been more capable with bimanual coordination tasks than others.

Definition of Terms

Acquisition: The learning of a skill, behavior, or characteristic; referred to experimentally in motor behavior as the performance phase of a study. Acquisition precedes retention and transfer and is usually administered 24 hours prior to the previously mentioned phases (Schmidt & Wrisberg, 2008).

Approximate entropy (ApEn): Entropy analysis for relatively short data series; uses self-matching vectors (Pincus, 1992).

Augmented feedback: Information regarding movement execution supplied by an external source (e.g. coach, instructor, etc.) (Fairbrother, 2010).

Autonomy: An individual's perception regarding their ability to make choices of valuable input within a given situation (Deci & Ryan, 1985).

Average feedback: A form of augmented feedback that provides the statistical average of two or more trials as opposed to feedback on one specific trial (Schmidt & Lee, 2014).

Adams' closed loop theory: Postulates that continuous feedback is necessary in the learning of a motor skill in order to process error detection and correction to meet certain goal demands. Does not allow for the inclusion of ballistic and fast based movement wherein feedback is only available after motor execution (see Schema Theory) (Schmidt & Wrisberg, 2008).

Attention: Taking notice of specific stimuli typically regarding someone or something of interest. Referred to in motor behavior as pertinent information for the learner in order to engage in error detection and correction for the purposes of information processing (Bandura, 1977; Schmidt & Wrisberg, 2008).

Basic psychological needs (BPN): The needs for perceived autonomy, competence, and relatedness as vital components for psychological growth and intrinsic motivation (Deci & Ryan, 2000).

Competence: The need to feel effective in one's ability to undertake a given activity or task (Deci & Ryan, 2000).

Constant error (CE): A measure of performance bias for a given trial or group of trials defined by the difference of an actual score from a predetermined target value (Schmidt & Lee, 2014).

Coping model: Used within the context of peer modeling, a coping model is defined as one who shares similar characteristics to that of the observer but is still attempting to learn or is "coping" with the acquisition of a skill or behavior (Lee, Swinnen, & Serrien, 1994).

Entropy: The amount, and rate of, information produced by a given dynamical system (Richman & Moorman, 2000).

Environmentalism: Philosophy wherein the environment or nurture plays a significant, if not defining, role in the shaping of behavior (Bandura, 1977).

Feedback: Information provided internally or externally regarding performance of skill execution; can be provided before, during, and after the movement (Magill, 2011).

Hereditarianism: Philosophy wherein heredity or nature plays a significant, if not defining, role in shaping behavior (Bandura, 1977).

Imagery: Referred to within the context of sport psychology as a behavior in which an individual creates a polysensory cognitive representation of a specific skill or scenario in order to facilitate learning or performance in future situations (McCullagh, Weiss, & Ross, 1989).

Inherent feedback (aka intrinsic feedback): Information arising internally as a natural result of movement execution (Schmidt & Lee, 2014)

Knowledge of performance (KP): Kinematic feedback regarding the quality of movement execution (e.g. movement form, structure, velocity, etc.) (Magill, 2011).

Knowledge of results (KR): Referred to within motor behavior as extrinsic feedback provided to a learner after a response regarding the outcome or goal of the intended motor movement (Schmidt & Wrisberg, 2008).

Knowledge of results delay (KR-delay): The interval of time calculated from the end of motoric movement to the provision of KR (Salmoni, Schmidt, & Walter, 1984).

Mastery model: Used within the context of peer modeling, a mastery model is defined as one who shares similar characteristics to that of the observer and has a competent grasp of the skill or behavior (Lee, Swinnen, & Serrien, 1994).

Modeling: Practice paradigm in which an individual demonstrates the to be learned movement or skill (Schmidt & Lee, 2014).

Mirror neurons: A cluster of neurons said to fire in the same manner as neurons found within the motor cortex during actual reproduction of a motor skill. These affectionately named neurological clusters are sometimes cited as the underlying mechanism for the benefit of observational learning (Gallese & Goldman, 1998).

Motivation: The underlying mechanism to engage in a certain behavior that is often referred to along a spectrum from amotivation, no desire whatsoever to engage in behavior, to intrinsic motivation, the desire to engage in a behavior without the need to external regulators or reinforcement (Bandura, 1977; Schmidt & Wrisberg, 2008).

Observational learning: Learning that can occur directly or indirectly as a result of imitation or modeling; typically, of another human being (Bandura, 1977).

Peer modeling: Referred to within the context of observational learning as an individual who shares similar characteristics to that of the observer (i.e. age, skill level, gender, etc.) (McCullagh, Weiss, & Ross, 1989).

Relatedness: The need to feel connected to others in a given task or scenario (Deci & Ryan, 2000).

Reproduction: The ability of a learner engaged in observational learning to reproduce the desired action (Bandura, 1977).

Retention: The active process of transforming and restructuring information for memory consolidation; referred to experimentally within motor behavior as the phase following acquisition in order to measure learning. Retention phase traditionally require the individual to perform the same task under the same parameters as those during acquisition (Bandura, 1977; Schmidt & Wrisberg, 2008).

Sample entropy: Entropy analysis for relatively short data series; does not use self-matching vectors (Stergiou, 2016).

Schema theory: Proposed by Richard Schmidt as a way to overcome Adam's closed loop theory of motor control: motor programs, schemas, are cognitive memory structures in the bran that allow for previously unpracticed parameters of a motor program to be executed without prior knowledge. Allows the inclusion of ballistic discrete skills in which feedback is only available after motor execution (Schmidt & Wrisberg, 2008).

Self-control: Allowing an individual control over certain feature(s) of their learning environment. For example, allowing a learner to control when they receive feedback in the form of knowledge of results (Janelle et. al., 1995).

Social learning theory: Posited by Albert Bandura, the theory follows that people learn from one another through observation, imitation, and modeling. Unlike previous theories of behavior, social learning theory does not require characteristics like reinforcement or punishment to be present in order for learning to occur (Bandura, 1977).

Transfer: The gain or loss of an individual's aptitude on one skill as a result of previous experience or exposure to another skill; referred to experimentally in motor behavior as the phase following retention. Unlike retention wherein the individual is tasked with performing the same task under the same parameters as that of acquisition, transfer requires the participant to perform the same task but under different parameters to asses transmission of learning to a novel skill (Schmidt & Wrisberg, 2008).

Yoked: A control group that receives the same treatment or condition in question as their paired self-control counterparts (Janelle, Kim, & Singer, 1995).

CHAPTER 2

Review of Literature

This chapter sets forth a review of research pertaining to the applicability of self-control manipulations, especially as they may operate concurrently with opportunities for observational learning. The theoretical background for both topics will be explored to identify potential similarities or interactions of their respective effects. The chapter concludes by showing how the literature is relevant to the present study.

Self-Control

Early examination of motor skill acquisition assumed that learning could not exist in the absence of knowledge of results (KR) following movement execution (Bartlett ,1948). This widely held belief was reinforced in a review by Bilodeau, Brown, and Merryman (1956), which asserted not only that learning could not occur in the absence of KR but that a 100% frequency of feedback was the optimal schedule to facilitate learning. KR was assumed to function as positive reinforcement that automatically bridged action and response without the need for conscious thought processing. Additionally, withdrawal of KR was associated with behavioral extinction (Boren, 1961). This early school of thought came to be known as the "assumption of equivalence of associability" and held that the general principals of learning were similar across tasks, scenarios, and organisms (Seligman, 1970).

Eventually, scholars came to realize that a 100% frequency of feedback can actually degrade learning compared to conditions that received feedback less frequently. It was thought that the benefits of receiving augmented feedback after every trial would eventually lead to dependency on this source of information (Salmoni, Schmidt, & Walter, 1982). Accordingly, the removal of feedback during subsequent tests of learning revealed degraded performance. Some researchers argued that as learners become dependent on feedback they fail to engage fully in necessary information processing or error detection to facilitate learning (Salmoni, Schmidt, & Walter, 1984, Schmidt, 1991).

Subsequent motor learning studies began to investigate methods in which the benefits of augmented feedback could be preserved without introducing the deleterious effects of feedback dependency. Research focused on exploring the effects of reducing feedback frequency (e.g., Winstein & Schmidt, 1990). The examinations of feedback reduction took many forms. For example, some studies reduced overall frequency (Winstein & Schmidt, 1990) while others faded frequency from 100% at the beginning of practice to a lower percentage at the end (Schmidt, 1991). Still others implemented accuracy bandwidths such that feedback was provided only when performance fell within or outside an established criterion (Lee & Carnahan, 1990). Ultimately, researchers became interested in ways to control feedback administration generally. One such technique – allowing learners to select when they received feedback – emerged in motor learning research in the 1990s.

Initial research on the effects of self-controlled feedback on motor learning was influenced by the literature concerning self-regulation in educational settings (Zimmerman, 1989). In education, self-regulation refers to the use of metacognitive strategies to manage one's own behavior, actions, and thoughts throughout the learning process (Zimmerman, 1989; Zimmerman & Martinez-Ponz, 1990). Self-regulated learners are characterized by active participation in the learning experience. Strengthening self-regulation skills allows learners to adjust strategies based on self-evaluation in reference to goals and achievement. Learners' beliefs in their capability motivates them to engage in different learning strategies (Zimmerman, 1989). Self-regulation emerges from the reciprocal interplay between behaviors and environmental outcomes.

Chen and Singer (1992) argued that self-regulation in the motor and sport domain may generate an optimal cognitive strategy for learning. This concept was subsequently explored by Janelle, Kim, and Singer (1995) in the first motor behavior study to investigate a self-regulated feedback schedule as a means of facilitating learning. Since 1995, the term *self-control* has become the most prominent label for examinations of the type of self-regulation examined in motor learning. Janelle et al asked participants to learn an underhanded golf ball toss using the non-preferred arm. Feedback was provided in the form of knowledge of performance (KP). Sample KP statements included "you threw the ball with (too much or not enough) force that time" and "your arm swing wobbled from right to left (left to right) that time". The self-control group was told that they could request KP following any trial. To counterbalance the potential effects of reduced frequency of feedback, participants in a yoked group received feedback according to the same schedule as a counterpart in the self-control group. Results indicated that the self-control group performed more accurately than the yoked group during retention testing, providing initial evidence for self-control effects on motor learning.

Subsequent research has examined a range of different self-controlled instructional assistance, including KR (Chiviacowsky & Wulf, 2002, 2005, 2007; Wu & Magill, 2011), practice termination (Post, Fairbrother, & Barros, 2011), viewing written instructions and video KP (Aiken et al., 2011), access to a physical assistance device (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012; Wulf & Toole, 1999), task complexity (Andrieux, Danna, & Thon, 2012, Andrieux, Boutin, & Thon, 2016), observation (Wulf, Raupach, & Pfeiffer, 2005), and even incidental choices (Lewthwaite, Chiviacwosky, Drews, & Wulf, 2014). Self-control studies have also incorporated a range of tasks and different populations (Carter & Patterson, 2012; Chiviacowsky, Kaefer, Wally, & Wulf, 2008; Hemayattalab, 2014). In general, research literature has shown that the effects of self-control on motor learning are robust. In addition to demonstrating the generalizability of effects, researchers examining self-control have also been interested in identifying potential mechanisms to explain the phenomenon.

Motivation

Two most prominent explanations for self-control effects relate to the roles of either information processing or enhanced motivation as underlying mechanisms (Janelle et al., 1997). The motivation perspective is based on the concept from Self-Determination Theory that autonomy is a basic psychological need (Deci & Ryan, 2000). Providing learners with choice has been argued to increase perceived autonomy (Chiviacowksy, Wulf, & Lewthwaite, 2012; Deci & Ryan, 2000; Sanli, Patterson, Bray, & Lee, 2013), which in turn increases motivation to engage in learning the task (Ste-Marie, Vertes, Law, & Rymal, 2013; Wulf, Chiviacowsky & Cardozo, 2014).

Information Processing

The other most prominent explanation has more relevance to the current study. The information processing perspective (Janelle et al. 1997) argues that self-control prompts learners to more deeply engage in processing tasks relevant information. Recent research has provided compelling evidence supporting the role of information processing producing self-control effects (Carter, Carlen, & Ste-Marie, 2014; Carter & Ste-Marie, 2017).

Individuals given control over aspects of the learning setting (e.g. feedback) are assumed to be self-regulated and thought to be metacognitively engaged in the task due to (Kanfer & Ackerman, 1989; Zimmerman, 1989). One feature of self-regulation involves processes of error estimation and correction. Choices about feedback administration are presumably based on the learner's subjective evaluation of performance and resulting error estimation (Carter & Ste-Marie, 2014; Chiviacowksy & Wulf, 2005). An initial test of this idea was reported by Chiviacowsky and Wulf (2005) in a study that compared self-controlled feedback in conditions that made the choice either before or after each trial. Although the two groups did not differ during acquisition or retention, the self-after group demonstrated superior learning on the transfer test. The opportunity to delay a feedback request until after movement execution was more effective than choosing feedback prior to execution. This result supported the idea that subjective evaluation processes following execution contribute to self-control choices and their effects. Additionally, the results challenged the motivation perspective because both groups were given the same degree of autonomy. One limitation to the study was the lack of yoked control groups and so there was no evidence demonstrating a typical self-control effect.

Carter et al. (2014) extended the findings of Chiviacowsky and Wulf (2005) and included yoked group). The two original groups, self-before and self-after, were included along with a self-both group. Participants in the self-both group were asked to make a preliminary decision regarding KR before a trial and they were also allowed to change their decision following movement execution. Results indicated that there was no difference between the self-before group and its yoked control group. In contrast, the self-after and self-both groups each outperformed their yoked control groups. Carter et al. (2014) argued that the self-after and self-both groups facilitated learning because they were given the opportunity to choose feedback after each trial. Presumably, both groups engaged in subjective performance evaluation to detect and correct errors. Subjective evaluations related to error detection and correction are thought to occur during the KR-delay interval, which is the period of time after movement execution but before feedback is administered (Shea & Upton, 1976).

Although early scholars discounted the role of the KR-delay interval in motor learning (Bilodeau, Brown, and Merryman, 1956; Koch & Dorfman, 1979), Shea and Upton (1976) demonstrated otherwise by using an interpolated event. The interpolated event filled KR-delay interval and produced interference compared to conditions with an unfilled interval. Consequently, the KR-delay interval has come to be viewed as a critical period to complete information processing supporting learning. Subsequent studies provided additional evidence that interrupting (Chandler, 1991) or eliminating (Swinnen et al., 1990) KR-delay interval degraded learning.

Carter and Ste-Marie (2017) directly examined the role of the KR-delay interval in the production of self-control effects. Participants were randomly selected to one of four groups: self-control empty, self-control interpolated, yoked empty, and yoked interpolated. Individuals in the self-control empty and yoked empty groups represented a traditional self-control comparison. In contrast, the self-control interpolated and yoked interpolated groups were required to guess a two-digit number via trial and error during the KR-delay interval. The typical benefits of self-control were observed only for the comparison of the empty groups. No benefit was found for the self-control interpolated group compared to its yoked interpolated control group. Additionally, neither of the interpolated groups differed from the yoked empty group during retention and transfer. The results of the study suggested that self-control effects are related to information processing during the KR-delay and that an interpolated event presumably disrupts this processing and eliminates the effect. Because both self-control groups were given the same level of autonomy, Carter and Ste-Marie argued that the fundamental advantage of the self-control benefit stems primarily from information processing and not motivation.

Post, Fairbrother, and Barros (2011) examined the effects of self-control over the amount of practice. In addition to showing a self-control benefit to selecting the total number of practice trials, results also provided evidence that supported the information processing perspective. Specifically, the self-control group took longer to prepare for throws and showed enhanced recall for the number of trials completed.

The longer preparation time was taken as an indication of deeper engagement in processing task-relevant details prior to movement execution (Schmidt, 1975). Additionally, the enhanced recall indicated that self-control participants engaged in metacognitive processes that allowed them to keep better track of their status with respect to accumulated practice.

Carter and Ste-Marie (2017b) conducted a study in response to Lewthwaite et al.'s (2015) claim that self-control over an irrelevant feature facilitated learning. Lewthwaite et al. concluded that benefits of control over the color of an arm band were evidence supporting the motivation perspective because the armband had no logical bearing on the performance of the task. Carter and Ste-Marie noted, however, that the study was limited by a failure to include a self-control comparison involving a task-relevant choice. The subsequent study they conducted included conditions with self-control over both task relevant and task irrelevant choices. They also included a no-choice condition. Participants in the task relevant group were given choice over the feedback schedule. Those in the task irrelevant group were allowed to choose the color of an armband worn during acquisition and a game played as a reward following completion of practice. Those in the no choice group followed the direction of the experimenter. Following acquisition, all groups completed an intrinsic motivation inventory (IMI) as a measure of perceived autonomy and competence. During retention and transfer participants were also asked to estimate their errors on each trial.

Results showed that the task relevant group displayed superior learning during retention and transfer compared to the task irrelevant and no-choice groups, which did not differ from one another The task relevant group was also significantly more accurate at estimating errors during transfer compared to the other two groups. There were no significant differences in IMI scores related to perceptions of autonomy or competences. Carter and Ste-Marie claimed the results supported the information processing perspective. It should be noted, however, that the task relevant and task irrelevant groups were afforded slightly different amounts of control. The task relevant group made a choice after every trial whereas the task irrelevant group made a single choice before practice. Nevertheless, no difference was detected between the group given control over the color of the armband and the no choice group.

Observational Learning

Observational learning is considered to be an efficient mode of inducing behavioral change (Bandura, 1977; Blandin, Proteau, & Alain, 1994; Blandin & Proteau, 2002; Carrol & Bandura, 1982; McCullagh, Ross, Weiss, 1989). The topic of observational learning (also known as modeling) has been studied extensively in the social sciences (Bandura, 1977; 1989; Everett, Schnuth, & Tribble, 1998; Huesmann, 1997), traditional psychology (Bandura & Jeffrey, 1973; Van Gog, Pass, Marcus, Ayeres, & Sweller, 2009; Varni. Lovaas, Koegel, & Everett, 1979), and even zoology (Bugnyar & Kotrschal, 2002; Mason, & Reidinger, 1981; Fiorito & Scotto, 1992) as a means of acquiring declarative and procedural knowledge. In the motor domain, observation of a model is thought to serve as an action plan generator for the learner (Calvo-Merino et al., 2005). Through observation, the learner creates an initial mental blueprint of the movement. The blueprint is then refined through subsequent observation and physical practice (Bandura, 1986).

Social Learning Theory

With the exception of a few basic reflexes, humans must learn behavioral patterns through personal experience or observation of the environment. Biological factors such as genetic predispositions and hormones also play a role in shaping behavioral patterns (Bandura, 1986). Observational learning has been regarded as an important mode of behavioral modification (Bandura, 1977).

Prior to the acceptance of observational learning, many scholars believed behavior derived solely from inner forces such as impulses, instincts, and unconscious drives (Bandura, 1971). This belief was eventually replaced by a r focus on external stimuli to modify behavior (Bandura, 1977). By manipulating a stimulus, behavior could be positively reinforced by praise and negatively reinforced by punishment. In the 1970s, Bandura proposed social learning theory, which rejected both extremes of exclusive internal or external drives for a model of interaction between the two (Bandura, 1977). Bandura's famous "Bobo doll" line of research became the theoretical framework for the development of this theory (Bandura, Ross & Ross, 1961, 1963). In the first Bobo doll experiment, Bandura divided pre-school aged children into three groups. The first group observed adults punching, kicking and hitting an inflatable Bobo doll in the head with a mallet. Those in the second group observed adults playing non-aggressively with the doll, and those in the control group had no interaction with the model. Children were then given the opportunity to interact with the doll and other toys. The children exposed to the aggressive behavior acted significantly more aggressively toward the doll than those in the non-aggressive and control groups. Additionally, participants in the aggressive group also imitated the behavior of the adults and appeared less inhibited in their aggression. The act of observing, even in the absence of reinforcement or punishment, was substantial enough to shape behaviors (Heath, Kruttschnitt, & Ward, 1986). The studies that followed provided additional empirical backing that learning can occur "without any reinforcers delivered either to the model or to the observer" (Bandura et al., 1963, p. 11).

The successive studies also demonstrated that humans have the capacity to symbolically represent anticipatory outcomes via the cognitive skill of foresight. Certain behaviors will be strengthened while others will be diminished or eliminated altogether (Dulany & O'Connell, 1963) based on internal cognitive functions that are influenced by the external system within which the person is situated. The relationship between cognitive function and the external setting is reciprocal. Bandura used the term "reciprocal determinism" to describe the continual cycle of observation and action Figure 1 shows the reciprocal causation model, which indicates that learning is most efficient when the leaner observes the environmental setting and acts while the setting also changes in response to the action of the learner.

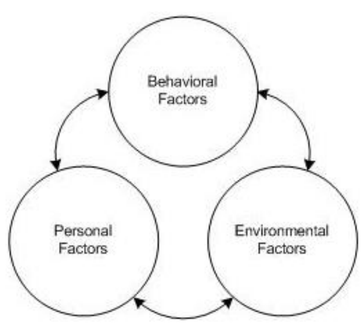

Figure 1. Bandura's (1978) *Reciprocal Causation Model illustrating the interactions among personal, behavioral, and environmental factors.*

To achieve optimal learning, Bandura recognized four necessary processes related to attention, retention, motor reproduction, and motivation (Bandura & Jeffrey, 1973). Figure 2 illustrates the sequence of the four processes. Attention is the process by which the features of stimuli are registered, symbolically coded, and organized into different memory structures (Treisman & Gelade, 1980). Observation of a model by the learner is transformed into a cognitive representation which then serves as a template for which learners can base their own movement execution and motor adjustments (McCullagh, Weiss, & Ross, 1989). Attention to the model's behavior is a precondition to the creation of the cognitive representation. Given that attention is finite (Cowan, Nugent, Elliot, Ponomarev, & Saults, 1999) and the observer may not be able to attend to every aspect of the modeled behavior, the learner must attend to relevant cues in order to form the most accurate representation. During the early stages of learning, in particular, it may be critical to guide the learner in directing attention to the most relevant aspects of the observed behavior. For example, in acquiring a relatively complex skill such as swinging a baseball bat, an early learner may benefit from directing attention to the basic movement of the arms first. Once proficient degree of proficiency is attained, attention can be directed to other aspects of the swing and to lower body movements.

Attentional cueing can be enhanced if the observer understands exactly what is shown by the model (Woolfolk, 2007). For example, it might be beneficial in learning the baseball swing to know that the model's hands will move in a specific pattern. Thus, the learner is alerted to anticipating the movement of the body part.

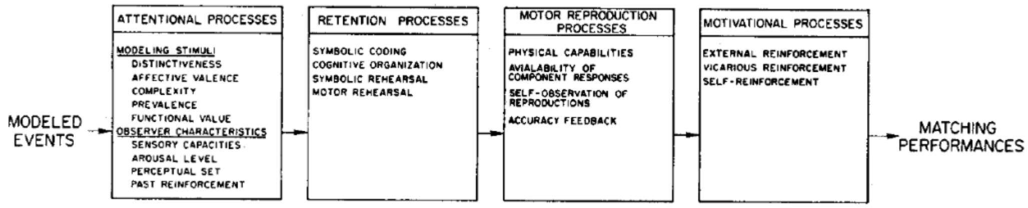

Figure 2. *Four processes of observational learning (Bandura & Jeffrey, 1973).*

The retention process of is vital in translating attention to behavior. Observed events must be remembered so that the desired behavior can be replicated once the model has been removed (Bandura, 1989). Cognitive representations based on observation are thought to be stored in long term memory as a one of two types of representational systems – imaginal (visual) and verbal – which emerge from continual reproduction of observed behavior into specific symbolic codes or "chunks" (Bandura, 1977; 1989). Chunks can be mentally rehearsed to strengthen the cognitive representation, which in turn serves to facilitate the desired motor response. The mediation between cognitive representation and motor response establishes a baseline upon which feedback can be interpreted to assist in error detection and correction when access to the model is removed (Bandura, 1977; Carrol & Bandura, 1990). One beneficial method for aiding retention during observational learning is to encourage engagement in a variety of learning strategies, including continuous visual or verbal rehearsal of the modeled behavior, use of mnemonic devises to create an organizational structure for the information, and elaboration by connecting information to previously learned knowledge (Mastropien & Scruggs, 1998).

The third process, motor reproduction, is the act of executing the observed behavior. It is thought that this process is required to finalize behavior change (Ormrod, 2004). It is possible, however, to learn without motor reproduction because the appropriate cognitive representation may have been successfully encoded. This learning might be seen in cases of physical impairment or lack of opportunity to engage in the activity (Blandin, Lhuisset, & Proteau, 1999). The fourth process is motivation, which specifies that a behavior is more likely to be imitated on a recurring basis if it is positively reinforced. In contrast, a learner might complete the first three processes but never establish routine engagement because of adverse consequences or punishment (Bandura, 1977). This perspective on reinforcement differs from earlier conceptualizations because it is not actually a prerequisite for learning. Instead, it acts as a facilitator or supplement to improve performance (Bandura, Grusec, & Menlove, 1966).

Like any theoretical model, social learning theory is not without its limitations. One limitation that is that learning cannot be directly observed. Measurements can show changes thought to be associated with learning, but they cannot reveal the underlying cognitive processes. The second limitation is that social learning theory does not account for how learners change over time. Observational learning and social learning theory have been viewed as part of a traditional model of information processing, which does not address potential changes in cognitive processing as a function of age. There has been little research examining the differences in how children and adults engage in observational learning and how such activity influences behaviors (Vinter, & Perruchet, 2001). The third limitation is related to social learning theory's overly-broad interpretation of learning. Social learning theory seeks to describe all learning in the context of the reciprocal triad of behavior, human interaction, and observation. Although social learning theory, and by extension observational learning, theoretically connects aspects of human behavior and learning such as self-efficacy, motivation, and cognition, it is nearly impossible to show a direct connection between these aspects as speculated by the theory (Muro & Jeffrey, 2008).

Application

Researchers in motor behavior generally agree that the most effective means for skill acquisition is physical practice (Blandin, Lhuisset, & Proteau, 1999; Shea, Wright, Wulf, & Whitacre, 2000). However, there are certain scenarios in which immediate engagement in physical practice could be ill advised or cause physical harm (Blandin, Lhuisset, & Proteau, 1999). An example is a gymnast attempting to learn a back-hand spring. To force a novice learner to immediately attempt a back-hand spring would be problematic. Thus, it is often desirable for the athlete to first develop an initial understanding or cognitive representation of the skill through observation of modeled performance (Carrol & Bandura, 1982; Cordovani & Cordovani, 2016; Pollock & Lee, 1992; Southard & Higgins, 1987).

One purported underlying mechanism for the benefit of observation closely aligns with that of physical practice itself. In fact, when observation is used in conjunction with physical practice it can be more effective than physical practice alone (Shea, Wulf, Whitacre, & Wright, 2000). Bandura theorized that observational learning may aid in strengthening error detection and correction capabilities (Carroll & Bandura, 1990). Studies using neuroimaging of brain activity related to physical practice and observational learning indicate that both activate similar structures (Gallese & Goldman, 1998). Other scholars argue that observational learning aimply affords the learner the unique opportunity to gather information that would normally be unavailable during motor production (Shea, Wulf, & Whitacre, 1999).

Regardless of the mechanism, observational learning has been found to produce learning and performance benefits within the motor domain (Blandin, Proteau, & Alain, 1994; Cordovani & Cordovani, 2016; McCullagh, Weiss, & Ross, 1989; Pollock & Lee, 1992). Observational learning has been found to facilitate motor learning compared to no physical practice at all (Shea, Wright, Wulf, & Whitacre, 2000). Additionally, the combination of observational learning with physical practice produced an additive benefit compared to physical practice alone. A lack of differences in transfer between participants who only observed during acquisition and those who physically practiced further suggested that some types of skill transfer can be accomplished in the absence of physical practice. Several researchers have argued that observational learning and physical practice employ similar cognitive mechanisms (Blandin, Lhuisset, & Proteau, 1999; McCullagh, Weiss, & Ross, 1989; Shea, Wright, Wulf, & Whitacre, 2000).

A study by Cross et al. (2009) revealed that observational learning and physical practice may indeed share similar neural substrates. Participants learned a dance routine by physically practicing the and watching t a video model. Functional magnetic resonance imaging (fMRI) was used to measure the degree of cognitive activation between observation and physical practice. The fMRI displayed similar neural engagement for observation and physical practice suggesting that the mental processes of both share certain characteristics (Cross, et al., 2009). Blandin and Proteau (2000) studied the effects that these types of practice have on error detection and correction. The conclusion of their experiment implies that the mechanism of error detection and correction are similar. Additionally, observing knowledge of results for the model can influence the observer in their own practice. In one condition the model and the observer received biased knowledge of results regarding the performance of the model. Both groups' error detection and correction skills were skewed, providing support for the notion that the two forms of practice share common cognitive processes.

Shea et al. (1999) argued that observational learning may also afford the learner certain informational benefits that cannot be processed during physical practice. The cognitive representation of a visual model affords the observer the opportunity to extract certain information regarding specifics of the movement that would be difficult, if not impossible, during actual physical execution (Wulf, Shea, & Lewthwaite, 2010). Accordingly, engaging in observational learning may provide the individual with an opportunity for motor skill enhancement not available during traditional physical practice. One potential way to take advantage of the benefits of both observation and physical practice is to implement a dyad practice approach. For example, one baseball pitcher could complete several pitches while another pitcher observes. After a set number of pitches, the two athletes can switch roles. Studies have shown that dyad practice facilitates retention and transfer to the same extent as physical practice alone. This is notable because the dyad approach reduces by half the total number of practice attempts during a given time period (compared to physical practice alone) (Shea et al., 2000; Shebilske et al., 1992).

Summary

Literature regarding self-control (Aiken, Fairbrother, & Post, 2012; Chiviacowsky & Wulf, 2002, 2005; Chiviacowsky & Thofehrn, 2017; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997;) and observational learning (Andreiux & Porter, 2016; Bandura, 1977; Blandin, Lhuisset, & Proteau, 1999; McCullagh, Weiss, & Ross, 1989; Pollock & Lee, 1992; Wulf, Shea, & Lewthwaite, 2010) in the motor domain surmise that both constructs pose a significant benefit to motor learning. The logical question for practitioners is how each can be applied in an effective and efficient manner. Researchers have speculated that both phenomena are related to similar mechanisms (e.g. motivation or information processing). Presumably, the effects of each manipulation may interact when used simultaneously. Although it is often recommended that instructors should explore ways to provide autonomy to learners, group settings may introduce complications. There is a need to determine if, for example, observation will mitigate or enhance the benefits of self-control. Presumably, this is possible since they are both thought to operate through similar mechanisms.

CHAPTER 3

Method

Participants

Participants consisted of 60 volunteers (41 women, 19 men) (M = 21.28, SD = 4.02), 55 of whom indicated they were right-handed. Participants were at least 18 years of age and provided voluntary informed consent using a form approved by the University of Tennessee Institutional Review Board. All were naïve to the purpose of the study.

Apparatus and Task

Participants learned a novel cup stacking task adapted from the 3 × 6 × 3 task used in previous research (Granados & Wulf, 2007; Hetzner, 2004). Participants built a 10-cup pyramid using commercially available stacking cups (Speed Stacks, Inc., Castle Rock, CO). Figure 3 shows the beginning and ending cup configurations. The stacking task was completed using a Gen3STACKMAT™, a StackMat Pro Timer Gen3, and a SpeedStacks Tournament Display Pro (NASCO, Fort Atkinson, WI), which allow for the measurement of elapsed time for a speed stacking attempt.

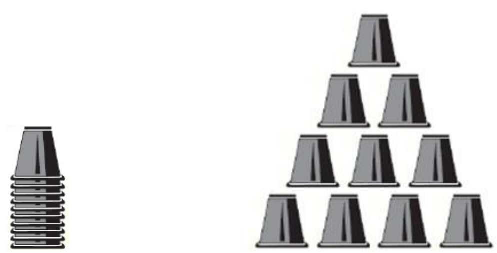

Figure 3. *Beginning (left) and ending (right) cup configurations for the task used during acquisition and retention (Images provided by www.speedstacks.com).*

Procedure

Upon arriving at the laboratory, participants were greeted and then completed a screening pretest. Participants were completed a single trial of the task as quickly as possible. If movement time (MT) of the pretest trial was less than 10 s, the participant was excused from the study. The 10 s criterion was based upon previous research (Granados & Wulf, 2007), the definition of a ‘novice’ from the SpeedStacks organization (WSSA Sport Stacking Rule Book, 2017), and pilot testing. If MT was 10 s or longer, the participant was asked to provide informed consent indicating voluntary participation. Participants were not informed about the reason of the pretest.

Participants were quasi-randomly assigned to one of five groups. Individuals were first assigned to the self-control groups as creating their feedback schedules must be done before yoked participants can be collected. Once several self-control participants from both groups were collected participants were then randomly assigned to one of the three yoked groups. The self-control group without observation (SC-NO) was filled first, followed by the yoked group without observation (YK-NO), the self-control group with observation (SC-O), the yoked group with observation (YK-O), and finally the second yoked group with observation (YK2-O). The SC-NO group was representative of a traditional SC group used in previous research. Participants were given the opportunity to request feedback following any trial and completed the protocol without the opportunity to observe others. Feedback was provided in the form of knowledge of results (KR) regarding MT. The YK-NO was representative of a traditional YK group. In the YK-NO group, participants received KR according to the schedule created by the requests of their SC-NO counterpart. They also completed the protocol without the opportunity to observe others. The SC-O and YK-O groups were similar to the SC-NO and YK-NO groups except they observed a video recorded model practicing the task. The YK2-O was created to allow for a test of the possibility that providing observation to a traditional yoked group would eliminate differences compared to a traditional SC group that did not engage in observation (SC-NO).

The observation groups (SC-O, YK-O, YK2-O) observed a video-recorded model practicing the task before each trial. All participants in the observation groups viewed a model based on their gender (Horn & Williams, 2004). The models were unfamiliar with the task (McCullagh, Weiss, & Ross, 1989; McCullagh & Weiss, 2014; Schunk, 1998). Models were provided KR following every trial which was visible to participants in each observation group when they viewed the video-recordings. The video recorder was positioned at a height of 1 m and placed approximately 1 m in front of the model (along the model's sagittal plane) so as to provide a clear view of the stacking movements but not the model's head. This controlled for the possible influence of model facial characteristics on observational learning (McCullagh, Weiss, & Ross, 1989). The model's KR was provided to participants because previous research has demonstrated that having such access supports observational learning (Hebert & Landin, 1994; Lee & White, 1990). Data for the models were not included in analyses.

Each participant was fitted with an inertial measurement unit (IMU, Opal sensor, APDM, Portland, OR) on the left and right wrists, which recorded three-dimensional (3-D) acceleration for every trial (see Figure 4). Raw acceleration data from the IMUs were sent wirelessly via an access point (APDM, Portland, OR) to a PC-compatible computer running APDM software. The data was subsequently exported as an HDF 5 file to be processed using a custom program written in Matlab (The Mathworks, Inc, Natick, MA).

Figure 4. *Positioning of the inertial movement unit (IMU) on the wrist.*

At the beginning of each trial, a single column of 10 cups was placed directly in front of the participant (see left panel of Figure 3). The participant was instructed to move all 10 cups to create a single pyramid configuration as quickly as possible (see right panel of Figure 3). They were also informed that they would return the following day to be tested on this skill. At the beginning of each trial, the participant placed both hands on a mat with a pressure-activated switch (Gen3 StackMat, NASCO, Fort Atkinson, WI). MT began when the participant lifted both hands off the mat and ended when both hands were returned to the mat after completing the pyramid. An error was defined as one or more cups falling from the stack. The experimenter manually tallied errors for each trial. If the participant committed an error, the trial was repeated.

The study consisted of acquisition, retention, and transfer phases. Acquisition consisted of five blocks of six trials each (30 trials total). The retention phase was administered approximately 24 hours after acquisition. Retention consisted of six trials of the same task used during acquisition. The transfer phase was administered 10 min after retention and required participants to build two six-cup pyramids as depicted in the right panel of Figure 5. Neither KR nor observation were provided during retention and transfer.

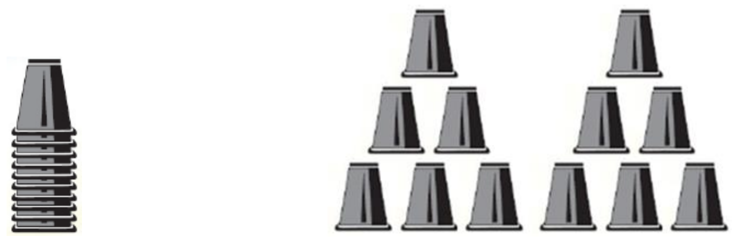

Figure 5. *Beginning (left) and ending (right) configurations for the transfer task. (Images provided by www.speedstacks.com).*

Data treatment and analysis

The dependent variables were MT, total number of errors, and raw 3-D acceleration, which were collected for every trial during each phase of the experiment. The trials for which KR was requested were also recorded for the SC-NO and SC-O groups. MT was considered the primary dependent variable.

For acquisition, MT data were averaged across six trials to create five blocks and then analyzed using a 5 (group) × 5 (block) analysis of variance (ANOVA) with repeated measures on the last factor. MT data were also averaged across KR- and no-KR trials and analyzed using a 2 (group) × 2 (trial type: KR vs. no-KR) ANOVA with repeated measures on the last factor. For retention and transfer, MT data were averaged into a single block for each test and analyzed using separate univariate ANOVA's comparing the five groups. Error rate during acquisition was analyzed using a 5 (group) × 5 (block) analysis of variance with repeated measures on the last factor. Error rate during retention and transfer was analyzed using separate one-way univariate ANOVAs. The rate was calculated for each block by the sum of the errors within the block and dividing by six which is the number of completed trials within any block. An error was defined as any time a cup, or the entire stack, would tip or fall over. If an error was repeated and continued until a stable stack was created. This particular method for defining errors was used both due to the definition of an error within competitive sport stacking (WSSA Sport Stacking Rule Book, 2017) as well as the criterion for the task: to create a stable stack. If a stable stack was not created the task could not be said to have been completed. Movement times following trials in which KR was or was not requested between both self-control groups (SC-NO, SC-O) were analyzed using a 5 (block) by 2 (trial type: KR vs. no KR) ANOVA with repeated measures on the last factor.

Raw 3-D acceleration data were used to calculate a single resultant acceleration value for each sampling event during a trial. Acceleration for the dominant hand was collected at 128 Hz and filtered using a second-order low-pass Butterworth filter to remove noise. The Butterworth filter was chosen as it has shown to have a smooth frequency response and been used in conjunction with the calculation of Sample Entropy in previous studies (Kokonozi, Michail, Chouvarda, & Maglaveras, 2008; Valencia, Porta, Vallverdu, Baranowski, Orlowska-Baranowska, & Caminal, 2009). Resultant acceleration values were then calculated and extracted from each trial for time period that coincided with MT for the trial. The beginning of a movement for a trial was identified by the initial spike in resultant acceleration and the end was the point that corresponded to the elapsed time represented by MT for that trial. Figure 6 shows an example of this bracketing technique, with the green and red dots representing the onset and offset of MT for the trial.

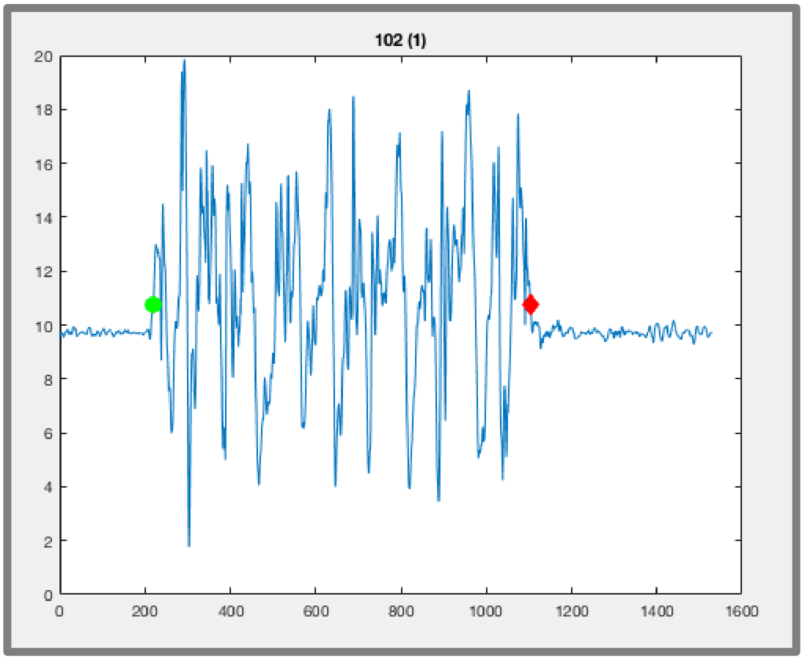

Figure 6. *Example of APDM resultant acceleration data with MT onset (green) and offset (red).*

For each trial, resultant acceleration values were used to calculate Sample Entropy (SampEn) as an index of the complexity of the time series (Sokunbi, 2013; Yentes et al., 2013; Sokunbi, 2014). In the current study, SampEn was used as a novel approach to examine changes in kinematic data over time. Calculated SampEn scores fall between 0 and 1 with lower values indicating a more predictable series and higher values indicating a less predictable series (Richman & Moorman, 2000; Yentes et al., 2013).

SampEn calculations require three specific input parameters – *m* (epoch length), r (tolerance criterion), and N (number of data points; Yentes et al., 2013). The parameter *m* is set to a predetermined value to designate the points of prediction (Pincus, 1995). That is, if *m* is set at 2 then SampEn would calculate predictability between time points 1 and 3, 4 and 6, 7 and 9, and so on. The parameter *r* is also set to a predetermined value to establish a tolerance level for the standard deviation of the raw signal (Pincus, 1995). Specifically, *r* is responsible for damping noise within the series due to variation in the values. The parameter *N* is simply the number of points in the series and varies based on the duration of the movement.

The specification of *m* and *r* both require modeling using the data to be examined (Chen, Solomon, & Chon, 2006; Yentes et al., 2013). The values are identified by comparing SampEn for one trial from one participant using a range of different values for each parameter (Yentes et al., 2013). Since there is no set combination of parameters that will work consistently across studies, much of the research into SampEn parameterization suggests the values of *m* and *r* should be set to result in the smallest degree of abrupt change from combinations using similar values (Stergiou et al., 2006; Yentes et al., 2013). That is, ideal values of *m* and *r* are those that result in the smallest changes in the entropy score when compared to adjacent scores (i.e., when an asymptote is reached). The results of modeling in the current study indicated that the values of 2 and 0.2 were appropriate for *m* and *r*, respectively. Comparisons were completed for multiple randomly selected participants using multiple trials sampled from the beginning to the end of acquisition. The parameter values were consistent with those identified as reasonable by previous research (Chen, Solomon, & Chon, 2006; Pincus, 1995; Richard & Moorman, 2000; Yentes et al., 2013).

For acquisition, SampEn was averaged across six trials to create five blocks and then analyzed using a 5 (group) × 5 (block) analysis of variance (ANOVA) with repeated measures on the last factor. For retention and transfer SampEn for resultant acceleration was averaged into a single block for each test and analyzed using separate univariate ANOVA's comparing the five groups.

The alpha level was set to 0.05 for all analyses. Bonferroni *post hoc* procedures were used following significant results of the ANOVAs. Any violations of sphericity in the repeated measures analyses were addressed using the Greenhouse-Geisser *df* correction.

CHAPTER 4

Results

The feedback request frequency for the two self-control groups were similar. The SC-NO group requested KR after approximately 26% of trials while the SC-O group requested KR after approximately 20%. Both of these frequencies were consistent with previous reports of feedback request frequencies (Chiviacowsky & Wulf, 2002; Wulf, Shea, & Lewthwaite, 2009).

Movement Time

The left panel of Figure 7 shows mean MT scores for the SC-NO, YK-NO, SC-O, YK-O, and YK2-O groups during acquisition. Table 1 displays the mean and standard deviation of MT across all blocks during acquisition, retention, and transfer. All of the groups performed similarly and showed marked reductions in MT from Block 1 to Block 5. These observations were supported by a significant main effect for block, F (4, 220) = 157.09 $p < .001$, $\eta^2 = .74$ *Post hoc* procedures revealed that each block produced a significantly faster MT score than the previous blocks for Blocks 1-4 ($p < .006$ for all comparisons). Blocks 4 and 5 were not significantly different from one another ($p = .063$). The main effect for group, F (4, 55) = 2.38; $p = .063$, was not significant. Neither was the Group × Block interaction, F (16, 220) = .64, $p = .790$.

The right panel of Figure 6 shows mean MT scores during retention and transfer. During both tests the YK-NO group displayed elevated mean MT relative to the other four groups, which performed similarly. These observations were supported by a significant main effect for group during both retention, F (4, 55) = 5.11; $p = .001$, $\eta^2 = .27$ and transfer, F (4, 55) = 6.15; p < .001 $\eta^2 = .31$. *Post hoc* comparisons following the significant effect for retention revealed that the YK-NO group produced a significantly larger mean MT score than all of the other groups ($p < .044$ for all comparisons). There were no significant differences between the SC-NO, SC-O, YK-O, and YK2-O groups. *Post hoc* comparisons following the significant effect for transfer also revealed that the YK-NO group produced a significantly larger mean MT score than the other groups ($p < .025$ for all comparisons). There were no significant differences between the SC-NO, SC-O, YK-O, and YK2-O groups.

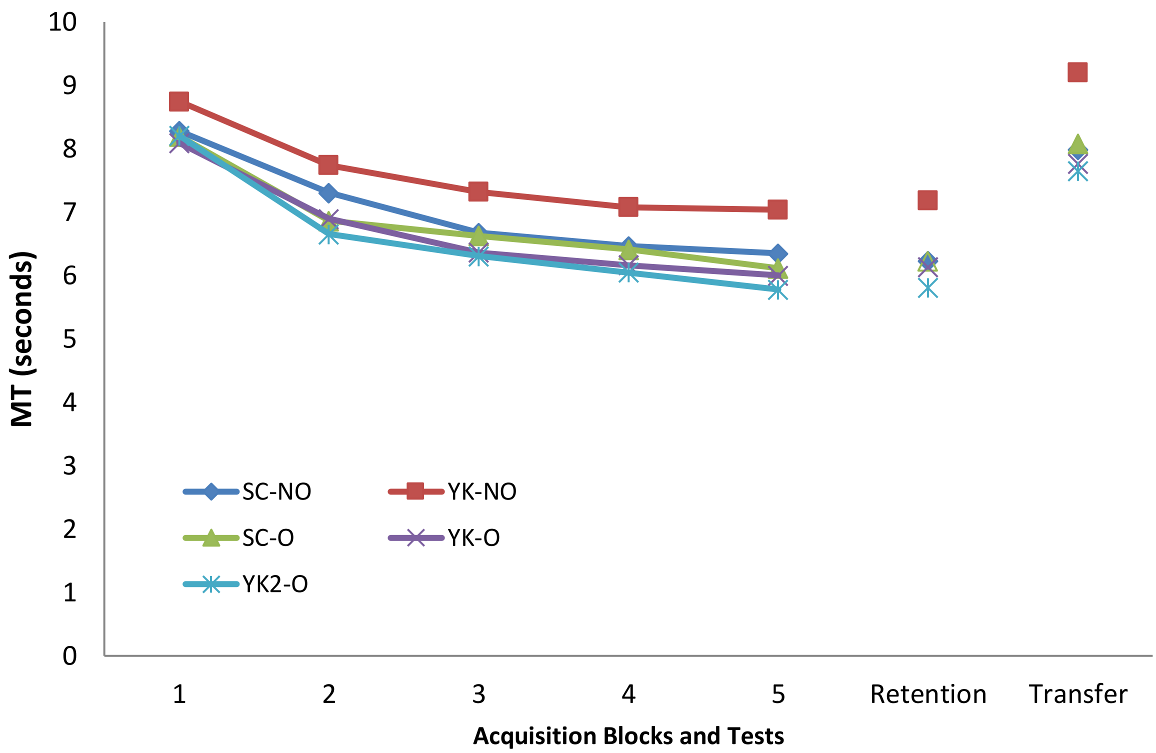

Figure 7. *Mean MT scores for all groups during acquisition, retention, and transfer.*

Table 1. *Mean and standard deviation for MT across all blocks during acquisition, retention, and transfer*

	M	***SD***
BL1	8.31	.89
BL2	7.09	1.10
BL3	6.66	.96
BL4	6.43	.88
BL5	6.26	1.02
Retention	6.32	.89
Transfer	8.14	1.00

KR versus No-KR trials. Figure 8 shows mean MT scores for KR and no-KR trials during acquisition. Table 2 shows the means and standard deviations for all groups on KR trials, while table 3 contains the means and standard deviations for all groups on No-KR trials. The comparison of MT on KR and no-KR trials for SC-NO and SC-O groups included 22 participants because one participant in each group did not request KR. Both groups produced similar mean MT scores on KR and no-KR trials during each half of acquisition. These observations were supported by the lack of significant main effects for group, F (4, 50) = 1.47, p = .226, and for acquisition half, F (1, 50) = .002, p = .965. The Trial Type × Acquisition Half interaction, F (4, 50) = .91; p = .464, was also not significant.

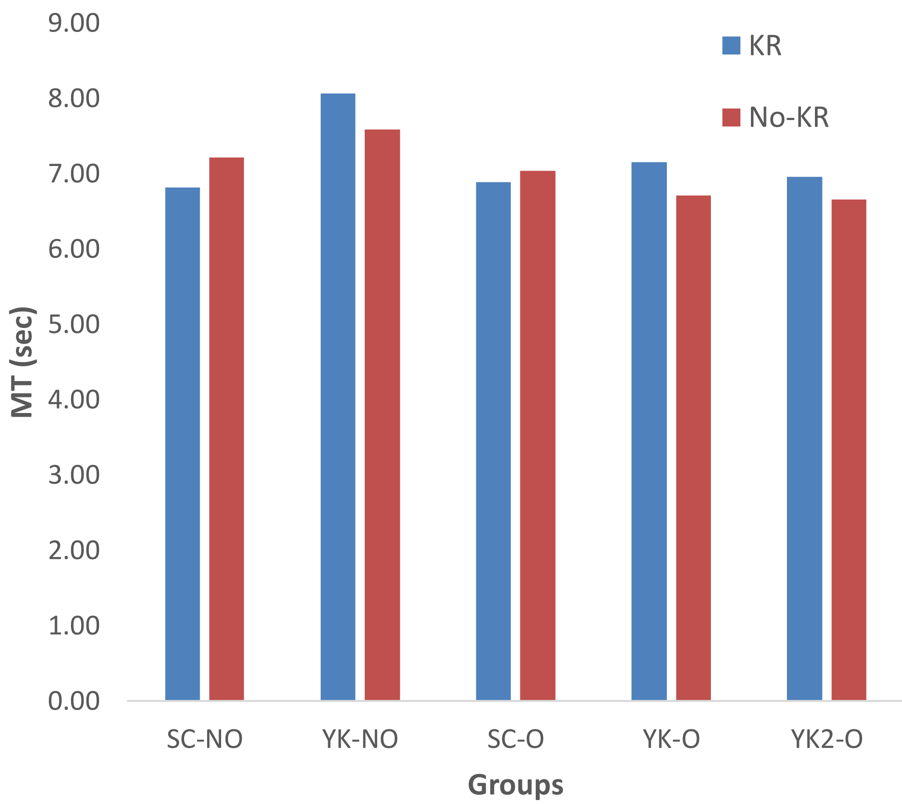

Figure 8. *Mean MT scores on KR and no-KR trials for the five experimental groups.*

Table 2. *Mean and standard deviation across all groups for KR trials during acquisition*

	M	***SD***
SC-NO	6.56	1.33
YK-NO	7.83	2.23
SC-O	6.88	1.37
YK-O	6.69	1.59
YK2-O	6.69	1.59

Table 3. *Mean and standard deviation across all groups for No- KR trials during acquisition*

	M	***SD***
SC-NO	7.72	.915
YK-NO	7.59	1.35
SC-O	7.02	.799
YK-O	6.71	.718
YK2-O	6.66	1.02

Error Rate

The left panel of Figure 9 shows the mean error rate for the SC-NO, YK-NO, SC-O, YK-O, and YK2-O groups during acquisition. Table 4 displays the mean and standard deviation for error rate across all groups. No significant difference was found across blocks during acquisition F (4, 220) = .89; p = .473, η^2 = .016, nor was there a significant difference in the Group × Block interaction F (16, 220) = .91; p = .550.

The right panel of Figure 8 shows the error rate during retention and transfer. There was no significant main effect for group F (4, 55) = 1.68; p = .169 during retention, nor was there a significant main effect for group F (4, 55) = 2.08; p = .095 during transfer.

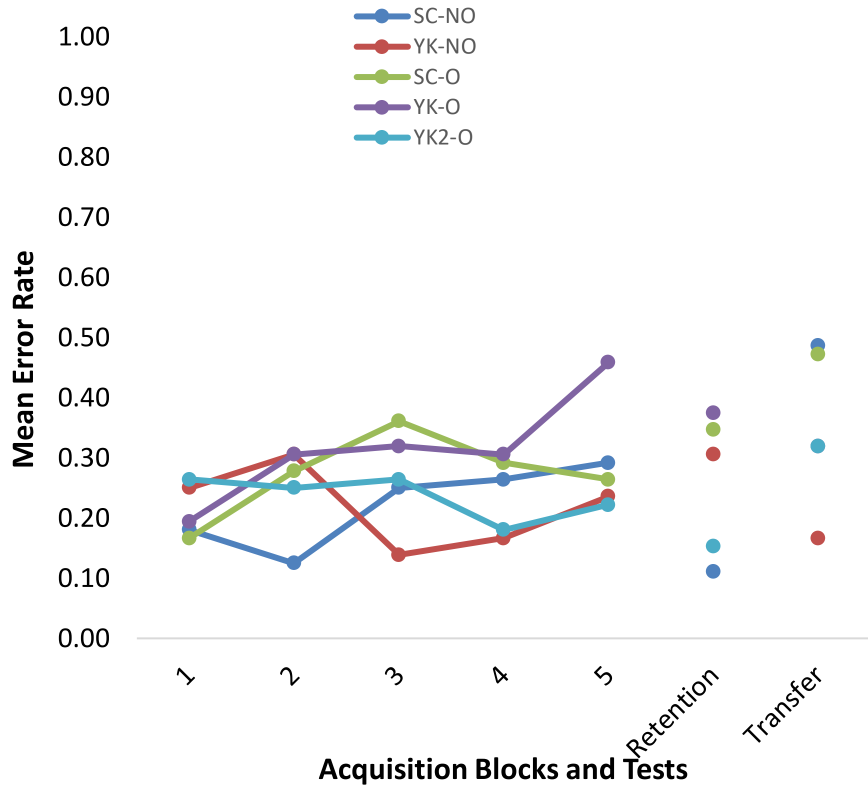

Figure 9. *Mean error rate for during acquisition, retention, and transfer for each experimental group.*

Table 4. *Mean and standard deviation error rate across all groups during acquisition*

	M	*SD*
SC-NO	6.56	1.33
YK-NO	7.83	2.23
SC-O	6.88	1.37
YK-O	6.69	1.59
YK2-O	6.69	1.59

Sample Entropy

The left panel of Figure 10 displays mean SampEn scores for the SC-NO, YK-NO, SC-O, YK-O, and YK2-O groups during acquisition. Table 5 shows the mean and standard deviation SampEn across all blocks during acquisition. No significant difference was found across blocks during acquisition F (4, 220) = .11; p = .965, nor was there a significant difference in the Group × Block interaction F (16, 220) = 1.57; p = .096. There was no significant main effect for group, F (4, 55) = 1.17; p = .331.

The right panel of Figure 9 shows the mean SampEn during retention and transfer. There were no significant main effects for group during retention, F (4, 55) = 1.74; p = .154, or transfer, F (4, 55) = 2.43, p =.058.

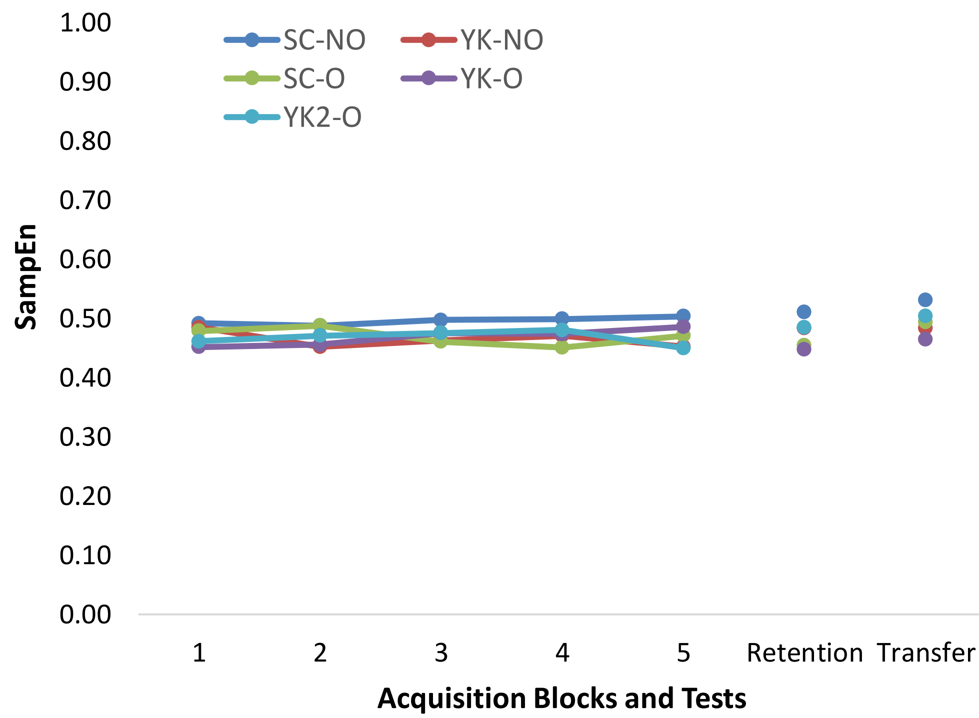

Figure 10. *Mean SampEn of resultant acceleration across acquisition, retention, and transfer for each experimental group.*

Table 5. *Mean and standard deviation across all blocks for SampEn*

	M	***SD***
BL1	.212	.207
BL2	.253	.340
BL3	.267	.281
BL4	.242	.296
BL5	.294	.355

CHAPTER 5

Discussion

Allowing control over an aspect of the learning environment has garnered significant interest in the motor behavior community over the past few decades. Research on self-control effects indicates that allowing participants to control some aspect of instruction facilitates learning compared to conditions not afforded such control (Janelle et al., 1995). The majority of studies investigating self-control have typically involved one participant and one experimenter at any given time, which is not representative of many practical settings such as team sports or group fitness instruction. Thus, the purpose of the present study was to examine self-control effects in the presence and absence of the opportunity to observe another learner.

Movement Time Hypotheses and Results

1. The self-control without observation group (SC-NO) will produce significantly faster mean MT than the yoked without observation group (YK-NO) during retention. This hypothesis was supported. The self-control group without observation performed significantly faster than yoked without observation group during retention F (4, 55) = 5.11; $p < .05$.
2. The self-control without observation group (SC-NO) will produce significantly faster mean MT than the yoked without observation group (YK-NO) during transfer. This hypothesis was supported. The self-control group without observation performed significantly faster than yoked without observation group during transfer F (4, 55) = 6.15; p < .05.
3. The self-control with observation group (SC-O) will produce significantly faster mean MT than the yoked only group (YK-O) during retention. This hypothesis was not supported.

There was no significant difference between the self-control with observation group (SC-O) and yoked with observation during retention according the post hoc tests.

4. The self-control with observation group (SC-O) will produce significantly faster mean MT than the yoked only group (YK-O) during transfer. This hypothesis was not supported. There was no significant difference between the self-control with observation group (SC-O) and yoked with observation during transfer according the post hoc tests.
5. The self-control without observation group (SC-NO) will produce significantly faster mean MT than the yoked with observation group (YK2-O) during retention. This hypothesis was not supported. There was no significant difference between the self-control without observation group (SC-O) and second yoked with observation group (YK2-O during retention according the post hoc tests.
6. The self-control without observation (SC-NO) will produce significantly faster mean MT than the yoked with observation group (YK2-O) during transfer. This hypothesis was not supported. There was no significant difference between the self-control without observation group (SC-O) and second yoked with observation group (YK2-O) during transfer according the post hoc tests.

Error Rate Hypotheses and Results

7. The self-control without observation group (SC-NO) will produce significantly lower error rates than the yoked without observation group (YK-NO) during retention. This hypothesis was not supported. There was no significant difference in error rates between the self-control without observation group (SC-NO) and second yoked with observation group (YK2-O) during retention according the post hoc tests.

8. The self-control without observation group (SC-NO) will produce significantly lower error rates than the yoked without observation group (YK-NO) during transfer. This hypothesis was not supported. There was no significant difference in error rates between the self-control without observation group (SC-NO) and yoked with observation group (YK-O) during transfer according the post hoc tests.
9. The self-control with observation group (SC-O) will produce significantly lower error rates than the yoked with observation group (YK-O) during retention. This hypothesis was not supported. There was no significant difference in error rates between the self-control with observation group (SC-O) and yoked with observation group (YK-O) during retention according the post hoc tests.
10. The self-control with observation group (SC-O) will produce significantly lower error rates than the yoked with observation group (YK-O) during transfer. This hypothesis was not supported. There was no significant difference in error rates between the self-control with observation group (SC-O) and yoked with observation group (YK-O) during transfer according the post hoc tests.
11. The self-control without observation group (SC-NO) will produce significantly lower error rates than the second yoked with observation group (YK2-O) during retention. This hypothesis was not supported. There was no significant difference in error rates between the self-control without observation group (SC-NO) and second yoked with observation group (YK2-O) during retention according the post hoc tests.
12. The self-control without observation (SC-NO) will produce significantly lower error rates than the second yoked with observation group (YK2-O) during transfer. This hypothesis was not supported. There was no significant difference in error rates between the self-control

without observation group (SC-NO) and second yoked with observation group (YK2-O) during transfer according the post hoc tests.

SampEn Hypotheses and Results

13. The observation groups (SC-O, YK-O, and YK2-O) will produce significantly greater Sample Entropy scores than the two groups without observation (SC-NO, YK-NO) during acquisition.

    This hypothesis was not supported. There were no significant differences between any groups regarding Sample Entropy scores during acquisition.

14. The observation groups (SC-O, YK-O, and YK2-O) will produce significantly lower Sample Entropy scores than the two groups without observation (SC-NO, YK-NO) during retention.

    This hypothesis was not supported. There were no significant differences between any groups regarding Sample Entropy scores during retention.

15. The observation groups (SC-O, YK-O, and YK2-O) will produce significantly lower Sample Entropy scores than the two groups without observation (SC-NO, YK-NO) during transfer.

    This hypothesis was not supported. There were no significant differences between any groups regarding Sample Entropy scores during transfer.

Conclusions

The primary aim of the study was to experimentally investigate whether self-controlled learning is sensitive to observational learning in what ways may limit its application. The results of this experimental approach suggest that these particular factors, self-control and observation, when taken in conjunction may mitigate the effects of each other. Specifically, the study hoped to explore whether these manipulations work independently of, or in tandem with, each other. If each manipulation functions independently, it is possible that an environment that incorporates both could create a possible learning benefit as opposed to one where one is available. Alternatively, if the effect of self-control and the effect of observation work in a similar manner there may be no additive benefit to the learner(s) by incorporating both. If the latter is possible then the applied nature of self-control may be rather limited in settings were observation is inherently available (i.e. groups or teams). Individuals within a group or team naturally serve as models for the learning of certain behaviors. This natural characteristic of observation in group settings does not hold true for self-control. Autonomy over aspects of the learning environment such as feedback must be intentionally integrated by the coach or instructor who may find it impractical or even impossible to do so in group settings due to time and availability.

The results of this study suggest the latter to be the case. Access to observation appeared to mitigate the self-control benefit. That is, although a self-control benefit was found for the traditional self-control and yoked pairing, when observation was available no difference was found between groups regardless choice over feedback. Furthermore, the lack of significant differences between self-control and yoked group given access to observation implies there may be no additive benefit in combining self-control and observation.

A self-control benefit was found for the traditional self-control paradigm (SC-NO, YK-NO) during retention and transfer ($p<.05$). However, there were no differences between instances of self-control and observation (SC-O), of observation and no self-control (YK-O, YK2-O), and of self-control with no observation (SC-NO) in retention or transfer ($p>.05$). All groups afforded either self-control, observation, or both outperformed the group afforded neither (YK-NO). These findings suggest the applied nature of self-control may be somewhat limited in group settings where observation is naturally available to learners.

The lack of differences between groups afforded self-control over feedback, observation, or both could indicate that the effects of self-control and observation function under similar effects. If self-control initiates an effect in the learner akin to that of observation, and vice versa, then an additive benefit may not be seen from a combination of both. If this assumption is correct then inclusion of self-control over feedback into scenarios where observation is available may be redundant or perhaps inefficient.

There exists another explanation for the findings that is not directly tied to the applied and exploratory nature of this study. It is possible that the results found in retention and transfer are not indicative of a self-control or observational learning 'benefit', but rather due to a yoked detriment. There was a traditional self-control benefit between the SC-NO and YK-NO group, but no self-control benefit appeared to emerge between the SC-NO and YK2-O or the SC-O and YK2-O groups. It is possible that the traditional self-control effect in this study emerged not as a result of the self-control being privy to a benefit, but rather to the yoked group being burdened by a detriment.

The origin of the yoking procedure was implemented as a means of balancing feedback frequency in self-control protocols. And although this procedure in a sense mimics the "real-world" concept of an externally imposed feedback schedule by an instructor, it does not mimic a practical feedback schedule. That is, a coach or instructor who allows for no choice and entirely dictates the feedback schedule of an individual will still give feedback based on their own knowledge or logic of the skill or learner. Although to a learner the feedback schedule may seem random there is, typically, a sense of logic by which an instructor will give feedback. However, this logical presentation of feedback is rarely seen in a self-control protocol, particularly those in which KR is the feedback. Researchers that appear to be aware of this dilemma have created protocols that seek to address, if not mitigate, the issue of yoking (Hansen, Pfeiffer, & Patterson, 2011)

An additional finding within the study is related to the frequency of feedback requests. There were no significant differences in feedback requests between the two self-control groups ($p>.05$) with those in the SC-NO group requesting feedback after approximately 26% of trials, and those in the SC-O group requesting feedback after 20% of trials. Although feedback requests have been reported as low as 5-7% across acquisition (Janelle et. al., 1997; Wulf et al., 2005), the frequency of feedback requests in the current study are still consistent with other studies in self-control (Aiken et. al., 2012; Chiviacowsky & Wulf, 2002). However, one finding of note was the way in which both of these groups tended to request feedback. The majority of studies in the self-control literature report that request for feedback tapers off toward the end of acquisition. That is, participants tend to ask for feedback more often at the beginning of practice than at the end (Aiken et. al., 2012; Chiviacowsky & Wulf, 2002; Janelle et al., 1997). The feedback request frequency for the traditional self-control group (SC-NO) tended to decrease from the beginning to end of acquisition, thus mirroring the results from previous self-control studies over feedback. Alternatively, the feedback request frequency for the self-control and observation group (SC-O) tended to remain consistent, and even increased, toward the end of acquisition. While not entirely unique in regard to the behavior found in the self-control literature (Laughlin et al., 2015), the fact that this self-control group (SC-O) differed in their request for feedback from the other self-control group (SC-NO) could be an avenue worth exploring in future research.

Lastly, although there were no significant differences within resultant acceleration SampEn within groups, similar to requests for feedback, some descriptive statistics emerged that could provide insight into future studies, particularly since this is the first study to incorporate entropy as a means of examining motor learning. The SC-NO group, while not statistically different, had a higher mean sample entropy score across acquisition, retention, and transfer compared to their YK-NO counterparts. Higher entropy indicates a more complex and less predictable system. Thus, the resultant acceleration of the SC-NO group could suggest that their pattern of movement changed more often than any other group. If such is the case this could further intimate that the SC-NO group was engaged in more movement strategy exploration than the other groups. An increase in strategy exploration has been put forth as a possible mechanism for the self-control effect (Laughlin et al., 2015). Individuals who are given control may more deeply engage with the task, and thus feel that they can explore different strategies compared to those who are externally controlled.

The entropy scores of the SC-NO group being higher than those of the standard yoked group (YK-NO), and by extension perhaps engaging in greater strategy exploration, follows based on previous claims made in the literature (Laughlin et al., 2015). However, there still remains the question of the other three groups (SC-O, YK-O, YK2-O) in regard to their entropy scores. None of the three aforementioned groups differed in learning or performance from the SC-NO group. The rationale behind this result could stem from access to observation. It is possible that, although learning and performance measures on the task did not differ, the SC-NO engaged in greater strategy exploration because they were not privy to observation. The lower entropy scores for SC-O, YK-O, and YK2-O could be associated with mimicking the movement strategy of the model. All three groups learned the task equally to that of SC-NO but may not have chosen to explore movement strategies in the same way as the SC-NO group because they adopted, and remained consistent with, the movement patterns of the model.

The findings of the current study insinuate the following:

1. The self-control benefit may extend to a complex discrete task like speed cup stacking.
2. The allowance of observation may mitigate any detriment that occurs from not allowing self-control over feedback.
3. There is possibly no additive benefit in giving self-control over feedback in scenarios wherein observation is inherently available.
4. Having control over feedback, while being privy to observation, may change feedback request behavior compared to what has previously been speculated in the literature.

Application

The results of the present study may contain practical value to real-world scenarios. The growing body of evidence regarding self-control points to the benefit that emerges when an individual is allowed control over an aspect of the learning environment (Aiken et al., 2011; Janelle et al., 1995; 1997, Chiviacowsky & Wulf, 2002, 2005). The ecological validity of self-control, however, may be somewhat limited in regard to team or group like settings. Most studies investigating self-control usually involve one learner with one experimenter. The results from this study suggest that providing control over KR in group settings may not be an efficient endeavor for facilitating motor learning. In group settings, where observation is unavoidable, practitioners may see no added benefit in attempting to provide control over feedback to learners.

There exists another plausible explanation for the current findings of the study. It is possible there is not additive effect in combining self-control over KR when observational learning is available, however, the results of this study could stem from mitigating the yoked detriment. Studies often cite the benefit of choice as the impetus for the learning benefit seen in self-control groups over that of their yoked counterparts. And while the yoking procedure balances the feedback schedule among groups it does not balance the rationale for providing feedback. That is, participants in self-control groups seem to request feedback based on some underlying logic pertaining to the task at hand, but participants in yoked groups are given feedback simply based on the predetermined of their self-control counterparts. This lack of logic pertaining to the yoked feedback schedule could provide a plausible explanation to the self-control benefit found in certain studies. Specifically, the results are due to a yoked detriment rather than a self-control benefit.

In conclusion, the primary results of the study suggest that allowance of self-control over KR when observation is inherently available may be redundant as access to observation could mitigate any self-control effects. Thus, coaches of certain team sports (i.e. basketball, baseball, hockey, soccer, etc.) may not need concern with providing self-control over KR during their practices as players naturally have access to observation of others. Coaches and instructors may find it more beneficial to direct their players' attention to the movement of others during practice rather than attempting to allow for control over feedback. This could be particularly attractive to coaches as it can be near impossible to provide complete autonomy of feedback in group settings. And although recent research has demonstrated that complete autonomy in regard to feedback is not necessary to create a self-control effect (von Linder & Fairbrother, in progress), attempting to provide self-control in a group setting can still be a daunting endeavor. However, if coaches instead were to direct their athlete's attention to observation they may find a similar learning effect to what may emerge if they were to provide self-control.

Limitations

The present study is not without limitations. First, the way in which errors were measured and corrected allowed for some participants to re-do more trials than others, perhaps giving them more practice with the start of the movement. However, there were no significant differences in error rate between groups during acquisition.

Another limitation was the absence of a post-training questionnaire. Particularly one aimed at the reasons or behaviors for certain requests for feedback. Furthermore, participants were required to watch each trial of the video model. Future research could emulate the study of Wulf, Raupach, and Pfeiffer (2005) wherein participants could observe the model when they choose and also control another aspect of the learning environment (e.g. KR, KP, practice termination, physical guidance, etc.).

Future Research

Further research should be conducted to investigate the effects of observation on self-control. The current study used video modeling, and access to feedback via KR, for the learner. It could provide more ecological validity to create a study wherein observational learning more closely mirrored the experience of practicing in a group. The present study was experimentally controlled due to the somewhat exploratory nature of combining self-control and observational learning. Thus, future research could investigate the more applied aspects of the current study. That is, to observe groups of two or more in real time versus a pre-recorded model. Additionally, individuals in the observational learning group were privy to the model's KR after each trial. And although intrinsic feedback was readily available for each participant based on the task, it may be worthwhile to examine a task in which KR of the model is not the sole focus point for the learner. To instead choose a task wherein the actual movement, or KP, is the focus for the learner of the model instead of KR.

The results of the present study suggest that allowing for self-control over KR when a video model is present may not lead to additive benefits. And although it is possible the lack of additive effects was due to the lack of a yoked detriment, future research could investigate other means of self-control when observational learning is available. Specifically, allowing for control over certain aspects of learning that cannot be compared, performance wise, to the model. Such was the case for the present study wherein participants likely compared their KR to that of the model. Several studies have allowed for control over aspects of the learning environment such as practice termination (Post et al., 2011), physical guidance (Wulf & Toole, 1999), or practice difficulty (Andreiux et. al., 2016). Future research could integrate conditions not pertaining to control over KR.

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APPENDICES

APPENDIX A

The effects of feedback on motor learning

INTRODUCTION
The purpose of this research study is to investigate how feedback influences the performance and learning of a motor skill.

INFORMATION ABOUT PARTICIPANTS' INVOLVEMENT IN THE STUDY
You will complete two sessions held two days in a row. The first session will last approximately 60 minutes and the second session will last approximately 20 minutes. Your performance will be recorded and stored on a computer for later analysis. You will learn to complete a cup stacking task. On the first day, you will complete 30 trials during a practice session. On the next day, you will complete two tests (6 trials each) to measure how much you learned. Please note that an initial screening procedure of one practice trial will be used to determine your potential involvement in the study. If you meet a certain pre-determined performance threshold during the screening procedure you will be unable to participate in the study.

CONFIDENTIALITY
The information in the study records will be kept confidential. Data will be stored securely and 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. Any information that can link participants with their data will be destroyed at the end of the study. Data will be retained for use in publications, presentations, and teaching. The results of this study may contribute to a better understanding of how people learn motor skills. Your research information will not be used with future researchers for future research, even if identifiers are removed.

RISKS AND BENFITS
The tasks used in this study pose no risks to you beyond those inherent in light physical activity. Although steps will be taken to prevent it, there is a risk that confidentiality will be lost. You may gain some insight into your personal preferences when learning a motor skill. Otherwise, there are no anticipated direct benefits to you resulting from your participation in the study. The results of the study may contribute to current understanding of how people learn motor skills.

Initials________

CONTACT INFORMATION

In the event of an injury due to your participation, or if you have questions at any time about the study or the procedures, please contact Andy Bass or his faculty supervisor, Jeffrey T. Fairbrother, via the contact information below. The University of Tennessee does not automatically reimburse subjects for medical claims or other compensation. If you have any questions about your rights as a participant, contact the University Of Tennessee Office Of Research Compliance at (865) 974-7697.

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty or loss of benefits to which you are otherwise entitled. 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. You participation may be ended without consent if you do not meet the performance threshold criterion in the screening procedure. If your participation must be ended due to this pre-determined criterion the data collected from the screening procedure will be destroyed.

CONSENT

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

Participant's name (please print): ____

Participant's signature: ____ Date: __________

Investigator's signature: _______________________________________ Date: __________

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APPENDIX B

Supplemental Informed Consent Statement
Debrief

Thank you for participating in the study. The purpose of this statement is to inform you about the exact nature of the study and why certain information was initially withheld from you. The aim of this study was to examine the effects that observation and self-controlled feedback have on the learning of a simple motor task (e.g. cup stacking). You may notice that the title of the initial informed consent you signed was simply "the effects of feedback on motor learning." We decided to withhold information about observation and self-control, along with the nature of the task, so as not to influence your interaction with the task as you learned it. To be told the parameters of how you would learn the task (e.g. observation, self-control, both, or none), may have influenced how you learned.

Furthermore, you may recall on the first day you completed a screening test. The purpose of the screening was to ensure that only people unfamiliar with the task would participate. We set the threshold of the screening at 10 seconds. If a participant completed the screening test in less than 10 seconds they were excused from the study. It is important that future participants remain unaware of the true purpose of the study. We politely ask that you not tell anyone about the details of the study. We hope you enjoyed your time cup-stacking and thank you once again for agreeing to be a part of this.

If you still agree for us to use your data for this particular study after this debrief please sign the supplemental consent below. You data will only be used for this study and will not be shared or used for future research.

CONSENT

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

Participant's name (please print): ____

Participant's signature: ____ Date: __________

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VITA

Andrew Duvier Bass grew up in College Grove, Tennessee. He attended and graduated from Battleground Academy in Franklin, TN. After high school he enrolled at Davidson College in Davidson, NC where he was a 4-year letter winner in baseball. Upon completion of his undergraduate degree, with a major in psychology and a minor in philosophy, he was selected in the 18th round of the 2011 Major League Baseball draft. He spent two years playing professional baseball in the Tampa Bay Rays and Chicago White Sox organizations, respectively. Following his release from professional baseball, he completed his master's degree in Kinesiology with a concentration in Sport Psychology and Motor Behavior from the University of Tennessee-Knoxville in 2015. In 2018, he received his Doctor of Philosophy degree in Kinesiology and Sport Studies with a specialization in Sport Psychology and Motor Behavior.