Examining the Optimal Frequency of Modeling Under Varied Constrained Choice Conditions for the Learning of a Dance Skill

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Abstract

Various constrained frequencies of skilled model observation, under self-controlled conditions, were examined to determine whether there was an optimal frequency of modeling for learning a dance movement. Forty-eight participants with no previous dance/gymnastics experience first did a pre-test, then learned the skill over 60 interspersed observational and physical practice trials in one of four conditions that consisted of either (1) 25%, (2) 50%, (3) 75% modeling frequencies, or (4) no constraint imposed. This 60-trials acquisition phase was followed by a 24-hour post-test. Physical performance, scored by two external evaluators, revealed a significant main effect of Time from pre- to post-test ($F(1, 44) = 120.43$, $p < .001$). Cognitive representation scores revealed a main effect of Time for an image selection test ($F(1, 44) = 39.09$, $p < .001$), and a Time by Decision interaction for a forced-choice test ($F(1.53, 67.48) = 7.00$, $p = .004$). While learning was demonstrated for all measures, evidenced by higher scores at post-test than at pre-test, no main effect of Group was obtained. Consequently, the frequencies of modeling tested here under self-controlled learning conditions were equally beneficial for the learning of the novel dance skill.

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Chapter 1: Introduction

Dance is an aesthetic sport in which athletes perform on stage in hopes of dazzling the audience or judges with their strength and artistry. In order to perform the skills they do, dancers need strategies to carry over from practice to practice, and from practice to final stage performance. This relative permanence in the level of execution of these dance skills from session to session is a key element in the definition of motor learning, and one which distinguishes learning and performance (Schmidt & Bjork, 1992). To elaborate, performance is the immediate changes in behaviour or skill level at the time of practice, whereas learning is inferred from increased performance from practice to performance measured at a later time (Kantak & Winstein, 2012). Thus, participants can show improvement in skill performance within a practice session, but learning cannot be inferred until a post- and/or transfer test is conducted that shows that improvement in performance was maintained across time (Kantak & Winstein).

The process by which people acquire new skills is of great interest in the field of motor learning. A highly researched area in motor learning is observational learning, which has also been referred to as emulation, imitation, or modeling (Ste-Marie et al., 2012). It has been shown continuously throughout the literature that observation can improve learning (McCullagh & Meyer, 1997; Pollock & Lee, 1992; Sidaway & Hand, 1993; Ste-Marie et al.). Areas that have been well-researched include aspects such as the functions that observation serve (Ashford, Bennett, & Davids, 2006; Ashford, Davids, & Bennett, 2007; Cumming, Clark, Ste-Marie, McCullagh, & Hall, 2005; Hancock, Rymal, & Ste-Marie, 2011), the model type used for observation (Andrieux & Proteau, 2013; Lee & White, 1990; McCullagh & Meyer, 1997; Rohbanfard & Proteau, 2011), and the feedback accompanying observation (Al-Abood, Davids,

Bennett, Ashford, & Martinez Marin, 2001; McCullagh, Stiehl, & Weiss, 1990; Sawada, Shiro, & Ishii, 2002).

An area in which there is a lack of research, however, concerns the optimal frequency of modeling for observational learning. In applied settings, there have only been two experiments in which frequency of model presentation was directly manipulated (Fagundes, Chen, & Laguna, 2013; Sidaway & Hand, 1993). In both of these experiments, it was concluded that a higher amount of modeling was more beneficial for learning, yet there were limitations in both experiments which I will expand upon in later sections.

A more recent area of research in motor learning is that which examines the effects of providing choice over different learning variables to the learner, referred to as 'self-controlled learning'. It has been demonstrated consistently that giving learners control over some aspect of the learning environment or task can increase motor learning (Wulf, 2007). Research, for example, has provided support for self-controlled learning to be beneficial with respect to the provisions of knowledge of performance (KP) feedback (Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997), knowledge of results (KR) feedback (Chiviacowsky, Wulf, de Medeiros, Kaefer, & Tani, 2008), and observation scheduling (Wulf, Raupach, & Pfeiffer, 2005). When compared to yoked groups (participants who have the same schedule as participants in a self-control group but with no choice), self-controlled learning groups often perform and learn more effectively (Wulf).

Interestingly though, when participants have been given choice over the use of a video model, participants have chosen to watch the model at a very low frequency. Of the three experiments that have provided choice over the use of video modeling, participants chose to do so on less than 12% of trials (Janelle et al., 1997; Wrisberg & Pein, 2002; Wulf et al., 2005).

This frequency is far lower than the optimal frequency advanced by previous research on the frequency of modeling (Fagundes et al., 2013; Sidaway & Hand, 1993). Is it possible, though, that learners are not choosing the most effective strategies for learning? There has been evidence in other domains that learners do not always select the best learning strategy (Carter & Patterson, 2012; Carter, Rathwell, & Ste-Marie, 2016; Flowerday & Schraw, 2003). Thus, there is a research gap concerning whether the benefits that choice provides to learners can be even more effective if this choice is provided with certain constraints for the learner to work within.

In the present experiment, I aim to examine whether there is an optimal frequency at which to observe a model under self-controlled learning conditions. This research is considered significant as it may provide information regarding the frequency of modeling required to optimize skill acquisition and learning. The results from the experiment may be applicable to sporting or rehabilitation environments. If an optimal frequency is obtained, we can recommend to coaches and practitioners how they can best implement observation to enhance learning. This can be especially beneficial in scenarios where there are time restrictions, as coaches and practitioners may be able to better combine physical and observational practice more efficiently and effectively in the time allotted.

In the upcoming chapters, I begin by outlining a social cognitive approach to observational learning proposed by Bandura (1977) that will guide my research. Next, I will introduce the research relevant to the effective use of observational learning through an applied model created by Ste-Marie et al. (2012). Using this model, I will define the gap in the literature pertaining to the frequency of modeling and define the research question. The methodology used in the present experiment will be described and will be followed by the results of the experimental manipulations. Finally, I will discuss the meanings and implications of the results.

Chapter 2: Review of Literature

Observational Learning

Observational learning was defined by Miller and Dollard (1941) as the process by which an observer brings his or her response to approximate that of a model. There have been two main perspectives on how this approximation might be acquired. Scully and Newell (1985) advanced a direct perception perspective, borrowed from Gibson's (1950) work on observational learning, in which the learner is said to pick up on relative motion information from the observed movement pattern that constrains the emergence of that movement when performed by the learner. Although this Gibsonian perspective of observational learning exists, I have chosen to align my research with the perspective forwarded by Bandura (1977) in his Social Learning Theory. I have chosen this because the majority of the researchers exploring observational learning use Bandura's Social Learning Theory as their guiding theoretical framework in which to study observational learning, as such, there is a larger literature on which to base my research. Consequently, I elaborate on this theory next.

Bandura (1977) proposed that four sub-processes guide the observational learning process: (1) attention, (2) retention, (3) motoric reproduction, and (4) reinforcement and motivation. Attentional processes refer to those which are used while the learner is attending to and recognizing the relevant features of the modeled behaviour (Bandura). If the learner does not attend to the relevant features, learning may not be facilitated. In this light, it is important to consider that certain models may command more attention than others. For example, a model who is seen as an expert or as having high status in the behaviour being observed, or a model who is similar to the learner, is likely to command more attention (McCullagh & Meyer, 1997). These types of models are often sought out because of associational preferences, whereas models who lack perceived wisdom are ignored (Bandura). Therefore, a model similar to the learner,

performing a motor skill perfectly (i.e., a peer-skilled model) should command sufficient attention to result in superior learning.

Retention processes, the next sub-process, are purported to allow learners to keep the modeled behaviour in their memory to guide future actions, as well as make the modeled behaviour meaningful (Bandura, 1977). Modeled behaviours are theorized to be transformed into symbolic representations to be retained in the learner's memory, which can later serve as relatively permanent images of the behaviour. References to these behaviours elicit cognitive representations in the absence of direct observation (Bandura, 1986). Once a correct cognitive representation of the movement is made by watching a skilled model, it is argued that a learner can compare his or her own behaviour to this cognitive representation when attempting the movement, and make corrections accordingly (Bandura, 1986). Thus, when learning a new skill, this cognitive representation may be used for error detection and correction mechanisms, which may drive superior physical performance (Carroll & Bandura, 1987, 1990).

The next sub-process involves the motoric reproduction processes, which are those used to transfer the cognitive representation of the modeled behaviour into actual overt actions (Bandura, 1977). Through the engagement of the overt actions, proprioceptive cues, verbal cues from others, or video playback, a learner can determine how well the modeled action has been reproduced, which can lead to an update of the cognitive representation (Bandura). The learner can then cycle through both physical and observational practice to develop the necessary cognitive representation that will lead to proper execution of the movement pattern.

Motoric reproduction of the movement may not always be possible due to physical limitations associated with performance of the skill, such as lack of coordination or strength; but that is not to say the learner has not showed learning of the skill. Indeed, researchers have

recommended that motor learning researchers use alternative assessments to that of physical performance to capture possible learning effects that may be limited by physical reproduction (McCullagh & Weiss, 2001). Cognitive representation tests, such as recognition and verbal construction, may be used to tap into the learning effects that might not be captured by physical performance assessments alone (Carroll & Bandura, 1987). Further, correlations between cognitive representation and physical performance scores have been included in previous research to establish a link between these two types of learning assessments (Robertson, St. Germain & Ste-Marie, 2017). In recognition of these different assessments of motor learning, the present experiment included both cognitive representation and physical performance test to assess learning, as well as a correlation analysis between the two types of tests.

Finally, reinforcement and motivational processes are what guide the learner to reproduce the modeled behaviour (Bandura, 1977). The learner may have attended to and retained relevant features of the modeled behaviour and have the physical ability for motoric reproduction, but with the lack of reinforcement and motivation, the learner may rarely execute the learned behaviour. As stated previously, factors related to model type, such as the use of a peer or skilled model, can influence a learner's motivation to execute the observed movement (Ste-Marie et al., 2012).

Observational learning has continuously been implemented as an intervention with the goal to acquire or improve motor behaviours. When used effectively, video presentation of a model has been shown to be beneficial over control conditions with no model presentation in both laboratory and applied settings (Al-Abood et al., 2001; Rohbanfard & Proteau, 2011; Sidaway & Hand, 1993; Wrisberg & Pein, 2002). A key caveat, however, is that the use of observation must be implemented effectively. Ste-Marie et al., (2012) highlighted that mere

observation is not sufficient for enhancing motor learning and identified a number of factors to be considered. In the next section, I elaborate on Ste-Marie et al.'s review and use it to guide my literature review, identify research gaps, and the selection of appropriate characteristics of observational learning for the present experiment.

An Applied Model for the Use of Observation

Ste-Marie et al. (2012) developed an 'Applied Model for the Use of Observation' which may be used to guide practitioners in the use of observational learning through the understanding of many factors that should be considered to use observation in an effective manner. This model was created through a review of 99 observation-based experiments that used applied tasks in their experiments (Figure 1). The model was framed in Beveridge Mackie's (2011) journalistic approach of the 5 Ws and 1 H (who, what, where, when, why, and how). The first step of the applied model was to consider the learner's characteristics and the task characteristics. Next, the setting in which the observation will take place (where) and the desired outcome of the observation intervention (why) should be determined. For the present experiment, the targeted learners were university-aged novices and the task to learn was the pirouette en dehors; a task that has an action or performance outcome goal. As well, the task was to be learned in a laboratory setting. These moderator variables and the context of the present experiment were used to drive the selection of the model, which I will expand upon in later sections. Once these features have been determined, it is argued that the model type (who), skill context (what), timing (when) and frequency or speed (how) of the observation intervention can be determined. Much of the present experimental design was based on this applied model framework and it also serves to situate the research gap to be addressed in the research presented here; consequently, it will be used to structure the remainder of this review of the literature.

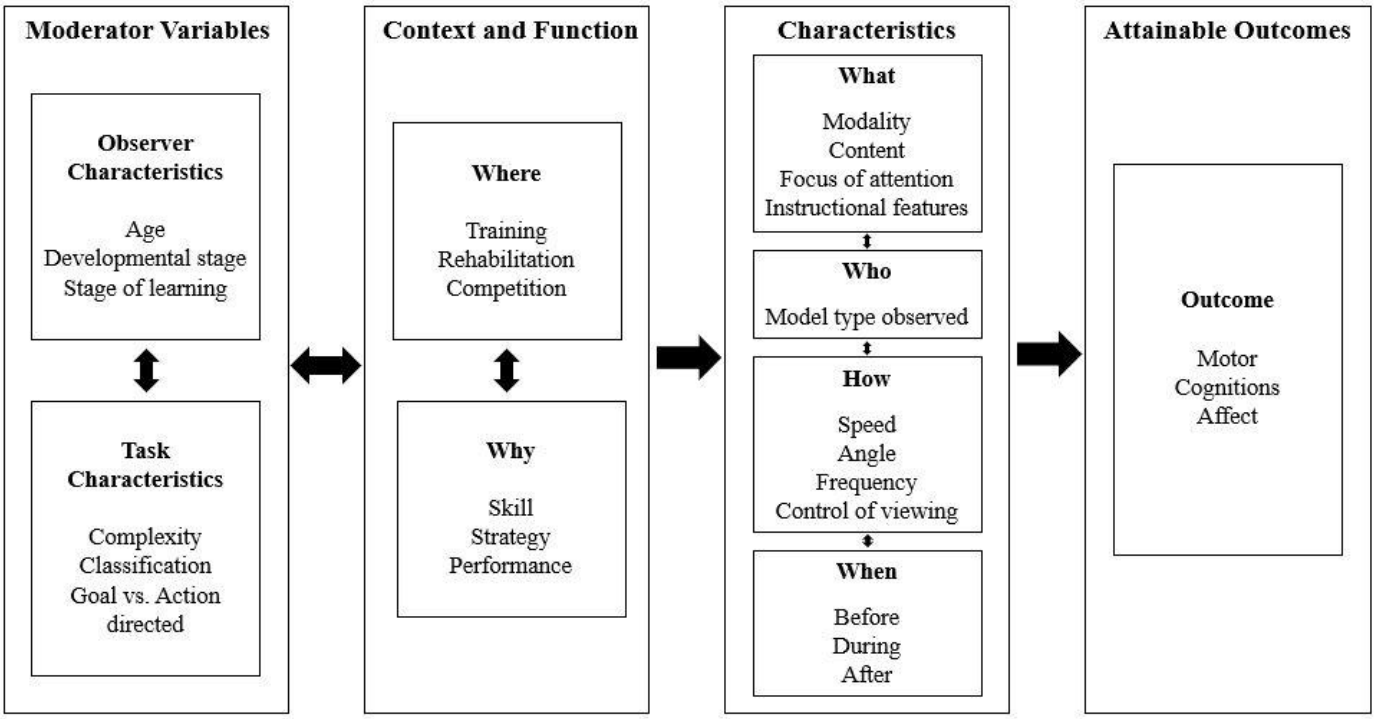

Figure 1. An applied model for the use of observation (adapted from Ste-Marie et al., 2012).

Where. The majority of the literature surrounding observational learning occurs in two settings: a laboratory setting or an applied setting. A laboratory setting can be advantageous because confounding variable can more easily be controlled. Learning tasks in laboratory settings have included timing tasks (Andrieux & Proteau, 2013; Rohbanfard & Proteau, 2011), computer tasks (Heyes & Foster, 2002; Lee & White, 1990; Pollock & Lee, 1992), and drawing tasks (Buchanan & Dean, 2010). It is unclear, however, whether the results obtained in a laboratory are transferable to real world settings such as sport or rehabilitation. This leads to an advantage of research conducted in applied settings; the results are more likely transferable between different sports or different applied settings. Examples of applied settings that have been examined are gymnastics (Baudry, Leroy, & Chollet, 2006; Robertson, et al., 2017), trampoline (Ste-Marie, Vertes, Law, & Rymal, 2013), and dance (Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006; Fagundes et al., 2013). It is, however, difficult to control for

confounding variables in applied settings, which may lead to difficulties with interpretation of the results. To address the advantages and disadvantages of both settings, the present experiment included an applied task in a laboratory setting. Further, learner control has been shown to be most beneficial in experimental designs which include an applied task in a laboratory setting as compared to traditional laboratory based tasks and applied tasks in a natural environment (Patall, Cooper, & Robinson, 2008).

What. Scully and Newell (1985) proposed that observing relative motion, the motion of individual elements in the configuration to each other, is the gold standard of observational learning interventions. A video that provides relative motion information via a skilled model should allow the learner to observe relevant motion information to guide their movement reproduction (Scully & Newell). Information pertaining to where limbs are relative to each other can provide spatial and temporal guides for proper movement execution. Further, for a complex whole-body movement with an action outcome, such as the pirouette en dehors, it has been argued that relative motion information may be necessary over end point effector information (Hodges, Hayes, Breslin, & Williams, 2005). Taking these factors into consideration, a full-body video model was used to demonstrate the to-be-learned skill.

Why. The learning functions of observation, which are defined by Ste-Marie et al. (2012) as the underlying intent or purpose of observing the desired behaviour, are outlined in the why section of the applied model. Cumming et al., (2005) found that athletes and coaches used observation for three functions: the skill function, strategy function, and performance function. The skill function is thought to be used for acquiring information concerning the technical execution of motor skills, the strategy function may be used to develop and execute sport strategies, and the performance function can used to reach optimal levels of arousal and mental

state to perform a motor skill. The skill function is the most commonly used in observational learning interventions (Hancock et al., 2011). Consistent with this, the observation intervention in the present experiment was also used to focus on the skill function; i.e., the learning of the technical aspects for performance of the skill.

Who. The type of model observed was of interest in the 'who' section of the applied model, as there have been many model types examined throughout the literature. These model types include skilled, unskilled, peer, non-peer, mastery, coping, learning, and self-models (Ste-Marie et al., 2012). Of most relevance here is the peer-skilled model. This would be a model that is the same age as the learner, and one who executes the task perfectly. Ste-Marie et al. concluded that a peer-skilled model was used in the majority of research designs. It was suggested that a peer-skilled model is most commonly used as it fits within Bandura's (1997) proposition that both model-learner similarity and an accurate cognitive representation for a reference of correctness (see also Sheffield, 1961) are of great importance when using observational learning. Thus, skilled models are argued to assist with the development of an error detection and correction mechanism through a proper cognitive representation, as the learners can see proper execution of a motor skill and problem solve to improve their physical performance (Bandura; Sheffield).

It has certainly been demonstrated that viewing a skilled model can aid skill acquisition. For example, Heyes and Foster (2002) found a skilled model to be beneficial for learning a serial reaction time task. In this experiment, participants were divided into three groups: observation of skilled model, physical practice, and control. The group that observed the skilled model watched the model perform 40 trials of the serial reaction time task, the physical practice group performed 40 trials of the serial timing task, and the control group received no information pertaining to the

task. In a retention test, the skilled model group performed similarly to the physical practice group, and better than the control group. These results provide support that observation of a skilled model can facilitate learning; thus, a peer-skilled model was used in the present experiment.

The previously noted idea of model similarity can also have an impact on the decision of the sex of the model used to demonstrate the skill. Researchers have shown that previous motor experiences influence mirror neuron activation (Calvo-Merino et al., 2006), which one would assume would influence the ability to learn from the demonstration. Specifically, Calvo-Merino et al. showed that professional ballet dancers had greater neuronal activity when watching gender-specific dance actions (male watching a dance action performed by both females and males) as compared to opposite-gender dance actions (male watching a dance action only performed by females). They explained these findings through the fact of their greater motor experiences with those dance actions. Knowing this, selection of the sex of the model was not expected to influence the learning of the skill selected here (pirouette en dehors) because it is a non-gender specific skill.

When. A question that has been posed throughout the literature is when should a model demonstration be shown to learners? The majority of experiments intersperse observation and physical practice, that is, the provision of observation both before and during practice (Ste-Marie et al., 2012). Weeks and Anderson (2000), for example, demonstrated that the volleyball serve was learned significantly better when observation was interspersed with physical practice, as opposed to having demonstrations solely provided before or only during practice. Similarly, Shea, Wright, Wulf, and Whitacre (2000) also showed benefits from interspersing physical performance and observation in the learning of a video game task. That is, during a 24-hour

retention test, participants who both physically practiced and observed a learning model performed similarly as participants who only did physically practice, and both of these groups outperformed the control group. Moreover, during a transfer test, participants who physically practiced and observed outperformed the physical practice only group, who outperformed the control group (see also Shea, Wulf, & Whltacre, 1999). These results not only show that learning is improved by the interspersed schedule, but also that less physical practice time is necessary when both observing a model and physically practicing a skill compared to physical practice alone. Practitioners may use this finding to increase motor learning when working with clients who are not physically able to perform movements often. It can also be used by athletes to avoid fatigue and allow for more rest and recovery during practice sessions without hindering learning.

These findings of the advantages of interspersed observational and physical practice have been explained in varied ways. Weeks and Anderson (2000) for example, borrowing from the ideas of Bandura (1986), hypothesized that observing a skilled model before physical practice can create a cognitive representation of how to do the task, and observing the model throughout physical practice allows the learner to update this cognitive representation through trial and error processes.

Alternatively, Ong and Hodges (2012) proposed that interspersing physical and observational practice is beneficial as it allows two types of processing to occur. Observation, they argued, allowed for explicit, strategy driven learning to occur whereas physical practice allowed for implicit, motor driven learning to occur. The implicit processes acquired through physical practice are thought to be acquired more slowly but be more robust than explicit processes. It was also suggested by Ong and Hodges that interspersing physical practice and observation may increase the motivation during practice, as it could make practice more

interesting and meaningful to learners. Regardless of the reasons for the greater learning acquired by an interspersed observational and physical practice, it is evident that combining these forms of practice is the best for motor learning, as compared to each practice form being used on its own. What is still unclear, though, is what is the best relative scheduling of these two forms of practice? This type of question deals more with the 'how' component of the applied model, described next, and is tightly tied in with the present research.

How. Relatively few experiments have been conducted to examine features related to the 'how' section of the applied model. Within this section, angle at which a model is viewed, speed of video demonstration, and modeling frequency were of interest. With respect to viewing angle of a model, three angles have been examined in the literature. The subjective view involves the learner being behind the model; the objective view involves the learner facing the model; and the looking glass view involves the learner facing the model, but the model is presenting a mirrored demonstration of the learning task (as if the learner was looking in a mirror at oneself) (Ste-Marie et al., 2012). It has been suggested that relative to the subjective view, the objective and looking glass views allow for deeper cognitive processing leading to superior learning through a stronger cognitive representation (Ishikura & Inomata, 1995). It was also suggested that a subjective view may allow for faster skill performance and acquisition, but at the expense of relatively permanent learning and a strong cognitive representation of the skill being learned (Ishikura & Inomata, 1998). An objective view was used in the present experiment in aim to increase the cognitive representation of the learning task.

Ste-Marie et al. (2012) highlighted that little research has been conducted concerning the frequency of model presentation, and thus it can be considered a research gap in the observational learning literature. To my knowledge, only three studies have been conducted with

applied tasks in which video frequency was the independent variable (Fagundes et al., 2013; Sidaway & Hand, 1993; Wrisberg & Pein, 2002). Sidaway and Hand (1993) carried out the first experiment, in which there were four experimental conditions of model video frequency: (1) 100% where participants observed a video prior to every physical attempt, (2) 20% where participants watched one video then completed five physical attempts, (3) 10% where participants watched a video then completed ten physical attempts and (4) a control in which no model was provided. The learning task was to hit a whiffle ball onto a target. It was found that the 100% frequency group performed significantly better than all other groups on a 24hr-delayed retention test, with the 10% group showing no significant differences from the control, and the 20% group marginally better than control (p = .08). These results thus lead to the conclusion that 100% frequency of modeling was the optimal frequency to be used. This was however a bold conclusion to draw given the large gap in the frequencies examined; i.e., a difference of 80% between the two highest frequency schedules. Also, a limitation to this experiment was that the absolute number of practice trials was not consistent across the different frequency conditions. All participants performed 150 physical practice trials, but the number of observational trials differed per group such that the 100% had 150 observational trials, the 20% group had 30, and the 10% group had 15. Observation of a demonstration, however, should be considered as a practice trial as there is opportunity for learning to occur much like that in a physical performance trial (Ong & Hodges, 2012). Thus, when combining the two types of practice trials, participants in the 100% group received 300 practice trials as compared to just 180 trials (20% group) and 165 trials (10% group), which may have contributed to the increased learning demonstrated by this group. This confound needs to be addressed in future research on observation frequency.

Another experimental paradigm that has been used which also provides information concerning modeling frequency is that of self-controlled learning. These experiments involve allowing participants a choice within the learning environment, as opposed to the experimenter's control over that variable. It has been suggested that providing choice to learners results in more active participation in skill acquisition, which may increase motivation and effort invested in practice (Wulf, 2007). Further, self-control over an aspect of practice may make practice better suited to learners' needs and preferences and results in greater cognitive processing as compared to experimenter-controlled practice (Carter, Carlsen, & Ste-Marie, 2014; Chiviacowsky & Wulf, 2002).

The first researchers to examine the impact of choice over observation frequency were Wrisberg and Pein (2002). They tasked participants with learning a badminton long serve under one of three experimental conditions: 100% frequency, self-control of amount of frequency, and a control group with no model observation. The findings showed no significant difference between the 100% frequency group and the self-control group, who both outperformed the control group. While at first glance this may not seem surprising, it is when one considers that the self-control group only chose to watch the model on an average of 9.8% of acquisition trials. Such results contrast with Sidaway and Hand's research that showed a 10% frequency of modeling to show no learning benefits and that such a low frequency was significantly different from that of a 100% group.

One can then ask, why does this low frequency of modeling enable learning within Wrisberg and Pein's experiment? Wrisberg and Pein argued that the self-controlled learning environment contributed to the learning advantages of a low frequency observation group, as well as the lack of differences between this group and the 100% frequency group. A limitation to

this experiment, however, was that no yoked group (a group receiving the same observation schedule and frequency as the self-control group, but without the aspect of control) was included in the experimental design. This is problematic because without this yoked group, it could not be concluded whether the learning benefits attained by the self-control group were in fact due to the aspect of self-control over the modeling frequency, or whether the differing frequencies between the self- and experimenter-controlled groups simply did not impact learning.

This result of a low self-controlled frequency of modeling being effective for motor learning has been replicated. Wulf et al. (2005), for example, also found that when given choice over when to observe a skilled model performing a basketball jump shot, participants chose to observe the model on only 5.8% of trials. Further, they included a yoked group to address the limitation of the lack of a yoked group in Wrisberg and Pein's (2002) experiment. By adding this yoked group, Wulf et al. were able to determine whether the choice provided over the frequency of observation was an important learning variable, and this was in fact the case; that is, the self-controlled group learned the task better than the yoked group. Similar results were found for learners performing an aiming task; participants decided to watch a self-observation video (i.e. video feedback of their just executed throw) after only 11.15% of acquisition trials, which again is a relatively low frequency (Janelle et al., 1997). More recently, when learning a golf chip putt participants self-selected to observe a split-screen of a skilled model and self-observation on only 9% of trials (Post, Aiken, Laughlin, & Fairbrother, 2016).

There are, however, other experiments in which participants have been shown to self-select higher frequencies of modeling. While learning skills on a double mini-trampoline, children selected to watch a self-observation video on almost 30% of trials (Ste-Marie et al., 2013). This higher frequency of modeling may have been due to the fact that the participants

were progressing though several skills of increasing difficulty throughout the experiment, and thus may have watched a video multiple times whenever they progressed to a new skill. It is also important to note that the population studied in that experiment was children, and thus cannot be directly compared to the adult populations in the other experiments discussed previously. The second experiment was completed by Aiken, Fairbrother, and Post (2012), and here participants selected to use video feedback in the form of self-observation after 27% of trials. While this frequency is higher than the range of 6-12% selected previously by adult participants, it is still low compared to the frequency of 100% deemed optimal by Sidaway and Hand (1993), and thus further research is warranted.

Overall, the average frequency chosen by self-control participants in the majority of these experiments is very low. Considering Sidaway and Hand's (1993) results of 100% frequency being superior to a 10% frequency group, it is unknown whether imposed constraints which encourage learners to use a higher observation frequency under self-selected scheduling would help to optimize the learning situation. Recent research by Fagundes et al. (2013) has suggested that higher self-selected frequencies could be better. In that research, the researchers combined self-control and frequency of modeling, however, choice was over the number of video demonstrations (2 vs. 6 presentations). The experiment included four experimental conditions: self-controlled with 2 video presentations, experimenter-controlled with 2 video presentations, self-controlled with 6 video presentations, experimenter-controlled with 6 video presentations This experiment not only measured physical performance of the learning task (a ballet passé relevé), but also included a cognitive representation measure. In retention, there were no significant differences between any groups for physical performance scores. However, the self-control groups' cognitive representation scores were significantly better than the experimenter-

controlled groups. Further, those who observed six demonstrations showed a better cognitive representation of the ballet movement than those who only viewed two demonstrations. These results align with those of Sidaway and Hand in that a higher amount of modeling lead to superior learning than a lower amount of modeling, thus providing more evidence for the need of an experiment to examine relatively higher frequencies of modeling under self-control.

There were, however, a number of limitations to this experiment. First, participants in the 2 model viewing groups only observed the model prior to physical practice began, but the participants in the 6 model viewing groups observed the model both before and during physical practice. This could explain the superior cognitive representation in participants who viewed the model six times as participants were able to update their cognitive representation throughout the experimental protocol. Another limitation of this experiment was that participants only completed fifteen physical practice trials, which is a very low number of trials for acquisition. A final factor to consider was that participants were only given choice at one time point between either two or six presentations. More often, in learning situations, choice can be provided throughout the practice session, and thus more research concerning learners being provided with choice over the use of a peer-skilled model video is warranted.

In summary, throughout the literature, it has been widely confirmed that the use of observation through peer-skilled modeling is beneficial for motor learning. There is, however, little information in the literature pertaining to the optimal frequency of model presentations for motor learning and that which is available has produced conflicting results. That is, when frequency was the only variable examined, a higher percentage of modeling was found to be beneficial (Sidaway & Hand, 1993), yet when learners were given choice over the frequency of model presentation, relatively low frequencies of model presentation have been found to lead to

similar learning outcomes as that of a 100% modeling frequency (Janelle et al., 1997; Wrisberg & Pein, 2002; Wulf et al., 2005). This conflicting evidence leads one to question whether a learner who is provided choice over when to observe a demonstration would learn even better if they were guided toward a higher frequency of observation.

This question becomes even more relevant in light of the fact that it has been shown that learners do not always know how to use self-control most effectively (Carter & Patterson, 2012; Carter et al., 2016; Flowerday & Schraw, 2003). This was first demonstrated when participants who were given choice over length of study time of a fictional story prior to answering essay-type questions about said story selected to study for about half of the amount of time that was imposed on an experimenter-controlled group (25.6 minutes versus 45 minutes respectively) (Flowerday & Schraw). Although interest levels in the story and task did not differ between groups, suggesting that both groups were engaged in the task, the self-control group performed significantly worse on the essay questions. Additionally, older adult participants did not experience the benefits of self-controlling the pace of knowledge of results feedback while completing a force production task (pushing a low-friction slider across a horizontal rail with a goal distance) when compared to younger adults (Carter & Patterson). Importantly, there were no differences in frequencies of requests for feedback between groups. That is, although older adults self-selected the same amount of feedback as the younger adults, their learning outcomes were significantly worse compared to the younger adults. These experiments provide evidence that participants may not be using effective strategies to self-control an aspect of their learning environment. In fact, Carter et al. (2016) performed an experiment that produced results which demonstrated that some participants engage in more effective self-control strategies than others,

and that being able to select these more effective strategies may be a contributing factor for the benefits of self-controlled learning.

Consequently, it is possible that participants given choice, but with the constraint of using a higher frequency of modeling than that whish is typically selected by participants (i.e., 10%), would lead to better learning than when participants are given choice with no such constraints. To date, no research has examined this possibility. Thus, my research question was: What is the optimal frequency at which to observe a skilled model under self-controlled learning conditions for the learning of a novel motor skill?

In the present experiment, participants were required to learn a pirouette en dehors. All participants were able to choose when they would like to observe the model with the constraints of (1) 25% model frequency, (2) 50% model frequency, (3) 75% model frequency, or (4) no constraint over model frequency. Given that the literature has consistently shown that a combination of observation and physical practice is superior to physical practice or observation only (Al-Abood et al., 2001; Catina, 2009; Lee & White, 1990; Rohbanfard & Proteau, 2011), these control groups were not included in the design. Cognitive representation and physical performance assessments were administered throughout the experimental design to explore the varied self-controlled frequencies for both performance (acquisition data) and learning (pre-test vs. post-test data). Due to the conflicting nature of the previously reported results (100% frequency of modeling is beneficial under experimenter-controlled conditions but low frequencies ranging from 6-12% are beneficial under self-controlled conditions), the present experiment was exploratory in nature. However, based on the aforementioned literature, it was hypothesized that the no-constraint self-control group would select a low frequency of modeling, likely around 10% of trials. This would then allow for comparisons of model frequencies ranging

from 10-75%, thus addressing the gap noted in Sidaway and Hand's (1993) research. Moreover, the amount of practice confound noted in Sidaway and Hand's research was also addressed by ensuring that all participants received the same number of practice trials regardless of experimental conditions.

Chapter 3: Method

Participants

Forty-eight students were recruited from the University of Ottawa. A power analysis was completed to determine the number of participants required to detect differences between the group should such differences exist (assumptions: probability (power) 0.8, type I error probability 0.05). Students with prior dance, gymnastics, or skating experience were excluded. This experimental design received approval from the Research Ethics Board at the University of Ottawa. Participants were required to sign consent forms prior to their participation in the experiment.

Materials and Task

Task. The learning task was a pirouette en dehors (Figure 2), which involved completing a 360-degree rotation on one foot. This turn was completed on the left leg, with the right leg lifted to the knee. This dance movement was chosen because it is a task which does not require previous training or skills specific to dance, such as flexibility, but was still challenging for the participants.

Figure 2. Visual depiction of the pirouette en dehors with proper sequencing from left to right.

Equipment. A video camera and tripod were use in the present experiment. A Lenovo Ideapad 310-15ISK laptop computer was used to play the skilled model video using Windows Media Player. Video recordings of participants were taken at a straight-on view such that the video camera was placed directly in front of the learners. These video recordings were saved for

physical performance assessment. This equipment was also used to create the skilled model video.

Modeling video. A peer-skilled model video of a female dancer performing a pirouette en dehors with no errors was used. Videos were shown from the objective view, where the model was facing the learner, as per the literature which has shown this to be a good viewing angle (Ste-Marie et al., 2012). All participants viewed the same modeling video.

Cognitive representation photos. The same dancer from the peer-skilled model video was displayed in the cognitive representation photos. There were two cognitive representation tests (forced-choice test and image selection test), both of which used still photos demonstrating different moments in time of the pirouette. For the forced-choice test, there was a selection of fifty photos of the pirouette en dehors, in which ten showed the proper execution of that time point of the skill and thus had no errors based on the key elements, whereas forty showed the dancer executing one error in the movement at that point of the skill.

For the image selection test, there were a variety of photos which included different time points of the pirouette en dehors (again, some with correct execution and others with incorrect execution). Some of the photos from the forced-choice test were also used in the image selection test. In addition, there were also a selection of photos of points in time of different turns in the dance repertoire which acted as distractor items. It is important to note that images were taken at various angles, and were not all from the straight-on view. This was done in attempt to capture different levels of development of the cognitive representation as it was assumed that participants who had a more developed cognitive representation would be better able to distinguish between correct and incorrect images regardless of the angle of the photo.

Procedure

Participants were recruited by word of mouth. The experiment took place in a small, quiet room that was free of obstruction such that the participants could safely produce the desired movement. All participants were involved in three phases of the experiment, which transpired over two consecutive days with the pre-test and acquisition phases occurring on Day 1, and the post-test on Day 2. Participants were randomly assigned to one of four groups, which were differentiated by whether there was a constraint (or not) imposed on the frequency at which they could observe the video demonstration. One group had no constraint imposed, whereas the remaining three groups had a modeling frequency imposed of either 25%, 50%, or 75% modeling frequency within the acquisition phase (more details provided in the acquisition phase section). To address the confound of unequal practice trials in Sidaway and Hand's (1993) research, all groups were provided the same number of practice trials. In the present experiment, the frequencies were relative to the number of observational trials to the total number of trials (more details provided in the acquisition phase section).

Pre-test phase. This phase involved three different components: (1) informational component, (2) physical performance component, and (3) cognitive representation component.

Informational component. Participants first received still demonstrations of three phases (beginning pose, mid-point of the turn, ending pose) of the pirouette en dehors with brief verbal instructions (see Appendix B for list of instructions). Next, participants were shown the skilled model video three times. For each video viewing, participants were cued to direct their attention to the positions of the arms, legs, and head at the beginning pose, during the turn, and the end pose. To elaborate, for the first video demonstration, participants were told to pay attention to the position of the arms, legs, and head at the beginning pose of the turn and to try to remember that

for when they went to perform the task. The second viewing involved the participants being told to focus on the position of the arms, legs, and head during the turn and at the end pose of the turn, and the third demonstration had them focus on those body parts for how to finish the movement. Following this, participants received a one-minute study period to read the list of twelve key elements upon which they were evaluated (Appendix C). They were told that this list of elements comprised a perfect pirouette, and that it was the list of elements that the evaluators would be using to score their video recordings. Participants were informed when 30 seconds of the study period remained.

Physical performance component. To provide a baseline measure of physical performance, participants completed a physical performance assessment which was comprised of three physical attempts of the pirouette which were video recorded. Participants were instructed to attempt to pirouette to the best of their ability. No augmented feedback was provided to the learners after these trials.

Cognitive representation component. Next, participants completed the two cognitive representation assessments, beginning with the forced-choice test. For this test, two images of someone doing a pirouette en dehors were presented on a computer screen for three seconds using PowerPoint (Busemeyer, 1985). One image demonstrated the model performing the pirouette with no errors in accordance with the key elements, and the other image depicted the model performing the pirouette with one error. Ten pairs of photos were presented during the forced-choice test. Participants made three decisions per photo pair: (1) which side depicted the error (the photo on the right side of the screen or the one on the left side), (2) which body part was making the error, and (3) what the error specifically was (Figure 3). Responses were provided verbally, and researchers recorded the response as either correct or incorrect.

A **B**

Figure 3. Example of what is depicted in the forced-choice test. In this example, image A is incorrect, the legs are making the error, and the error is that the right leg should be extended back (as shown in the first image of the sequence in Figure 2)

Four photo sets were created (labeled as photo set A, B, C, and D) and the photo sets were counterbalanced across participants within the four experimental groups. A counterbalancing procedure was used because the cognitive representation tests were administered at four different time points during the experiment, and thus it was important to ensure that any differences in scores seen across the different phases of the experiment were related to the time point in which the cognitive representation occurred and not due to variations in the difficulty of decisions associated with a particular photo set. Thus, every labeled set rotated through all time points in which the cognitive representation assessment was administered. For example, if the first participant in the 25% group used photo set A for the pre-test cognitive representation assessment, then the next participant randomly assigned to the 25% group used photo set B, the third used photo set C, and the fourth used photo set D, and so on. No feedback was provided to the participants with regard to their responses.

The second cognitive representation assessment was the image selection test. The 36 cards, which consisted of still images of the dancer, were placed in a 6x6 card array on a table in front of the participant. Six of the photos were of the dancer at different moments in time while

doing the pirouette en dehors with all of the twelve key elements performed correctly. The other thirty photos were distractor images in which the dancer was either executing a dance turn that was not the pirouette en dehors, or, it was the pirouette en dehors, but not all of the key elements were being executed correctly. Participants were instructed to select the six correct images of the pirouette en dehors and that they were allowed to touch and move the cards however they pleased. Two minutes were allotted to complete this task, and participants were provided with updates on time remaining every 30 seconds. No feedback was provided in terms of the accuracy of the images selected.

Acquisition phase. The acquisition phase consisted of a total of 60 self-paced practice trials of the pirouette over four blocks of 15 trials. It is important to note that both a physical attempt and an observation of the model video were considered as a practice trial. Thus, while each group was allotted the same number of practice trials, they varied in terms of the relative proportions of physical versus observational practice trials based on experimental group. As an example, participants in the 25% modeling frequency group were assigned 15 observational practice trials intermixed with 45 physical practice trials and were able to choose how they would like to schedule these trials. Similarly, participants in the 50% modeling frequency group had 30 observational practice trials intermixed with 30 physical practice trials, and the 75% modeling frequency group had 45 observational practice trials intermixed with 15 physical practice trials. To ensure participants were aware of the number of physical or observational trials remaining, an experimenter tracked the number of each type of trial completed on a blackboard that was in full view for the participants (see Appendix E for example). As well, all participants were informed when they had five trials remaining in a block. Participants in the self-control with no-constraints group were simply told that they could schedule practice

however they wanted, and that they could watch the video or physically practice the pirouette as many times as they would like within the total 60 practice trials.

After every block of 15 trials, participants completed a physical performance assessment, which, similar to pre-test, consisted of three video recorded attempts of the pirouette. After the first physical performance assessment during acquisition, participants received augmented feedback in the form of knowledge of performance (KP) from a researcher with over 15 years of dance experience. This KP was provided on a score card in which participants were informed about their performance relative to the first six key elements (see Appendix G). Participants also received KP feedback after the second physical performance assessment about the last six key elements of the dance skill. These score cards were studied for thirty seconds. No feedback was provided after the third and fourth physical performance assessments as it has been shown that feedback is most beneficial early in practice and that feedback at the beginning of practice can produce relatively long term changes in movement patterns (Bilodeau, Bilodeau, & Schumsky, 1959). Participants also completed the cognitive representation assessments after blocks one, two, and three, following the same procedures as those described in the pre-test.

After completing the acquisition phase, participants were asked: “Why did you choose to schedule practice the way that you did?”. As well, throughout acquisition, a researcher recorded the participants’ practice schedule. That is, they recorded on which trials participants observed the modeling video and on which trials participants physically practiced the pirouette (see Appendix H). At the end of Day 1 of the experiment, participants were asked not to practice the pirouette en dehors during the time between leaving the laboratory and returning for the post-test.

Post-test phase. A post-test was completed approximately 24 hours after completion of the acquisition phase. No reminders of the 12 key elements were provided, either by video or study sheet prior to them beginning the two components of the post-test. Participants again completed three physical attempts of the pirouette with no KP provided, which were video recorded. This was followed by the two cognitive representation assessments.

Dependent Measures

Physical performance. Participants were given a physical performance score ranging from 0-12 based on their ability to execute the key elements. These elements (Appendix D) were created by a dance teacher with over twenty-five years of experience and who completed the teaching program at the National Ballet School of Canada. All physical performance assessments were recorded on video and sent to two judges with dance teaching experience who were blind to the condition in which the participant was assigned. Judges used a marking grid to score the videos (see Appendix F for example). The order of the trials was randomized on the videos in order to avoid possible biases associated with judges' expectations that the performance would improve throughout the practice session. Physical performance scores were generated by first averaging the scores of the three trials in the physical performance assessments to create a mean score from each judge. Next, the scores from both judges were averaged to compose one physical performance score for each assessment phase: pre-test, blocks 1-4 in acquisition, and post-test.

Cognitive representation. The forced-choice test was scored by giving one point for a correct response and a score of zero for an incorrect response. Participants had the ability to receive a score from 0-10 on each decision (which side had the error, which body part was making the error, what the error was) at each time point throughout the experimental protocol.

For the image selection test, among the array of 36 photos, there were six that should be selected to make up proper execution of the pirouette. A score of zero was given if an incorrect photo was selected, and a score of one was given if a correct photo was selected, resulting in a possible score that could range from 0-6.

Correlation scores. A correlation matrix was performed to determine whether a link existed between physical performance and cognitive representation measures. Scores for all dependent measures were analyzed across all time points.

Chapter 4: Results

Preliminary Analyses

Descriptive statistics were run to explore the data. Box plots were used to identify any outliers and all statistical analyses were run both with and without the outliers included. There were no changes to any of the significant findings whether the outliers were included or not, therefore the outliers remained in the analyses. The assumption of normality was violated, however the ANOVA is highly robust to non-normality when there are more than ten participants per group (Norman, 2010), and thus we proceeded with this test. If Mauchly's Test of Sphericity was violated, a Greenhouse-Geisser correction was applied. Post-hoc analyses were completed using Bonferroni corrected t-tests for any significant main effects or interactions. This test was selected as it is reported to be the best for conserving both type I and type II errors when the number of comparisons is low, which was the case here (Bender & Lange, 2001).

Evaluators' inter-rater reliability was determined using a two-way random, consistency, single-measures intra-class correlation (ICC) to measure consistency in physical performance scores. This analysis was conducted at the level of each of the 12 elements that comprised the total score to ensure consistent ratings across every aspect of physical performance. It was determined that the evaluators had a high degree of agreement, ICC = .924.

Acquisition

Cognitive representation: forced-choice. To examine the acquisition data, a 4 Group (NC, 25%, 50%, 75%) x 3 Time (block 1, 2, 3) x 3 Decision (side, body part, error) mixed analysis of variance (ANOVA) with repeated measures on the last two factors was performed. There was a significant main effect of Time $F(2, 88) = 8.13$, $p < .001$, $\eta_p^2 = .156$, as well as a significant main effect of Decision, $F(1.28, 56.21) = 165.58$, $p < .001$, $\eta_p^2 = .790$. These main effects, however, were superseded by a significant Time x Decision interaction, $F(3.05, 134.10)$

= 3.59, p = .015, η_p^2 = .075. Post-hoc comparisons revealed that the interaction was driven by the lack of difference in participants' scores on the decision of which image contained the error (side) across the different time points, but the decisions concerning body part and error did differ across time points. Specifically, body part decisions were more accurate in block 2, p = .008, and 3, p = .001, than at block 1, and scores at blocks 2 and 3 were not different from each other. The same trend was evident for the decision of error whereby scores were higher at block 2, p = .015, and 3, p = .001 than they were at block 1 (refer to Figure 4). No other main effects or interactions were obtained, all p-values > .05.

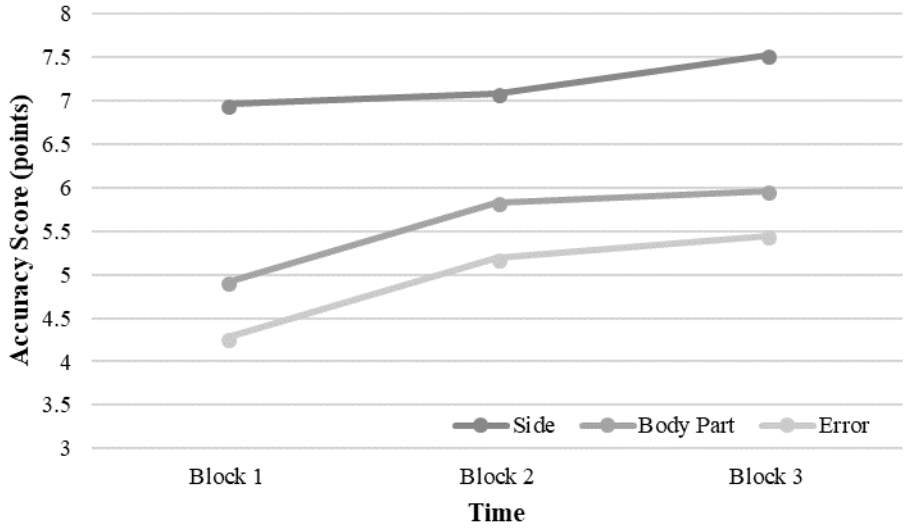

Figure 4. Average scores (max = 10), collapsed across groups, for the three decisions of the forced-choice test.

Cognitive representation: image selection. Acquisition data was analyzed using a 4 Group (NC, 25%, 50%, 75%) x 3 Time (block 1, 2, 3) mixed ANOVA with repeated measures on the last factor. There was a significant main effect of Time, $F(2, 88) = 7.41$, p = .001, η_p^2 = .144. Post-hoc comparisons revealed that scores at block 3 (M = 3.44 (1.219) points) were significantly higher than block 1, (M = 2.69 (1.170) points) p < .001, but that block 2 was not

significantly different than blocks 1 or 3. The main effect of Group and the Group x Time interaction were non-significant, $p > .05$.

Physical performance. Scores obtained from the judges analyzed using a 4 Group (NC, 25%, 50%, 75%) x 4 Time (block 1, 2, 3, 4) mixed ANOVA with repeated measures on the last factor. Again, there was a significant main effect of Time, $F(3, 108.9) = 19.14$, $p < .001$, $\eta_p^2 = .303$. Post-hoc tests indicated that participants' scores were significantly higher at blocks 4, 3, and 2 than at block 1, $p < .001$. Further, participants scored significantly higher at block 4 than they did at block 2, $p = .030$, but block 3 did not differ from blocks 2 or 4 (refer to Figure 5). No main effect for Group or interaction was obtained.

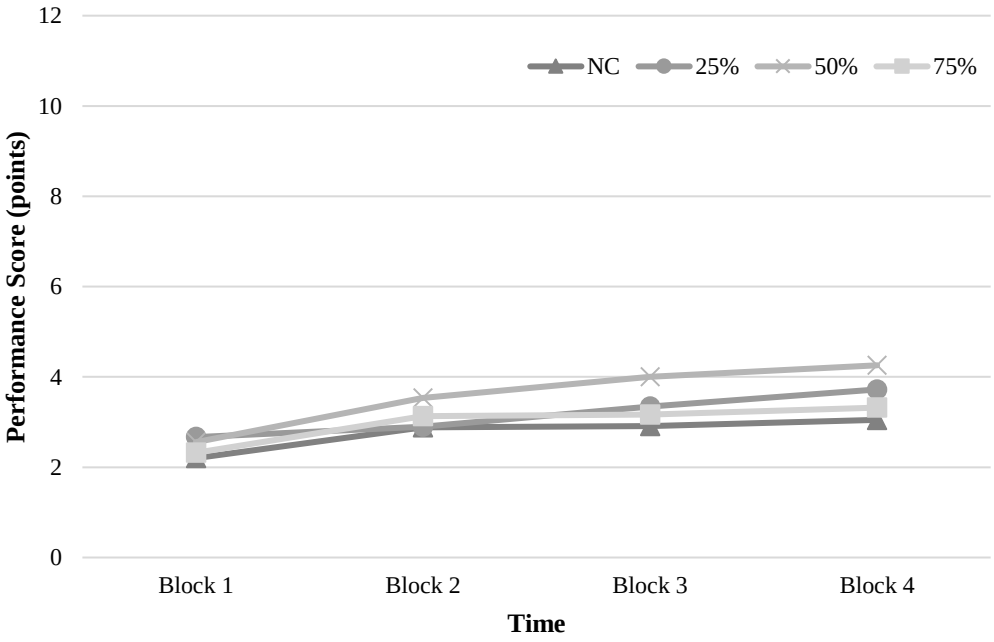

Figure 5. Average scores (max = 12) for the physical performance assessments for the four experimental groups throughout acquisition.

No-constraint group frequency selection. Participants in the no-constraint group selected to observe the model video on an average of 50.28% of trials, with a range from 18.33%-93.3%. The distribution of frequencies is displayed in Figure 6.

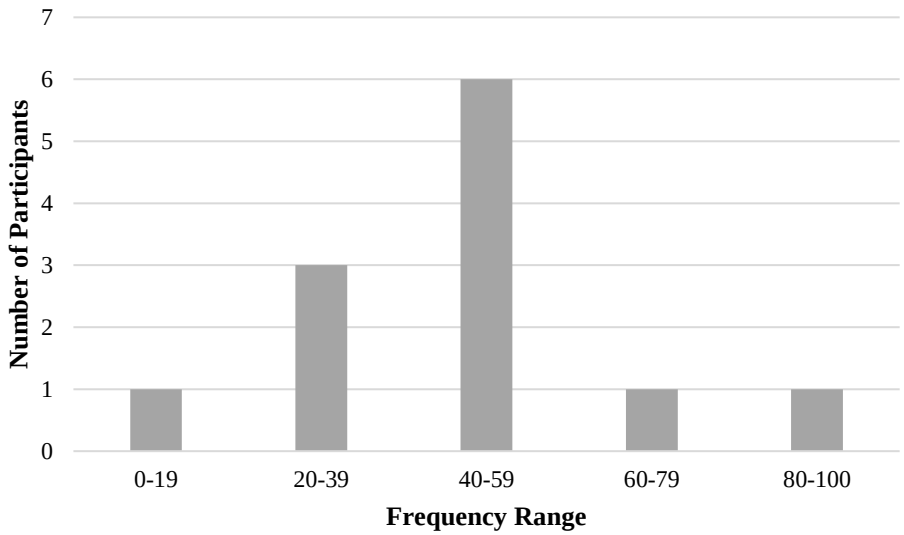

Figure 6. Number of participants in the no-constraint group who selected varying frequency of modeling ranges.

Practice scheduling. Data concerning the schedule adopted by learners was tracked during the acquisition phase. Table 1 shows the number of trials in which participants chose to observe the skilled model video. As a reminder, each group had a different number of observation trials what they were to schedule across the 60 trials as follows: 25% group were to schedule 15 trials, 50% group were to schedule 30 trials, 75% group were to schedule 45 trials, and the no-constraint group were free to choose the number of observation trials.

Table 1

Mean Number of Observational Practice Trials During Each Practice Block Across the Four Experimental Groups

Group	Block 1	Block 2	Block 3	Block 4
25%	5.00	3.17	3.83	3.00
50%	9.08	6.83	7.17	6.92
75%	10.64	9.64	12.00	12.73
No-constraint	7.92	7.75	7.08	7.50

Learning

Cognitive representation: forced-choice. Learning data was analyzed using a 4 Group (NC, 25%, 50%, 75%) x 2 Time (pre-test, post-test) x 3 Decision (side, body part, error) mixed

ANOVA with repeated measures on the last two factors. Similar to the acquisition data, there was a significant main effect of Time, $F(1, 44) = 72.14$, $p < .001$, $\eta_p^2 = .621$, as well as a main effect of Decision, $F(1.42, 62.30) = 120.79$, $p < .001$, $\eta_p^2 = .733$ (refer to Table 2). Both of these main effects were superseded by the Time x Decision interaction which was significant, $F(1.53, 67.48) = 7.00$, $p = .004$, $\eta_p^2 = .137$.

Table 2

Average Scores (max = 10) of All Participants for Each Decision of the Forced-Choice Test at Pre-Test and Post-Test

Decision	Pre-test	Post-test	**Average**
Side	6.10 (1.789)	7.35 (1.537)	6.80 (.884)
Body	4.19 (1.818)	5.96 (1.611)	5.08 (1.252)
Error	3.42 (1.843)	5.48 (1.762)	4.45 (1.457)
Average	4.57 (1.380)	6.26 (.971)	

While the scores for each decision type were significantly different from pre- to post-test, the magnitude of the change was different across the three decisions. This was determined by a simple effects test that was completed on the change scores, which were calculated by subtracting the pre-test score from the post-test score, followed by a Bonferroni corrected multiple comparisons post-hoc analysis. Specifically, it was revealed that the change score for the decision concerning side was significantly lower than both the decision of body part, $p = .039$, and error, $p = .014$; however, the change scores for the decisions of body part and error were not significantly different from each other (refer to Figure 7).

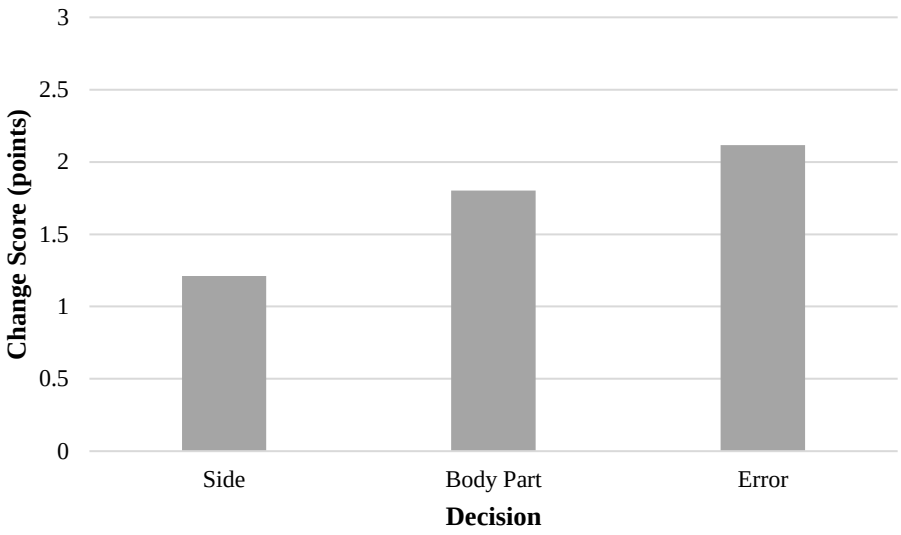

Figure 7. Mean change scores of decisions from post- to pre-test collapsed across experimental group.

Cognitive representation: image selection. To examine the learning data, a 4 Group (NC, 25%, 50%, 75%) x 2 Time (pre-test, post-test) mixed ANOVA with repeated measures on the last factor was performed. Again, there was a significant main effect of Time $F(1, 44) = 39.09$, $p < .001$, $\eta_p^2 = .470$. Participants scored higher at post-test ($M = 3.21$ (1.166) points) than they did at pre-test ($M = 1.896$ (1.189) points), $p < .001$. The main effect of Group and the Time x Group interaction were non-significant, $p > .05$.

Physical performance. The learning data was analyzed using a 4 Group (NC, 25%, 50%, 75%) x 2 Time (pre-test, post-test) mixed ANOVA with repeated measures on the last factor. Figure 8 shows the pre- and post-test scores for each of the four experimental groups. The analysis revealed a significant main effect of Time $F(1, 44) = 120.43$, $p < .001$, $\eta_p^2 = .732$. Physical performance scores were significantly higher at post-test than they were at pre-test, $p < .001$ (refer to Figure 6). The main effect of Group and the Time x Group interaction were non-significant, $p > .05$.

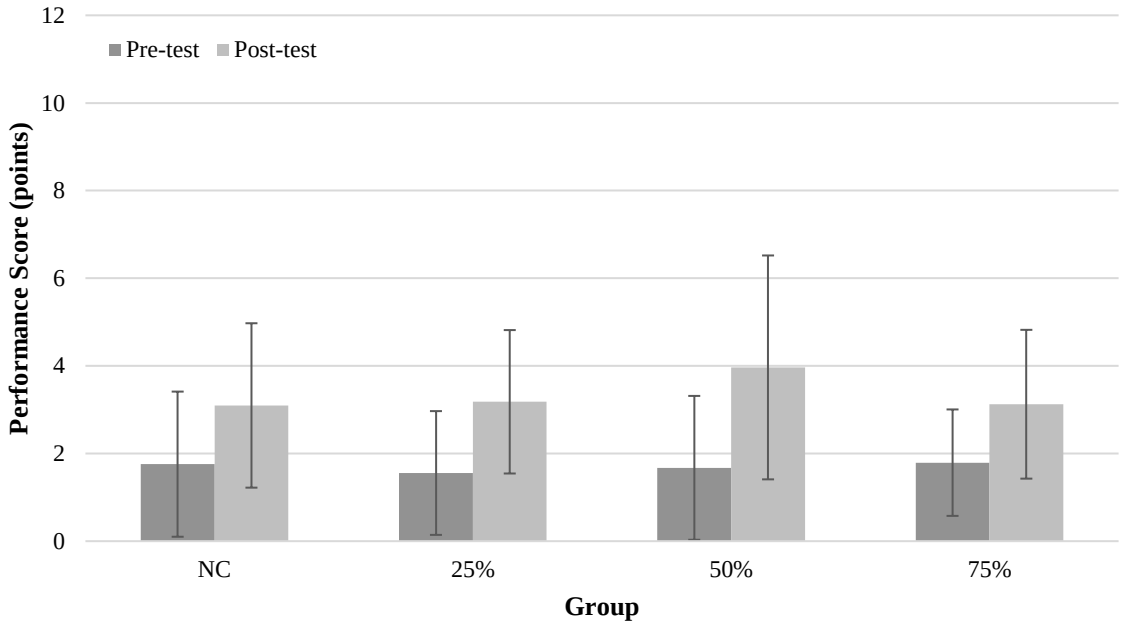

Figure 8. Average scores out of 12 on the physical performance tests at pre- and post-tests of all experimental groups. Error bars represent standard deviation.

Correlation

A correlation matrix using Pearson's correlation was performed on all dependent measures. Of most interest were the correlations between cognitive representation scores and physical performance scores at both the same time point as well as the subsequent time point; as an example, cognitive representation scores of block 1 were compared to physical performance scores at blocks 1 and 2. It was found that accuracy scores of the forced-choice decisions, after block 1, were all significantly correlated with physical performance scores, with the exceptions of the decision concerning which image was incorrect (side) in the forced-choice test; this decision was not significantly correlated at block 2, nor at post-test, $p > .05$. Further, scores on the image selection test were significantly correlated with physical performance scores throughout acquisition, $p < .05$, and at post-test, $p = .051$. Table 3 shows the relevant correlation coefficients.

Table 3

Pearson's Correlation Coefficients of Cognitive Representation and Physical Performance Scores

	Block 1				Block 2				Block 3				Post-test			
Physical performance	Forced-choice			IS	Forced-choice			IS	Forced-Choice			IS	Forced-choice			IS
	Side	Body	Error		Side	Body	Error		Side	Body	Error		Side	Body	Error	
Block 1	.016	.159	.206	.338[a]												
Block 2	.045	.209	.204	.412[b]	.193	.371[b]	.451[b]	.305[a]								
Block 3	.149	.272	.343[a]	.451[b]	.321[a]	.532[b]	.599[b]	.357[a]	.363[a]	.447[b]	.452[b]	.410[b]				
Block 4	.201	.221	.243	.388[b]	.295[a]	.425[b]	.484[b]	.353[a]	.357[a]	.392[b]	.406[b]	.328[a]				
Post-test	-.023	.220	.193	.268	.298[a]	.363[a]	.455[b]	.273	.297[a]	.392[b]	.426[b]	.383[b]	.131	.309[a]	.322[a]	.284[c]

IS = image selection test

[a] is significant at $p < .05$

[b] is significant at $p < .01$

[c] $p = .051$

Chapter 5: Discussion

Learning motor skills in the most efficient way is of interest to many, such as researchers, athletic coaches, and rehabilitation specialists. Two ways to increase learning efficiency are through the observation of a model (Ste-Marie et al., 2012) and through providing the learner with choice over an aspect of practice, termed self-controlled learning (Wulf, 2007). These two learning techniques were combined to address a question that is still unclear; that is, "at which frequency should a model be observed under self-controlled conditions to optimize practice, and more importantly, learning?".

Throughout the literature there is conflicting evidence concerning the response to this question that is dependent on the experimental paradigm used. Under an experimenter-prescribed frequency schedule, it has been concluded that a higher frequency of modeling is more effective for motor learning, with a 100% frequency group learning a motor skill significantly better than those who observed under 10% and 20% schedules (Sidaway & Hand, 1993). When learners were given choice over when to observe a model, however, a low self-selected frequency of 6% allowed for similar learning outcomes as that of an experimenter-prescribed 100% modeling group (Wrisberg & Pein, 2002). Other experiments have also shown that participants who are given choice over when to observe a model during practice, select a relatively low frequency of modeling, ranging from 6-12% (Janelle et al., 1997; Post et al., 2016; Wulf et al., 2005).

Given that Sidaway and Hand's 10% group showed no benefits from observing at such a low frequency, the question remained as to whether learners are selecting the most optimal frequency at which to observe a model. It was questioned here whether increased optimization of these self-controlled observation conditions could occur by still providing choice to the learners, but imposing constraints within the practice that encouraged a higher frequency of observation than the 10% typically chosen by participants. The constraints imposed in this experiment

involved telling learners that they could control the scheduling of observational and physical practice within a practice session, but must observe a given percentage of the practice trials (25%, 50%, or 75%). A standard self-control group was also included in which no constraint was given, and it was hypothesized that this group would select a relatively low frequency of modeling (10%). With these four groups, it was anticipated that we could compare learning outcomes, via both cognitive representation and physical performance tests, across self-controlled modeling frequencies ranging from 10-75%.

Cognitive Representation Tests

McCullagh and Weiss (2001) suggested measuring learning in ways other than physical performance, such as the use of recognition or recall tests, to capture learning in the absence of improvements in overt actions of the individual. This recommendation is in line with Bandura's (1977) proposition that learners create a symbolic representation of the movement in their minds that is retained and used to guide subsequent action. Indeed, other researchers have reported changes in performance/learning throughout practice and at retention through the use of cognitive representation tests (Carroll & Bandura, 1987, 1990; Robertson et al., 2017). Thus, heeding this advice, two cognitive representation assessments were included in the present experiment: forced-choice and image selection. The use of two tests was done for two main reasons. First, because the sensitivity of the measures was unknown, it was thought that using two outcome measures made it more likely that we could detect changes to the participants' cognitive representations should any changes exist. Second, having two measures tapping into these possible changes in the cognitive representations would allow for corroboration of the data should both measures yield similar findings.

The main effect of Time for the image selection test suggested that a stronger cognitive representation was formed by the end of acquisition as participants were significantly more accurate in block 3 of acquisition with the selection of the correct images as compared to block 1.

The Time x Decision interaction (Figure 4) from the acquisition data of the forced-choice task also supports this notion of the cognitive representation becoming more developed during acquisition. More specifically, the results of the forced-choice test showed that participants could easily distinguish which of the two images contained the performance error, and that their capability to do this did not change over time. The decisions concerning the body part and the specific error, however, followed a different pattern. Here, participants first struggled to determine these features but were significantly better able to determine the body part making the error, and the specific error in question, as seen by a significant improvement in decision scores from block 1 to block 2, with accuracy maintained in block 3.

In line with Bandura's (1977) ideas, these improvements on the image selection and forced-choice tests are argued to reflect that the participants are building their cognitive representation of the movement. That is, throughout acquisition, participants were likely able to cycle through physical and observational practice trials where they could use proprioceptive cues gained from their own motor reproduction of the task, some augmented feedback, and the skilled model video in order to update the cognitive representation The lack of change in scores from blocks 2 and 3 for the forced-choice test suggests that any updates made to their cognitive representation after block 2 were not sufficient to produce changes with their decisions regarding the body part and specific error (Figure 4). With only 60 practice trials, however, participant may not have been able to update their cognitive representations enough to be able to discern the

actual errors of the images with a high rate of success. It is possible that scores on the forced-choice test could have increased with more practice after block 4, however cognitive representation assessments were not completed after that acquisition block, so this possibility could not be captured.

Although the acquisition data provided information about immediate changes for the cognitive representation, what is of more interest are the changes from pre- to post-test, because it provides information about the relative permanence of the learned skill (Kantak & Winstein, 2012). On both the image selection and the forced-choice tests (Table 2), participants' decision scores improved significantly from pre- to post-test, demonstrating learning on all aspects of the tests. For the forced-choice task, however, there was a significant Time x Decision interaction (Figure 7) whereby participants' scores on the decisions of body part and error improved more from pre- to post-test than the decision of side. This provides further evidence for the fine-tuning of the cognitive representation that may also have been occurring during acquisition. These more precise decisions of which body part was making the error and what the specific error was were arguably more difficult than distinguishing which photo contained an error. Overall, the improvement in decision scores from pre- to post-test are taken as evidence that the participants' cognitive representation of the movement developed through their observational and physical practice of the skill. Thus, both cognitive representation tests demonstrated improvement in scores over time, providing further evidence that interspersing observational and physical practice at different frequencies can generate improvements in motor learning.

A point to consider when interpreting the forced-choice test decisions is the probability of a correct response for each decision and how that may have affected the pattern of scores. The decision as to which image contained the error had a 50% probability of a correct answer

because there were only two options. Considering the decision of body part, during the pre-test participants were provided with attentional cues about the arms, legs, and head, and may have discerned that the decision of body part making the error would be one of these three options, thus leading to a 33% probability that participants would make the correct decision by chance. The decision concerning the specific error, however, was more difficult as participants were not made aware of the varied possibilities of errors and would need to generate these on their own. Taking this into account, it is noted that during the post-test, participants were effectively able to select the incorrect image almost 75% of the time, had a greater understanding of the body part making the error with 60% correct decisions, and had started to determine the specific errors in performance (55% decision accuracy). Given these findings, although participants could have been providing correct answers to the forced-choice test decisions by chance, we argue that participants' scores were increasing due to the development of a cognitive representation as participants' scores did increase with time and practice.

It is interesting to note that no differences emerged in terms of the cognitive representation scores across the different constrained frequency groups. These findings do not align with those of Fagundes, et al. (2013) who had some participants determine whether they wanted to observe two or six demonstrations of a skill (or be provided two or six demonstrations if they were in the yoked groups). In their experiment, it was found that the groups with a higher frequency of modeling had better cognitive representation assessment scores than those with a lower frequency of modeling. This dissimilarity is likely explained by the different practice scheduling implemented within the two experiments. In the Fagundes et al. experiment, the groups that had a lower frequency of modeling only observed the model before physical practice, whereas the higher frequency group had the observational practice interspersed with their

physical practice. In our experiment, however, regardless of experimental condition, an interspersed physical and observational practice structure was used. Thus, it is possible that this interspersed schedule is necessary for the updating of one's cognitive representation.

Physical Performance Assessments

The development of a cognitive representation is believed to guide overt physical performance (Carroll & Bandura, 1982, 1987) and the results from the present experiment support this tenet of the social cognitive theory. Similar to the cognitive representation data, participants received low physical performance scores at the beginning of acquisition but were able to improve these scores with practice. Specifically, there was a significant increase in physical performance scores between blocks 1 and 2, as well as between blocks 2 and 4 (Figure 5). This increase in physical performance scores across acquisition blocks is similar to the increase in scores of the cognitive representation tests, suggesting that the increases in cognitive representation scores may have been driving the increase in physical performance scores. In fact, once the first block of trials was done, most cognitive representation measures were significantly correlated with physical performance scores of the same block and the proceeding block (Table 3). Importantly, the error identification measure of the tests (the decision of what the specific error was) was most strongly correlated with physical performance scores, suggesting that this was the most sensitive measure of the two cognitive representation tests. Cognitive representation scores continue to be correlated with physical performance scores at post-test whereby the decisions of body part and error on the forced-choice test were significantly correlated with physical performance, and scores on the image selection test were nearly significant at $p = .051$ with physical performance. These consistent and significant correlations between cognitive representation and physical performance acquisition scores may support the

conjecture that the cognitive representation is in fact driving physical performance, yet it is known that no causation can be assumed with correlations so only a link between cognitive representation and physical performance scores can be concluded.

Turning to the learning outcomes, similar to the cognitive representation data, we see an increase in physical performance scores from pre- to post-test, indicating that motor learning occurred (Figure 8). These results again differ from those of Fagundes et al. (2013) in which no changes to physical performance scores during acquisition or from pre- to post-test were observed. In that experiment, however, the maximal amount of practice was 6 observational practice trials and 15 physical performance trials, which perhaps was not enough to elicit changes in physical performance. While our 75% frequency group also only received 15 physical performance trials, the observational practice received was much greater and likely contributed to the physical performance changes. Thus, even with relatively few physical practice trials, the combined use of these trials with an adequate amount of observational practice trials may be sufficient to drive motor learning.

No-Constraint Group

Although no specific hypothesis was proposed for the learning outcomes associated with the varied modeling frequency groups, it was hypothesized that the no-constraint group would select a relatively low frequency of modeling (approximately 10%). This hypothesis was not supported. Our no-constraint group, in fact, selected to observe the model on an average of 50% of trials, with a range of 18.3%-93.3% (Figure 6). While there have been other experiments where a self-selected frequency higher than 10% occurred (30% in Ste-Marie, et al. (2013) and 27% reported by Aiken, et al. (2012)) there are two important differences to consider. First, the

frequency of 50% selected by the no-constraint group here still exceeds these higher frequencies by over 20%.

The second point concerns the fact that both observational trials and physical practice trials were considered as ‘equal’ practice trials, which has not been the same method used in other experiments. Instead, other researchers would typically keep the number of physical practice trials constant and change the number of observation trials to determine the frequency (Aiken et al., 2012; Wrisberg & Pein, 2002; Wulf et al., 2005). Thus, a 100% frequency of modeling group would have an equal number of observational and physical practice trials, and typically with an alternating schedule (observation-physical-observation-physical, etc.). Given this methodology difference, our self-control no-constraint group selecting a frequency of 50% in our protocol would be similar to the previously reported 100% groups, which is dramatically higher than both the 5-12% range (Janelle et al., 1997; Wrisberg & Pein, 2002; Wulf et al., 2005) and the 27-30% reported in the literature (Aiken et al., 2012; Ste-Marie et al., 2013). Thus, not only did our results not support our hypothesis, but they are also drastically different from the literature.

The high frequency level selected by the no-constraint group was unexpected and may have occurred for a number of reasons. First, task characteristics may have affected this outcome. As an example, experiments which included throwing tasks (Janelle et al., 1997; Wrisberg & Pein, 2002) allowed for immediate feedback pertaining to the outcome of the task (i.e. hit the target or not), whereas no such feedback is available for the pirouette en dehors as there is no immediate outcome of the task. Further, tasks such as a basketball free throw or throwing a ball with the non-dominant hand are arguably more common than the pirouette en dehors, thus the novelty level of these tasks may be different to the participants. The difficulty

level of the pirouette en dehors, as reflected by mean group scores never exceeding 4.5/12, may have also influenced the frequency of modeling selected by the no-constraint group. Second, there were limited amounts of feedback provided to the participants in the present experiment. Participants only received feedback after blocks 1 and 2 and were presented with feedback on six key elements at once which may have overwhelmed the learners. Further, limited information was presented with the modeling video, differing from previous literature. In the present experiment, participants were given attentional cues while observing the model three times during pre-test, but subsequently were not provided information about the video leading to participants perhaps being unable to extract relevant information from the video. Past experiments where participants have selected these low frequencies of modeling have either provided information about what was being done incorrectly in a self-observation video (Janelle et al.), included a split-screen of a skilled model along with self-observation that was viewed both at normal speed and slow motion (Post et al., 2016), or were provided with multiple viewing angles of the skilled model (Wulf et al., 2005). The limited amount of information pertaining to task outcome and specific features of the modeling video may have led to participants in the no-constraint group selecting a high frequency of modeling. This idea is supported by the higher frequency of modeling selected by learners (27%) in the experiment by Aiken et al. (2012) as in that experiment learners were not provided with any additional feedback or information about the video being observed, much like in the present experiment.

As previously mentioned, both observational and physical trials were considered as practice trials in the present experiment, but this has not been the case throughout the literature. Thus, what was considered a 50% frequency in the present experiment (in both the constrained 50% group and the no-constraint group which self-selected about a 50% frequency) would be

similar to the 100% frequency group in Sidaway and Hand's (1993) experiment such that there were equal numbers of observational and physical practice trials. When considering this, our results refute those of Sidaway and Hand where it was found that 100% frequency of modeling was most beneficial, as there were no differences noted between our 50% and 25% frequency of modeling groups. Moreover, if calculating the modeling frequencies in the present experiment in a similar manner to the literature, our examined frequencies would be 33.3%, 100%, and 300% (25%, 50%, and 75% respectively). As such, we did not capture the lower frequency of 10% as originally intended, and further research is warranted to investigate such frequencies.

Self-Selected Practice Scheduling

As a reminder, participants' practice schedules were recorded throughout the acquisition phase. This was done because the practice scheduling data may have provided information about how participants were using the modeling video while attempting to learn the skill in an effective manner. Throughout the literature, participants with self-control over when to observe a modeling video have typically selected a faded schedule where the video was observed more during early acquisition, and was rarely used in late acquisition (Janelle et al., 1997; Post et al., 2016; Wrisberg & Pein, 2002; Wulf et al., 2005). Indeed, participants in the experiment by Wrisberg and Pein experiment selected to observe 82% of the model demonstrations during the first half of acquisition on the first day of two acquisition sessions. As seen in Table 1, our participants in the no-constraint group did not select a faded schedule. On average, these participants observed a model on 8/15 trials in blocks 1 and 2, and 7/15 trials in blocks 3 and 4. This group is most comparable to self-control groups in the literature because there was no constraint imposed, and the schedule selected by participants in the present experiment differs from what participants typically select throughout the literature where it seems as though

participants abandon the modeling video after the first half of acquisition trials (Aiken et al., 2012; Wrisberg & Pein; Wulf et al.). In experiments where a faded observation schedule was used by participants, perhaps practice was self-scheduled this way as participants used observation to guide early practice but used it less as they perceived themselves to be more proficient at the task as practice continued. If this is the case, it is likely that participants in the present experiment did not perceive themselves to be proficient at the task and opted to intersperse their observational practice trials all the way throughout acquisition. Perhaps if there was a longer acquisition period, with either more practice trials or practice over multiple days, this faded schedule would have been observed as there would have been more of an opportunity for participants to reach a more proficient skill level.

Limitations and Delimitations

There were some limitations and delimitations in the present experiment, as there is with all research. First, it is important to understand the difference between limitations and delimitations. A limitation is a constraint that is beyond the control of the researcher, and often flows from the methodology used. A delimitation differs in that it results from choices made by the researcher in the development of the study design (Simon & Goes, 2013).

To mention a few limitations, one concerns that we relied on the participants to be interested in accomplishing this task. This may not be the case, and thus, participants may not attend to the modeling video. Further, some participants in the no-constraint group selected to physically practice very few trials of the pirouette, which may indicate a lack of interest in the skill. Another area out of our control is the individual differences concerning motivational components of observation. Each group my have had participants that had little motivation to learn the skill due to the lack of reinforcement during acquisition, in line with Bandura's social

cognitive theory (1977). If some participants had more interest in completing the task than others, or had more motivation, some may have attended to the video more than others perhaps resulting in more information being extracted from the model by some participants.

Another limitation is associated with the use of correlation analyses. While it can be concluded that there is an association between cognitive representation and physical performance, it cannot be concluded from this analysis that increases in cognitive representation scores caused increases in physical performance scores. Finally, the self-control no-constraint group selecting a frequency of modeling of 50.28% limited the ability to compare the present results to the literature or compare frequencies ranging from 10-75% as hypothesized.

One delimitation to consider was the use of the pirouette en dehors as the learning task. This skill has not previously been used in the literature and the difficulty level of the skill may have influenced results. The use of the pirouette en dehors leads to another delimitation in that there was no objective measurement of physical performance, thus we had to rely on the subjective opinions of two evaluators to provide physical performance scores. A third delimitation of the present experiment was the inadequate amount of feedback provided to the learners. Perhaps learners would have been better able to use the modeling video with a higher amount of feedback which may have allowed for group difference to emerge.

Future Research

Recommendations can be made to guide future research which may address some of the limitations and delimitations mentioned above. First, future researchers may include more augmented feedback or varying types of feedback in their designs to allow learners to use modeling videos effectively. Second, it would be worthwhile to examine the same research question, but include a group constrained to lower frequencies of modeling; e.g., 10%. This

would allow for comparisons of learning outcomes of the pirouette en dehors between frequencies ranging from 10-75% where all participants are allowed self-control over practice scheduling within these constraints. Third, future research might include a different learning task, such as a badminton long serve (Wrisberg & Pein, 2002) or a basketball jump shot (Wulf et al., 2005), which has been previously used in the literature and captured group differences in frequency of modeling experiments. As no group differences emerged from the aforementioned data, the above recommendations may allow for these differences to emerge should they exist.

Conclusion

While providing varied constraints of modeling frequencies under a self-controlled learning environment was shown to be beneficial for the learning of a pirouette en dehors, no group differences emerged for any of the dependent factors. Thus, it can be concluded that under the self-controlled learning environment within this experiment, the frequencies of 25, 50, and 75 percent of modeling lead to learning gains in a dance skill that are relatively permanent, under conditions in which the modeling is interspersed with physical practice

These findings could be applied in sports settings either to reduce athlete fatigue or when working with an injured athlete. Coaches could allow their athletes to select how often to physically practice versus observe a skill to any frequency from 25-75% to allow for motor learning to occur. Moreover, these results could also be invaluable in rehabilitation settings. If clients are unable to physically perform a task time and time again due to physical limitations, or other reasons, they might benefit from observing a video more often than physically practicing, if they are provided with the choice over how to schedule this practice. Using this strategy, coaching sessions, rehabilitation sessions, and overall rehabilitation time could be reduced. For example, let’s assume that it takes 60 practice trials to learn a particular skill, but a client is only

able to physically perform 5 physical trials in one session; instead of having 12 sessions comprised of five physical trials, practitioners could introduce sessions that intermix both observational and physical practice and reduce the total number of sessions. Such a strategy could reduce the time and costs associated with motor learning and recovery.

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Appendix A

Ethics Approval

File Number: H04-17-19 **Date (mm/dd/yyyy):** 05/11/2017

Université d'Ottawa University of Ottawa
Bureau d'éthique et d'intégrité de la recherche Office of Research Ethics and Integrity

Ethics Approval Notice

Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

First Name	Last Name	Affiliation	Role
Diane	Ste-Marie	Health Sciences / Human Kinetics	Supervisor
Molly	Brillinger	Health Sciences / Human Kinetics	Student Researcher
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Hilary	Cotnam	Health Sciences / Human Kinetics	Research Assistant

File Number: H04-17-19

Type of Project: Master's Thesis

Title: Examining the optimal frequency of modeling under varied constrained choice conditions for the learning of a dance skill

Approval Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
05/11/2017	05/10/2018	Approval

Special Conditions / Comments:
N/A

Appendix B

Verbal Description of Pirouette en Dehors

The pirouette en dehors consists of doing a 360-degree rotation on one leg. For the beginning position, you will start with your right arm in front of your right shoulder, your left arm to the left of your left should. Your left foot will be in front of your body, right foot behind the body, and your knees will be bent. Your head will be pointing forward. *demonstrate beginning position* During the turn, your arms will bend to come in front of the body between the belly button and shoulders, and the right leg bends so the right foot is touching the right knee. Finally, your head will stay pointed at the front of the room for as long as possible, before whipping around to point to the front of the room again. *demonstrate turn position* At the end of the turn, your arms will come down beside your body. You will end with your weight on your right foot, left foot pointed to the side, and bent knees. Your head will be pointing forward. *demonstrate end position*

Appendix C

Key Elements Study Sheet for Participants

i) Beginning arm position
   i. Keep your right arm in front of your body at shoulder height
   ii. Keep your left arm to the side of your body at shoulder height

ii) Beginning leg position
   i. Have your left foot facing straight forward in front with your leg bent and your heel on the ground
   ii. Keep your right foot behind you, parallel with your front foot, with your right heel raised, and your right leg bent

iii) During the turn, keep your bottom leg very straight and strong

iv) During the turn, make sure your left heel is raised as high as possible

v) While turning, keep your right foot attached to the left knee

vi) During the turn, your head stays pointing to the front of the room for as long as possible before whipping around to point to the front of the room again

vii) During the turn, bring your arms in front of your body, with rounded elbows and your hands in between your chest and belly button

viii) 360-degree rotation completed in a clockwise direction

ix) Land by stepping onto a bent right leg, left foot pointed to side, arms by sides

x) Make sure to complete the pirouette on the longitudinal axis, with a controlled landing

Appendix D

Checklist of Key Elements for Judges

xi) Arms straight in fourth position

i. Right arm in front of the body at shoulder height (1 point)
   1. 1 point for arm straight and in front of the body
   2. 0.5 points for arm within 45˚ of in front of the body (ex: too far to the right so it is no longer in front of the body)
   3. 0 points for arm more than 45˚ away from midline or meeting both criteria for 2 or having arms in completely wrong position

Left arm to the side of the body at shoulder height (1 point)
   1. 1 point for arm straight and beside the body
   2. 0.5 points for arm within 45˚ of the body but shoulders are still square to the front (winding up arms but not shoulders)
   3. 0 points for arm more than 45˚ away from side, winding up shoulders,

If they have their arms in perfect fourth position but with the left arm in front (as if preparing for a left turn), give them 0 for 1a and 0.5 for 1b

xii) Feet in parallel fourth position

i. Left foot facing straight forward in front with heel on the ground and a bent leg (1 point)
   1. 1 point for left foot parallel and in front with heel on ground in plié
   2. 0.5 points for left foot in front with heel on ground and no plié, OR with plié but left heel raised, OR turned out but in plié and heel on ground (but no more than one of these)
   3. 0 points for more than one criterion in number 2, or anything else

ii. Right foot behind, parallel with front food, and with the heel raised (1 point)
   1. 1 point for right foot parallel, in the back, and heel raised
   2. 0.5 points for right foot to the side with the heel raised, OR for right foot in the back but heel on the ground (but not both)
   3. 0 points for both criterion in number 2, or anything else

If they have their feet in perfect fourth position but with the right foot forward (as if preparing for a left turn), give them a 0 for 2a and a 0.5 for 2b

xiii) Left leg straightens with pulled up hamstrings and quadriceps (1 point)
   1. 1 point for strong, pulled up supporting leg
   2. 0.5 points for lazy supporting leg
   3. 0 points for bent supporting leg

xiv) Left heel is raised high (1 point)
   1. 1 point for high relevé (use judgement for what a high relevé is for each person)
   2. 0.5 points for lazy relevé
   3. 0 points for flat foot

xv) Right leg at proper parallel retiré position, with the foot beside the left knee (1 point)
   1. 1 point for proper retiré position
   2. 0.5 points for foot attached to leg, but foot lower than knee (low reitré position)
   3. 0 points for foot not attached to leg, or for left leg lifted

xvi) Strong spot with head whipping quickly (1 point)

1. 1 point for strong spot
2. 0.5 points for attempted/weak spot OR for spotting in wrong direction (ex: to the stage left wall), but not both
3. 0 points for stiff neck (no spot whatsoever) or both from 2

xvii) Arms supported in first position, with rounded elbows and hands in between the chest and the belly button during the rotation (1 point)

1. 1 point for proper ballet first position
2. 0.5 points for arms too low/too high OR arms slightly too wide (but not both)
3. 0 points for both of the criterion in 2 or anything else

xviii) 360-degree rotation completed in outward right direction (1 point)

1. 1 point for full pirouette in outward right direction
2. 0.5 points for 360-degree rotation, but incorrect direction (inward right or turning to the left), OR for correct direction (outward right) but under- or over-rotating (but not both)
3. 0 points for both in 2 or anything else

xix) Land by stepping onto a bent right leg, left foot pointed to side, arms by sides (1 point)

1. 1 point for meeting above criteria
2. 0.5 points for having both legs straight, OR having weight on wrong foot, OR having arms other than down by sides (no more than one)
3. 0 points for more than 1 of any criterion in number 2, or for having weight on both legs

xx) Pirouette was completed on the longitudinal axis, with a controlled landing (1 point)

1. 1 point for meeting all above criteria
2. 0.5 points for uncontrolled landing, OR for rotating off axis (but not both)
3. 0 points for both in 2 or anything else

Appendix E

Example of Number of Trials Remaining Chart for 25% Modeling Frequency Group

Physical Practice Trials Remaining	Observational Practice Trials Remaining
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Appendix F

Physical Performance Scoring Grid

Key Element	Trial 1	Trial 2	Trial 3
Arms in fourth position: right arm in front of the right shoulder			
Arms in fourth position: left arm to left of the left shoulder			
Feet in fourth position: left foot parallel in front of body, left leg on plié			
Feet in fourth position: right foot behind body, heel raised, right leg on plié			
Left leg straightens, hamstrings and quadriceps pulled up			
Left heel is raised high			
Right leg at proper retiré position			
Strong spot with head whipping quickly			
Arms supported in first position, with rounded elbows and hands in between the chest and belly button			
360-degree rotation completed			
Landing controlled by stepping onto a bent right leg, arms by sides			
Pirouette was completed on the longitudinal axis			

Appendix G

Feedback Grid for Physical Performance Assessments

After First Physical Performance Assessment

Key Element	Correct	Incorrect
Right arm straight and in front of body at shoulder height		
Left arm straight and to the side of the body at shoulder height		
Left foot in front facing straight forward, leg bent, and heel on the ground		
Right foot behind, parallel with front foot, right heel raised, and right leg bent		
During the turn, bottom leg kept straight and strong		
During the turn, left heel was raised as high as possible		

After Second Physical Performance Assessment

Key Element	Correct	Incorrect
During the turn, the right foot was attached to the left knee		
During the turn, the head stayed pointed at the front of the room for as long as possible before whipping around to point to the front of the room again		
During the turn, the arms were in front of your body, with your arms bent and your hands in between your chest and belly button		
360-degree rotation completed in a clockwise direction		
Landed by stepping onto a bent right leg with your left foot pointed to the side, your left leg bent, and your arms by your sides		
Completed the pirouette on the longitudinal axis with a controlled landing		

Appendix H

Recording of Practice Schedule

Acquisition Block 1 Schedule

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Acquisition Block 2 Schedule

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Acquisition Block 3 Schedule

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Acquisition Block 4 Schedule

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15