

Running head: SPEED OF DEMONSTRATION

The Influence of Video Speed Demonstration Under Mixed-Modeling Conditions on the
Learning of a Complex Novel Motor Skill

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Abstract

The effect of slow-motion video speed demonstration under mixed-modeling conditions (skilled model plus self-observation) on the learning of a pirouette en dehors was examined to identify whether there was an optimal speed for learning a dance skill. Fifty-one participants were assigned to one of three groups with different video demonstration speeds: (1) slow-motion (2) real-time, or (3) a combination of slow-motion and real-time. Following a pre-test, participants completed eight blocks, each comprised of five physical and four observational practice trials. Physical performance and cognitive representation assessments revealed that participants' scores significantly improved for both assessments throughout acquisition ($ps < .05$), as well as from pre- to post-test ($ps < .001$), thus indicating learning of the skill. There were no significant differences, however, among the three experimental groups. Thus, under mixed-modeling conditions, slow-motion video demonstration (either alone or combined with real-time) did not provide additional learning benefits over real-time demonstration.

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Chapter 1: Review of Literature

Introduction

In order to navigate our daily lives and complete even the most basic of tasks, such as walking or brushing our teeth, it was at some point necessary to learn these motor skills. This process of motor learning is presumed to occur by engaging internal processes that lead to the development of a relatively permanent motor memory of the movement, gained through practice and experience for its later reproduction (Schmidt & Lee, 2011). Motor learning is not, however, limited to these basic skills, but rather extends to more complex motor skills, such as a cartwheel in gymnastics or the pirouette en dehors in dance; and so one can ask ‘what are the factors that facilitate the learning of these skills?’. Motor learning researchers ask such questions and, critical to answering these, is the implementation of a sound experimental paradigm.

For the study of motor learning, the basic experimental design includes an acquisition phase, a retention interval and then a retention phase (Adams, 1987). During acquisition, participants practice the motor skill with the introduction of the experimental manipulation, such as the interspersed observation of a model between physical performance trials. Following this session, there is a retention interval in which no practice is supposed to occur. This can be a short interval of 5-30 minutes (immediate retention), a long interval of 24hr+ (delayed retention), or both tests can be administered at those time delays. A retention test, during which the motor skill is performed in the absence of the manipulation, is used to test the strength of the motor memory following a period of rest. Removing the manipulation allows researchers to determine whether the motor skill can be reproduced in its absence. A transfer test, which modifies an element of the learned motor skill, whether that be a parameter of the movement or something within the context, can also be included in the experimental design to determine the generalizability of the motor memory (Schmidt & Lee, 2011).

Irrespective of the difficulty of the skill to be learned, motor learning is presumed to operate via three key phases: encoding, consolidation, and retrieval (Kantak & Winstein, 2012). These three phases are argued to make up the basis of motor memory formation, and while they occur at different time points within a motor learning paradigm, they all remain inter-dependent (refer to Figure 1). The process of encoding is proposed to occur while a skill is being practiced during acquisition, and is thought to result in motor memory formation as the learner processes relevant task information (Kantak & Winstein). Following acquisition, during the retention interval, consolidation of the motor memory is thought to occur (Robertson, 2004; Robertson & Cohen, 2006). Finally, retrieval occurs when the learner must recover the motor memory in order to perform the skill again at a later time point, such as during a retention and/or transfer test.

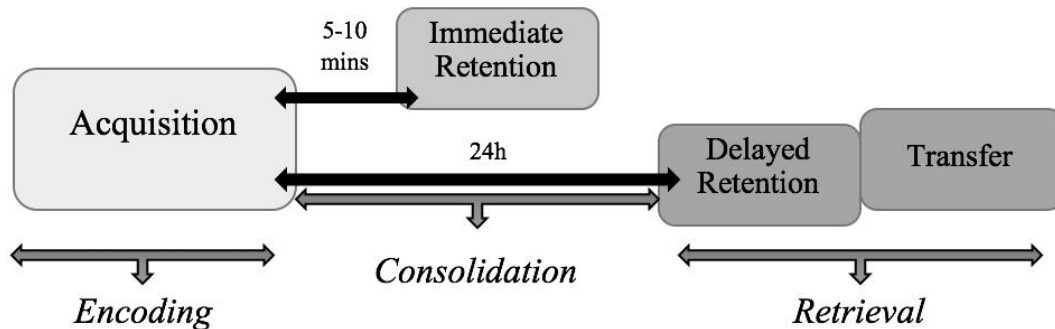


Figure 1. The three phases of motor memory formation (encoding, consolidation and retrieval) during a typical motor learning paradigm.

As should be noted from this description of the experimental design for motor learning, to accurately assess learning, it is essential to consider not only the motor performance demonstrated during acquisition, but also the relative permanence of the motor skill; a key characteristic of learning (Schmidt & Lee, 2011). This learning is typically inferred based on the results from a delayed retention and/or transfer test (Schmidt & Bjork, 1992). While the superior

(or inferior) performance of one group during acquisition may seem to suggest they are (or are not) learning, it is possible that transient factors such as motivation or fatigue, are influencing performance during acquisition. Consequently, the delayed retention or transfer test enables these transient factors to dissipate, providing a better indicator of the effect of the variable tested on learning (Schmidt & Bjork, 1992). This notion that performance during acquisition may not truly capture learning is described as the *learning-performance distinction* and highlights the need to include both phases (acquisition and retention) in any motor learning experimental design (Kantak & Winstein, 2012).

The Use of Observation

Motor learning researchers are interested in interventions that can assist the learning process, and the use of observation is one of these interventions. Observation used specifically for motor learning, herein referred to as observational learning, is defined as a process in which either self-observation or the observation of another person, enhances the learning of a motor skill (McCullagh, Ste-Marie, & Law, 2014). Observational learning has been proven to be an effective intervention, both when combined with physical practice and without, and for both laboratory and applied tasks within various settings (e.g., Amara et al., 2015; Gruetzmacher, Panzer, Blandin, & Shea, 2011).

Two distinct perspectives provide explanations regarding the benefit of incorporating observation. First, there is the direct perception perspective outlined by Scully and Newell (1985), which highlights the importance of understanding *what* visual information the learner extracts during observation. More specifically, and in line with research conducted by Gibson (1950) and his direct perception theory, it is proposed that learners extract the necessary relative motion information needed for movement coordination from observation. This relative motion

information then acts as a constraint on the learner's coordination pattern, with little need for cognitive processing of information. Another perspective, that of the Social Cognitive Theory proposed by Bandura (1977; 1986), emphasizes four cognitively-based processes, which are inter-dependent, and work together in the development of a cognitive representation of a skill by the learner following the observation of a model through varied informational processes.

While both perspectives exist within the literature, I have chosen Bandura's Social Cognitive Theory as the guiding framework for my research for a few reasons. First, there is a comprehensive literature of over 14 000 citations that build from Bandura's seminal work, thus providing a sound grounding for the development of our understanding of observational learning. Additionally, in support of this cognitive perspective, there is evidence that shows that disrupting or enhancing those cognitive processes advanced within the Social Cognitive Theory moderates the effect of observation (McCullagh, Ste-Marie, & Law, 2014). Finally, the proposed research builds from other research on the use of observation which was guided by Social Cognitive Theory, and thus the adoption of this framework maintains this continuity (Martini, Rymal, & Ste-Marie, 2011; Vertes & Ste-Marie, 2013).

Given Bandura's (1986) Social Cognitive Theory will act as the guiding theoretical framework, greater elaboration of the theory is provided. Bandura proposed that four key processes were essential for observational learning: attention, retention, motor reproduction and motivation. First, it was postulated that the learner selectively attends to key information being presented during observation and interprets this information based on their own unique experience. The retention process, during which the memory of the observed skill is thought to develop, is posited to result in the creation of a cognitive representation of the skill. The cognitive representation is thought to emulate a blueprint and provides a reference of correctness

for the learner (Sheffield, 1961). The process of motor reproduction is argued to allow the learner to use the cognitive representation of the skill to guide physical performance. As information is provided to the learner about their performance, either through their own intrinsic feedback or extrinsic feedback, the cognitive representation is said to be updated and refined. The final motivational sub-process proposed emphasizes the role that motivation plays in terms of the learner's desire to attend to the modeled information, to want to spend the time to retain that information, and/or to reproduce the behavior that was observed. In the absence of motivation, for example, the learner may choose not to execute the skill that was observed, which reinforces the inter-dependent nature of these four processes (Bandura).

An important consideration emerges from these four proposed sub-processes; that of assessing learning not only through measures associated with the physical reproduction of the skill, but also with the cognitive measures that can tap into the development of the cognitive representation that has yet been translated into physical performance (McCullagh & Weiss, 2001). In the absence of this cognitive representation score, researchers risk not capturing possible observational learning benefits. Research has previously demonstrated the tight coupling between cognitive representation and physical performance scores when learning was assessed using both measures (Carroll & Bandura, 1987; Laguna, 1991; St. Germain, Lelievre, & Ste-Marie, 2019). As such, both measures will be considered in this experimental design to maximize our understanding of the effects of the observation intervention.

Research concerning the use of observation to enhance learning spans across many disciplines, with some examples including sport (e.g., Sakadjian, Panchuk, & Pearce, 2014), rehabilitation (e.g., Park, Kim, Lee, & Oh, 2014), and education (Snyder et al., 2011; Domuracki, Wong, Olivieri & Grierson, 2015). The learning benefit of observation over other

techniques, such as verbal guidance or simply over a control group who only physically practices (Rohbanfard & Proteau, 2011; Sakadjian et al., 2014) is often evidenced. Despite the general understanding that observational learning is effective, there is still a need for a better understanding of how observation can be used most effectively, with the goal to generate recommendations for evidence-based practice (Ste-Marie et al., 2012).

An Applied Model for the Use of Observation

Following a review of applied motor learning research that focused on the use of observation as an intervention, Ste-Marie et al. (2012) argued that the mere observation of the self or another person did not guarantee learning benefits and that a variety of factors needed to be considered. These factors were presented within an applied model for the use of observation that was developed by the researchers. Specifically, the applied model includes two moderator variables and six factors that relate to the use of observation as an intervention, which were contextualized within the 5 Ws and 1 H framework: Where, Why (functions), Who, What, When and How. In terms of the two moderator variables, it was purported that a practitioner needs to first consider the observer's characteristics and the task characteristics, because both of these can influence the success of an intervention. Within the second level of the model, the authors proposed that a practitioner should next consider the context factors (*where*) and function (*why*) of the intervention, with the notion that understanding both the setting in which the intervention would be applied and the goal of the intervention were important parameters to best develop an effective intervention. With these aspects known, the specific characteristics of the intervention related to the remaining four factors could then be considered by the practitioner. These four factors were: *what* would be observed, *who* the model would be, *how* the model would be displayed, and *when* the model would be observed (Ste-Marie et. al).

The review produced by Ste-Marie et al. (2012) allowed the researchers to confidently conclude that observation benefits occurred under conditions in which novice learners (learner characteristics) observed an expert model demonstration (who) in real-time (how) for skill acquisition (why) in a laboratory setting (where). The emphasis on the skill function of observation, as opposed to strategy or performance functions (see Cumming, Clark, Ste-Marie, McCullagh, & Hall, 2005) for elaboration on the three functions of observation), the consistent use of a skilled model over other model types, and the emphasis on research in a laboratory setting leave many elements within each factor without empirical support (Ste-Marie et al.). In addition, while there were many studies that examined certain features of the use of observation, there were few studies examining the how factor. For this reason, the proposed research is focused on the *how* factor of the applied model, with specific interest on the effects of changing the speed of demonstration. Before expanding on this, however, the *who* factor will be elaborated upon as it influences certain methodological features of the research undertaken.

Who. An important characteristic of an observation intervention is to consider the type of model to observe. Indeed, questions surrounding the best model type to use are those in which the most research has been conducted within the use of observation for applied tasks (Ste-Marie, et al., 2012). Some of the previously examined model types include: skilled, unskilled, and learning models, as well as the self-as-a-model (for a review see (McCullagh et al., 2014). While each of these have shown merit for their use, skilled models and the self-as-a-model are of most relevance to the proposed research. A skilled model, also referred to as an expert model, is defined as a model which has much experience with the skill and can demonstrate to the learner the proper execution of the skill with little or no errors (Andrieux & Proteau, 2013; Clark & Ste-Marie, 2007). This model type is argued to provide the learner with a reference of correctness,

based upon which future physical performance can be referenced (Sheffield, 1961). There is strong empirical evidence to support the benefit of the observation of a skilled model for motor learning (e.g., Al-Abood, Davids, Bennett, Ashford, & Marin, 2001; Bird, Osman, Saggerson, & Heyes, 2005; Heyes & Foster, 2002).

The other relevant model type, in the context of the proposed research, is that of the self-as-a-model. While there are varied self-as-a-model types available (see Dowrick, 1999 for a review), self-observation is of most interest. Self-observation, typically occurs through video replay of a learner's just performed executions of a skill, without any editing to that video (Dowrick). This unedited observation of the self, is suggested to provide the learner with information regarding both error detection, and subsequent error correction, which can then lead to the development of new movement strategies (Badets, Blandin, Wright, & Shea, 2006). Indeed, the use of self-observation has been demonstrated as beneficial for motor learning (e.g., Marques & Corrêa, 2016).

Due to the observed benefits noted from the observation of each model type individually, the combination of two model types (herein referred to as mixed-modeling) has been of interest to researchers. Mixed-modeling has been shown to be better than a single model for both applied tasks, like that of gymnastic skills (Baudry, Leroy, & Chollet, 2006; Roberston, St. Germain, & Ste-Marie, 2018), as well as laboratory-based tasks (Rohbanfard & Proteau, 2011), although others have not replicated the benefit in a wave-form laboratory task (Moore, Lelievre, & Ste-Marie, 2019). For example, Robertson, et al. showed that the combination of a skilled model followed by self-observation led to a better cognitive representation and skilled performance on delayed retention tests as compared to either model type used singularly.

Given the findings that mixed-modeling has been shown to be advantageous for the use of observation, the combination of self-observation and a skilled model was used in the present experiment. Additionally, research conducted by St. Germain et al. (2019), using only a skilled model, resulted in low levels of learning of a pirouette en dehors. It was conjectured that the lack of feedback and an understanding of their own performance may well have led to the lack of changes in movement scores associated with the learning of the task. Here, however, with the use of the mixed-model approach, it was anticipated that the feedback provided through the self-observation coupled with the skilled model would provide a better learning context for the task.

In sum, there is evidence that different model types can benefit learning. Moreover, the couplings of different model types were considered more advantageous for learning than that of a single model; as such a mixed-modeling approach was used here. Although much information has been gleaned about model types, and the potential advantages of their combination, little is still known about *how* the model types should be delivered, thus highlighting an important research gap.

How. The how characteristic of the applied model includes elements such as: video viewing angle, observation or modeling frequency, the provision (or not) of control to the learner, and speed of demonstration (Ste-Marie et al., 2012). Currently, there is very little information available regarding the optimal use of any of these elements within an observation intervention. Consequently, this lack of understanding will be the driving force of the experiment, with our emphasis on whether changes to speed of demonstration, specifically the use of slow-motion, will impact motor learning outcomes.

The interest in the use of slow-motion is not solely found in the observational learning literature, but also in the motor imagery domain, as athletes have self-reported performing imagery at different speeds, which includes slow-motion imagery (Fournier, Deremaux, & Bernier, 2008; O & Hall, 2013). Given the evidence that suggests that observation and motor imagery share some common characteristics, as highlighted by the neurophysiological similarities found between these two interventions (Gatti et al., 2013; Holmes & Calmels, 2008), it is possible that the reasons athletes reported for using slow-motion imagery may also provide insight into the possible benefits of slow-motion demonstration during observation. Fournier et al., for example, conducted an exploratory qualitative study to determine how expert, experienced and novice sky divers used imagery. The results revealed that the speed of imagery used and the level of expertise were linked; specifically, all novices interviewed reported using slow-motion imagery and, regardless of expertise level, imagery performed slowly was reportedly used for both skill acquisition and stress reduction. Additionally, a qualitative analysis conducted by O and Hall (2013) demonstrated that competitive athletes reportedly imaged in slow-motion for a variety of reasons, with some of these reasons being directly related to skill acquisition. For example, the provision of a more in-depth analysis of skills and the benefit of being able to break down a skill into small pieces for further analysis were listed as reasons to use slow-motion imagery. The combination of both slow-motion and real-time imagery was also elaborated upon, as athletes specified ending with a real-time speed of demonstration to limit any learning loss of the temporal elements. Overall, research conducted within the motor imagery domain has demonstrated that athletes report using slow-motion imagery for skill acquisition, and that they prefer to conclude with imaging in real-time speed.

Despite the limited understanding in the utility of slow-motion motor learning or imagery, there is certainly evidence from the field that demonstrates that slow-motion video is being used. Both popular trends (e.g., sport training tools) and current observation interventions (e.g., Bang, Shin, Kim, & Choi, 2013) continue to feature the use of slow-motion as a method to enhance the learning of motor skills. A brief internet search featuring the phrase “slow-motion video” and various sports, such as golf, revealed many slow-motion videos being shared. For example, to enhance golf swing performance, slow-motion videos of professional golfers, like Luke Donald, are shared on YouTube (Golf, 2011). Additionally, video analysis software packages that feature the ability to develop slow-motion videos, such as MotionView™, are being marketed and sold as coaching tools (AllSportSystems, 2015). Indeed, this intuitive speculation found in popular trends, i.e., that slow-motion video speed would be advantageous for learners, is also evidenced in observation research in which researchers incorporate varied video speeds during observation within the methodology, with no explanation provided concerning why video speed was modified (e.g., Amara et al., 2015; Bang et al., 2013; Bertram, Marteniuk, & Guadagnoli, 2007; Post, Aiken, Laughlin, & Fairbrother, 2016). For example, Bang et al., investigated the effectiveness of observation for re-learning in chronic stroke patients through the demonstration of video models performing treadmill walking at various speeds (including slow-motion), and within their article, there was no justification for the inclusion of these different speeds. The speculation that slow-motion demonstration speeds are beneficial to learning may arise from the proposition of what is gained through its use in current trends. More specifically, by slowing down a modelled demonstration, or by using video replay in sport, the information presented can be broken down in greater detail. This increases the chances that the viewer will be able to see the relative features of the modelled demonstration, understanding in

greater depth how they relate to one another. For example, this may be the movements of limbs in relation to one another during a cartwheel, or the ball relative to a player during game review. Conversely, it's important to consider what might be lost from the inclusion of a slow-motion video speed into an observation intervention. As you slow down the speed of a demonstration, there is also speculation that learners will lose the timing component of the skill, whether that be overall movement time or the timing of limbs within a larger movement.

Taken together, and despite evidence of its use, there is limited research within the observational learning literature that has examined the influence of speed of demonstration on subsequent motor learning outcomes. Moreover, of the research articles which include specific manipulations for a slow-motion speed of demonstration, the results are conflicting (Al-Abood et al., 2001; Scully & Carnegie, 1998; Williams, 1989). In the absence of conclusive empirical support regarding the optimal speed of demonstration, it is problematic that it is being incorporated into experimental protocols, or popular coaching trends and new technology, without a full understanding of its impact. Given this, research on the utility of slow-motion video speed for motor skill acquisition is warranted. Next, the three articles that have specifically examined this issue are reviewed.

First, Williams (1989), used the point light display (PLD) technique, in which key markers were placed on relevant limbs, and the observer viewed the motion pattern of a skilled model. The task for participants in the first part of the experiment was to identify the movement pattern observed in PLD, which was a dart throwing task. The participants were first allocated to one of three groups: (1) fast speed (closest approximation to the actual task execution) (2) medium speed and (3) slow-motion demonstrations. The results demonstrated that participants

were less accurate in identifying the movement pattern as the demonstration speed was slowed down.

In the second part of the experiment, three participants (one from each original group who had correctly identified the movement pattern) were selected and viewed 30 additional trials of the PLD, where each trial was randomly presented at one of the three previously mentioned speeds. Immediately, after each observation, participants were instructed to perform the action and reproduce the speed of demonstration. For example, if the participant observed the slow-motion demonstration, immediately afterwards they were required to reproduce the movement at that slow speed. The results showed that all three demonstration speeds resulted in similar improvements in the reproduction of the spatial parameters of the movement. The researchers suggested that slowing the display likely allows vital information to be interpreted. Conversely, reproduction of the timing of the demonstration was significantly more accurate for the fast (closest to real-time) viewing speed, whereas participants were faster than the model when reproducing the movement following slower than real-time demonstrations. The researchers recommended that the use of altered timing, such as slow-motion, be an element of consideration in motor-skill instruction. Noteworthy, however, is that there was no retention test in the design. Additionally, the second part of the procedure included only three participants, none of which were randomly selected. Such methodological flaws seriously limit the interpretation of the reported findings.

Next, Scully & Carnegie, (1998) compared the use of slow-motion video speed, real-time video speed and still picture observation during the learning of a complex ballet jump. The results demonstrated that the slow-motion group was superior in both their foot placement upon landing, relative timing and movement form, however their absolute timing/speed was

significantly worse compared to the two other groups. Taken together, the researchers suggested that slow-motion may enhance a learner's ability to retain the kinematic information (such as movement form), and distort the kinetic information (such as velocity). There were noted limitations to this research, however. The limitations included the short, 10-trial acquisition session, thus leading one to question whether there was sufficient physical practice time associated with the skill. Further, participants only viewed the model three times before physically practicing, which is a limited exposure to a model. Finally, there was no clear information regarding the length of the retention interval provided after model viewing/physical practice and the performance trials that were analyzed. The lack of succinct information about the retention interval does not allow the results to be clearly attributed to either performance (short retention interval) or learning (long retention interval) and consequently, cautious interpretation of these findings is warranted.

In a final study, Al-Abood et al. (2001) compared the learning of two groups of young men on an underarm throwing task. For all the video demonstrations of the skilled model, the first group observed the model executing the task in slow-motion video, while the second group viewed the model performing the task in real-time video. Prior to beginning the acquisition session, participants viewed their respective video demonstration once. During the acquisition session, observation and physical practice were interspersed, such that following 10 physical practice trials, there was one observation trial. Overall, both groups viewed 10 video demonstrations during acquisition, which were interspersed evenly over the 100 trials of physical practice. The results demonstrated that the slow-motion viewing group had a less accurate representation of the model's relative motion (coordination) pattern, as determined by the comparison of both groups' performance at a delayed retention test. Additionally, the slow-

motion viewing group had poorer movement outcome scores, and there were no differences observed between groups for the movement control measure, which included elbow release angle, velocity and movement time. In contrast to the findings of Scully and Carnegie (1998), where slow-motion provided some learning advantages regarding the learning of relative motion, there were no distinct learning advantages demonstrated in this experiment. Notable is that this was the only study to feature a design that included both a long delay interval following the end of acquisition and before the retention test, and sufficient acquisition trials to anticipate learning outcomes.

Overall, it has been suggested by Ste-Marie et al. (2012), that task and learner characteristics likely play a role in determining which speed of demonstration is most appropriate, and it needs to be noted that there has been conflicting results from the research that has manipulated video speed demonstration. That is, there has been no support for the use of slow-motion demonstration shown (Al-Abood et al., 2001), whereas others studies have shown some benefits for its use, albeit, dependent on the measure identified and with questionable research designs (Scully & Carnegie, 1998; Williams, 1989). Given the methodological limitations of the research to date and the conflicting results, further research on whether slow-motion demonstration is a viable and effective observation technique is merited. The viability for the use of slow-motion demonstration certainly exists given the varied technologies that exist.

Technology

With the advancement of new technology occurring at such a rapid rate, new tools are continuously emerging and available. The smartphone is a great example of a multifaceted tool that the majority of the population has in the palm of their hands. Within this device, there are tools that can be specifically utilized to aid motor learning, such as the ability to record oneself,

and immediately receive feedback about one's performance. More specifically related to the *how* factor of observation, the speed of video demonstration can be directly altered on the device. Due to the accessibility of these tools to the general population, within a clinical setting, and in the classroom (etc.), the technology is readily available to provide different speeds of video demonstration, such as slow-motion, within these settings. As such, with an interest in the research being easily translated to practitioners' or coaches' use of this intervention, the research here incorporated the use of a smart phone.

Research Question

To summarize, the literature has provided a fundamental understanding that observation is a beneficial intervention, however, there are many factors that remain to be determined regarding how to most effectively use observation to enhance motor learning. Additionally, the literature available on the efficacy of slow-motion video feedback (Al-Abood et al., 2001; Scully & Carnegie, 1998; Williams, 1989) is limited, un-cohesive, and leaves much room for further research. Moreover, popular trends have also begun to perpetuate the idea that slow-motion demonstration is beneficial to motor learning, despite lacking empirical support. To our knowledge, no literature has explored the influence of slow-motion video compared to real-time or a combination of both to assess the impact on learning a complex motor skill. Consequently, the research question was: Under mixed-modeling conditions, with the use of a skilled model and self-observation, what is the influence of video speed demonstration on the learning of a novel complex motor skill?

To examine this question, three experimental groups were included, in which all used mixed-modeling with a skilled model being coupled with self-observation. The groups were only differentiated by the demonstration speed of the observational trials: (1) real-time speed, (2)

slow-motion speed, or (3) a combination of real-time and slow-motion speed. All participants were tasked with learning the pirouette en dehors and were involved in the following three phases: (1) pre-test, (2) acquisition, and (3) delayed post-test. Two measures were included to assess the cognitive and physical performance and learning of the skill over time. Both the cognitive representation and physical performance scores were assessed once at pre-test and post-test respectively, and four times during acquisition after every second block. Although not all of the available literature is methodologically sound, there is some evidence to suggest that while slow-motion may be beneficial to learning spatial elements, it's important to include real-time to offset the disadvantages to learning seen when temporal elements are measured. Qualitatively, athletes have also indicated the use of both slow-motion and real-time imagery, in that sequential order, when they chose to image (O & Hall, 2013). These athletes reported imaging first in slow-motion, and then finishing with real-time imagery to keep the integrity of the timing element of the skills being imaged. Based on these factors, the first hypothesis forwarded was that delivering the mixed-model demonstration in a sequential order of a first viewing in slow-motion followed by that of a real-time speed viewing (combined group) would result in the greatest amount of learning. A secondary hypothesis, in line with Bandura's seminal work (1986) that cognitive representation development guides physical performance, was that the cognitive representation scores would be correlated with physical practice scores when measured within the same acquisition block, as well as a subsequent acquisition time point.

Significance

In addressing the research question, it was anticipated that practitioners would be provided with information concerning the use of observation to enhance motor learning of a novel, complex skill. Moreover, the use of easily accessible tools, such as an iPhone, was implemented with the goal of more straightforward knowledge translation of the findings. Additionally, this research aimed to provide empirically based insight into the use of slow-motion demonstration as a potential tool to facilitate learning.

Chapter 2: Method

Participants

A power analysis was conducted to determine the necessary number of participants to recruit using the G Power software. Based on the assumptions (medium effect size 0.25, probability (power) 0.8 and type I error probability 0.05), 51 students both male (n=25; mean age = 23.04) and female (n=26; mean age = 22.68), were recruited from the University of Ottawa¹. Participants were excluded if they had either prior competitive dance, gymnastics or figure skating experience or had participated in any of the aforementioned sports recreationally in the last ten years. Furthermore, participants with cognitive or sensorimotor impairments were excluded. Approval from the Research Ethics Board at the University of Ottawa was obtained prior to data collection. The relevant consent forms were signed by the participants prior to their participation in the study.

Materials and Task

Task. The task was a pirouette en dehors, which is a complex dance skill comprised of a 360-degree turn performed on one foot. Figure 2 illustrates a sequence of pictures to provide an understanding of the movement to be learned by the participants. This turn was to be completed on the left leg, with the right foot touching the left knee. A list of 13 key elements² was used to evaluate the turn (see Appendix B).

Equipment. An iPhone 7 was used as the camera with which the participants' physical performance videos were recorded and saved for later analysis. All videos were taken in the frontal plane, providing a straight-on view of the participants, such that the iPhone was held

¹ Only 42 participants were required to be recruited to power the experiment, however, additional participants were recruited in the event that outliers needed to be removed from the analysis, as previous research using this task resulted in outliers.

² This task and all relevant material have been previously used in a master's thesis (St. Germain, 2018).

directly in front of the learners at approximately chest height. The iPhone was pivoted manually, such that it was turned around for the specific function needed; i.e., facing one way for recording and the other way for the participant, on select trials, and turned for participants to view the video demonstration of the self. A 13" MacBook Pro laptop was used by participants to view the skilled model video demonstration, while a 17" Toshiba Satellite X200-20s laptop was used by participants to complete the cognitive representation assessment.



Figure 2. Correct sequential representation of the pirouette en dehors from left to right.

Modeling videos. A skilled model video, which was previously created for this specific task, demonstrating a correct pirouette en dehors with no errors from an objective viewpoint was used³. The skilled model video featured a female who was a similar age to the participants and who performed the skill with near perfect execution.

Video speed. For trials in which a change of demonstration speed (slow-motion) was required for the self-observation videos filmed during the experimental sessions, the app *Slo Mo Video* was used. All slow-motion videos were manipulated to be 50% slower than the real-time speed. The app allowed the videos to be filmed in real-time, and instantaneously be adjusted to the desired speed for demonstration to the learner. In the case in which both a real-time viewing speed video and slow-motion viewing speed video were required from a single filmed trial, the

³ Permission was obtained from the skilled model for the continued use of the video and the images for the cognitive representation assessment.

app was able to switch between both video speeds easily, with very little delay. While the self-observation component was viewed on the iPhone, the skilled model video was shown on the laptop. To manipulate the speed of the skilled model video, the *Slo Mo Video* app was also used to create the skilled model slow-motion video, which was saved on the laptop along with the original real-time demonstration speed video. Thus, both a real-time speed and a slow-motion speed of the skilled model were available for the manipulation.

Cognitive representation photos. A forced-choice cognitive representation assessment⁴ was administered to the participants, which included still images of the skilled model at various time points of the pirouette. Of the 80 images presented to the participant, only 40 were correct and demonstrated no errors, according to the list of key elements of the pirouette en dehors. The remaining 40 photos demonstrated some degree of error, at different time points during the turn. There were eight pairs of photos presented for each cognitive representation assessment and a total of five different photo sets for assessment were created. The presentation of photo sets was counterbalanced across participants such that every set was presented at every point in time at which the cognitive representation assessment was administered. This counterbalancing ensured that any differences in the decisions were attributed to the time at which the assessment was occurring and not the images themselves.

Procedure

Participants were recruited through word of mouth at the University of Ottawa. The experiment took place in a quiet room that was clear of any obstructions to allow participants sufficient space to safely learn the task. There was tape in the shape of a box on the floor to guide participants where to practice the skill, and to ensure all the participants' movements were

⁴ This cognitive representation assessment was previously developed and used for this task (St. Germain, 2018).

captured during the recorded trials. All participants were involved in a three-phase experiment that included a pre-test, acquisition, and delayed post-test.

Participants were randomly assigned to one of three groups, all of which were provided with a mixed-model demonstration of the task during the acquisition phase that included both skilled model and self-observation demonstrations. The groups, however, were differentiated by the speed of demonstration of both modelled demonstrations provided. One group viewed the alternating observation trials of the skilled model followed by the self-observation (repeated twice for a total of four), with a slow-motion speed for all video demonstrations (SM). The second group viewed all observation trials of the same mixed-model order with a real-time speed of demonstration (RT). Finally, the third group viewed the first skilled model and self-observation trials with a slow-motion speed of demonstration followed by the two featured at real-time speed (RT-SM). This ordering was chosen based on qualitative imagery data which showed that competitive athletes used this alternating technique of slow-motion to real-time without prompting (O & Hall, 2013).

Pre-test phase. First, participants viewed three images (one at time), that displayed the three key positions of the task, including starting, middle and end positions of the turn with concurrent verbal cues provided by the experimenter (see Appendix C). Following this, participants viewed the skilled peer-model video three times, and received verbal cues concerning where to direct their attention prior to the video demonstration. More specifically, on the first observation trial of the skilled model, participants were told to observe the head, arms and legs at the start of the turn. On the second trial, they were instructed to focus on those same body parts during the middle of the turn, and, finally the third viewing emphasized attending to

those body parts at the end position of the turn (see Appendix C). This resulted in three skilled peer-model video demonstrations.

Once the basic information about the skill to be learned was provided, participants then executed three consecutive physical attempts of the pirouette en dehors. These physical trials were recorded via the iPhone 7 for physical performance evaluation at a later time point. The three physical performance trials were followed by a forced-choice cognitive representation assessment. This assessment was presented on a laptop screen using PowerPoint, and included eight slides with two side by side images of the skilled model at some time point during the pirouette en dehors. One of the images demonstrated the skilled model performing a position of the pirouette en dehors with no errors (based on the key elements), while the other contained the model performing the pirouette en dehors with a single error. The participant viewed each pair of photos for three seconds before they disappeared. Upon the presentation of the pair of photos, participants were asked to verbally identify which image contained the error (right or left side of the screen), what body part was making the error, and the specific error that was detected (see Figure 3 for an example). The experimenter recorded the participants' answers on an answer key.

Finally, to ensure all groups were equally motivated to attend to the modelled information, a motivation measure was included within the experiment. Bandura's (1986) Social Cognitive Theory forwards four key processes essential for observational learning, in which the last sub-process is motivation. As such, participants were asked to fill out a seven item motivation questionnaire, which was derived from the task interest/enjoyment subset of the Intrinsic Motivation Inventory (see Appendix D). In order to reduce bias in participants' answers, they were asked not to write their names on the questionnaire to encourage honest

responses. The questionnaire responses were later coded to be identifiable only to the researchers involved.

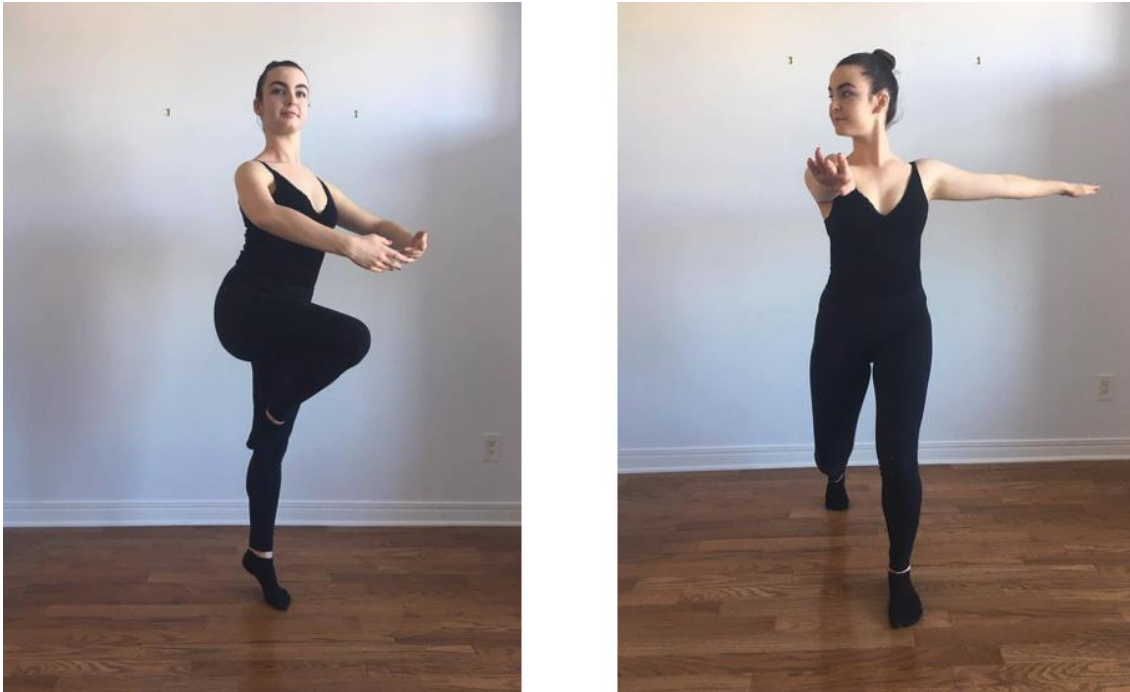


Figure 3. Example of the forced-choice cognitive representation assessment. In this example the image on the right is incorrect, the head is making the error, and the error is that the head should be facing the front (as shown in the first image of the sequence in figure 2).

Acquisition phase. To begin this phase and orient participants to learn the pirouette exactly as the skilled model performed it, participants had up to one and a half minutes (if needed) to review a list of the 13 key elements of the task. This served to inform them of the criteria upon which they were to be evaluated and about how to execute the skill.

The acquisition phase consisted of 72 trials broken down into 40 physical practice trials and 32 observational practice trials. These trials were split into eight blocks. Each block consisted of five physical practice trials and four observation trials (see Figure 4 for a schematic of the protocol). The four observation trials consisted of two viewings of the skilled model followed by self-observation. The self-observation component was completed by having the participants view a recording of their last physical practice trial of each acquisition block. All

three groups (SM, RT, RT-SM) followed this procedure of having four observation trials with the only difference being the speed of the video demonstration. The speed of the self-observation and skilled model was dictated by the group assignment, such that the video demonstration were in real-time (RT) for one group, in slow-motion (SM) for another group, and in the pairing of slow-motion for the first mixed-model viewing and then real-time for the second viewing (RT-SM).

Throughout the acquisition phase, participants were tested to monitor changes to physical performance and the cognitive representation. Specifically, after the completion of two acquisition blocks (i.e., after blocks 2, 4, 6, and 8), the participants executed three physical attempts that were recorded for later analysis, followed by the completion of the forced-choice cognitive representation assessment.

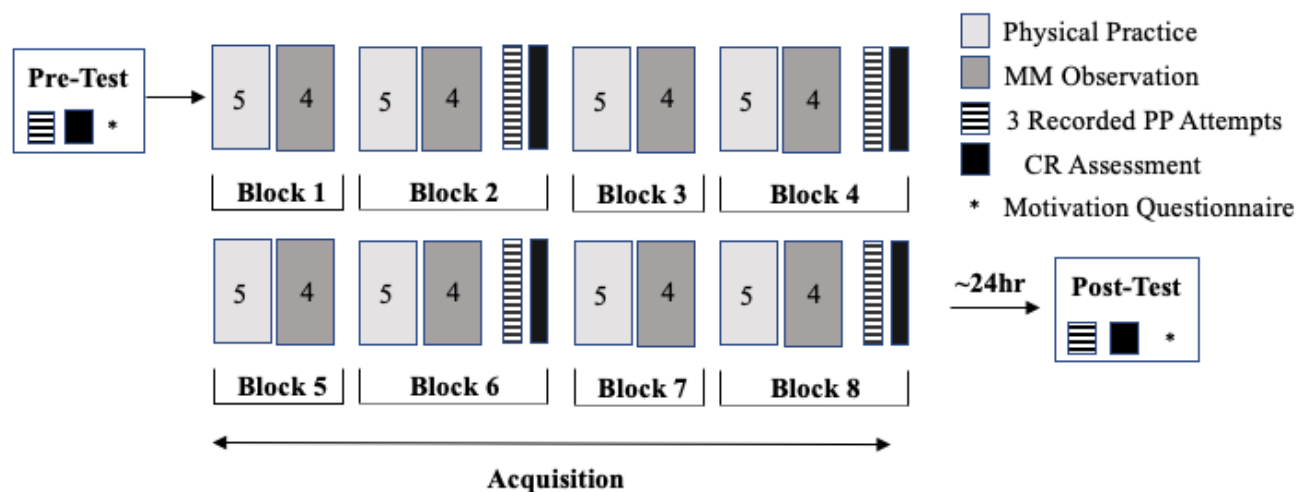


Figure 4. Overview of the experimental procedure.

Post-test phase. The post-test occurred approximately 24 hours following the acquisition session and followed the same procedures as that of the pre-test phase, with exception of no opening instructions or skilled model video demonstration. Thus, the participant

completed the motivation questionnaire, performed three physical attempts of the pirouette en dehors, which were video-recorded on the iPhone, and executed the final forced-choice cognitive representation assessment.

Dependent Measures

Cognitive representation. At each time point the forced-choice cognitive representation assessment was given to participants, they had eight pairs with which three decisions were made; (1) which image contained the error (right or left side of the screen), (2) what body part was making the error and (3) what the error specifically was for this body part (see Figure 3 for an example). Each decision was given a score of 0 if the response was incorrect and a score of 1 for a correct response; thus a range of 0-8 can occur for each decision. It is to be noted that if participants had an incorrect error on the first decision, the subsequent error scores were 0. While the participant was asked to make three decisions, for our analyses only the score of the decision in which the participant was required to specifically identify the error was analyzed. This decision was made for two reasons. First, from a theoretical standpoint that is in accordance with Bandura's theory (1986), it is assumed that to correctly answer the third question of the test, the learner's error detection capabilities are being relied upon. Thus, improvements on the specific error judgments were used as an index on the development of the cognitive representation. Second, previous research in which this forced-choice cognitive representation assessment for this dance task was used, it was demonstrated that final decision concerning identifying the error consistently demonstrated the strongest correlation to physical performance (St. Germain et al., 2019). Given these two factors, the third error score, herein referred to as the error decision score, was the only score considered in the analysis.

Physical performance. All video-recorded attempts of the pirouette en dehors were given a subjective score from 0-13, based on the 13 identified key elements of the turn (Appendix B). These 13 key elements were developed by a dance teacher with over twenty-five years of experience, in addition to completing the teaching program at the National Ballet School of Canada. The person scoring (i.e., evaluator) the videos had a background in dance with 15 years of experience and was very familiar with the scoring system for the pirouette en dehors that had been designed for a previous experiment (St. Germain et al., 2019). Further, the evaluator underwent a training period for the scoring process. This involved the evaluator scoring existing data that was available (i.e. videos of participants completing the pirouette en de hors from a prior experiment) and that had already been scored by two other judges. The scores obtained by this new evaluator were compared to the scores of the two previous judges at the end of two training intervals. In the first training round, the evaluator scored two participants full data sets twice, one week apart, which resulted in 3 trials scored during pre-test, 12 trials scored during acquisition and 3 trials scored for the post-test for each participant, at each time point. At the conclusion of this first round of training, there were certain key elements which yielded lower inter-class correlation (ICC) values. As such, the marking grid was refined to be more specific for those key elements based on a discussion with the researchers and the evaluator. A similar round of scoring was then conducted on a different participant's existing data, comparing only the new judge's scoring at two timepoints, one week apart. The results demonstrated a high agreement between the scores from week one and two for all key elements (see Table 1). Once the acceptable intra-rater reliability was confirmed, the judge was sent all filmed physical attempts and began scoring the data from participants in the present experiment based on the refined breakdown of 13 key elements (see Appendix E), using a specific scoring grid to

determine the score out of 13 (Appendix F). The judge was blinded to the condition that each participant was assigned to, and the order of the video-recordings was randomized to reduce bias. Each set of three pirouettes was scored and the average was used to produce one score, to yield a total of six scores per participant: pre-test, four acquisition blocks (after block 2, 4, 6 and 8), and post-test

Table 1.

Intraclass correlation coefficients (ICC), absolute agreement, for all 13 key elements of sample data scored by the judge during the training process at two time points one week apart.

Key Element												
1a	1b	2a	2b	3	4	5	6	7	8	9a	9b	10
.898	.615	1.00	.932	.864	.858	.964	1.00	.828	.759	.789	.968	.872

Correlation scores. Both the cognitive representation (CR) and physical performance (PP) tests were included to measure learning by examining more than the overt physical reproduction, as learning can occur in the absence of the ability to physically perform a skill. Moreover, Bandura (1986) speaks to the notion that the cognitive representation guides the physical performance of the to-be-learned motor skill. As such, the correlation scores from a correlation analysis were included as a final dependent measure to be analyzed. The correlations of specific interest were (1) the relationship between the CR and PP scores at the same time point and (2) between the CR score of one block and the PP score of the block of the next tested time point (i.e. CR and PP +2).

Chapter 3: Results

Preliminary Analyses

Descriptive statistics were used for preliminary analysis on the data. To identify any potential outliers, box plots were used, and three outliers were detected. The first two outliers were found in acquisition block 6 and block 8, and the third was found in the cognitive representation data of the post-test. Subsequently, analyses were conducted both with and without the outliers. Given there was no change to the pattern of the data, the decision was to report the analysis with the outliers included. The assumption of normality was violated, however as the Analysis of Variance (ANOVA) is robust when the group numbers are equal, it was decided to continue to use this analytic technique (Donaldson, 1968). When Mauchly's Test of Sphericity was violated, a Greenhouse-Geisser correction was applied. For significant main effects or interactions, post-hoc analyses were completed using the Bonferroni corrected t-test. The Bonferroni correction was selected based on the small number of comparisons performed, as it controls for both type I and type II errors in this case (Field, 2009).

Motivation scores were analyzed separately using a one-way between subjects ANOVA to assess group differences (RT, SM, RT-SM) in motivation. At both pre-test and post-test, the motivation scores were not significantly different from one another across the three groups, $p > .05$.

Acquisition

Cognitive representation. The acquisition data for the error decision score of the forced-choice cognitive representation assessment was analyzed using a 3 Group (RT, SM, RT-SM) x 4 Time (block 2, 4, 6, 8) two-way mixed analysis of variance (ANOVA) with repeated measures on the last factor. There was a significant main effect of Time $F(2.68, 128.65) = 5.295, p = .003, \eta_p^2 = .099$. Post-hoc comparisons revealed that scores at block 6 ($M = 4.06$

(1.38) points) and block 8 ($M = 4.16$ (1.24) points) were significantly higher than block 2 ($M = 3.35$ (1.53) points) $p = 0.017$ and $p = .024$ respectively, but that blocks 6, and 8 were not significantly different from another. No significant main effect for Group $F(2, 48) = .658, p = .523, \eta_p^2 = .027$ or interaction was obtained $F(5.36, 125.65) = .333, p = .903, \eta_p^2 = .014$ (see Figure 5).

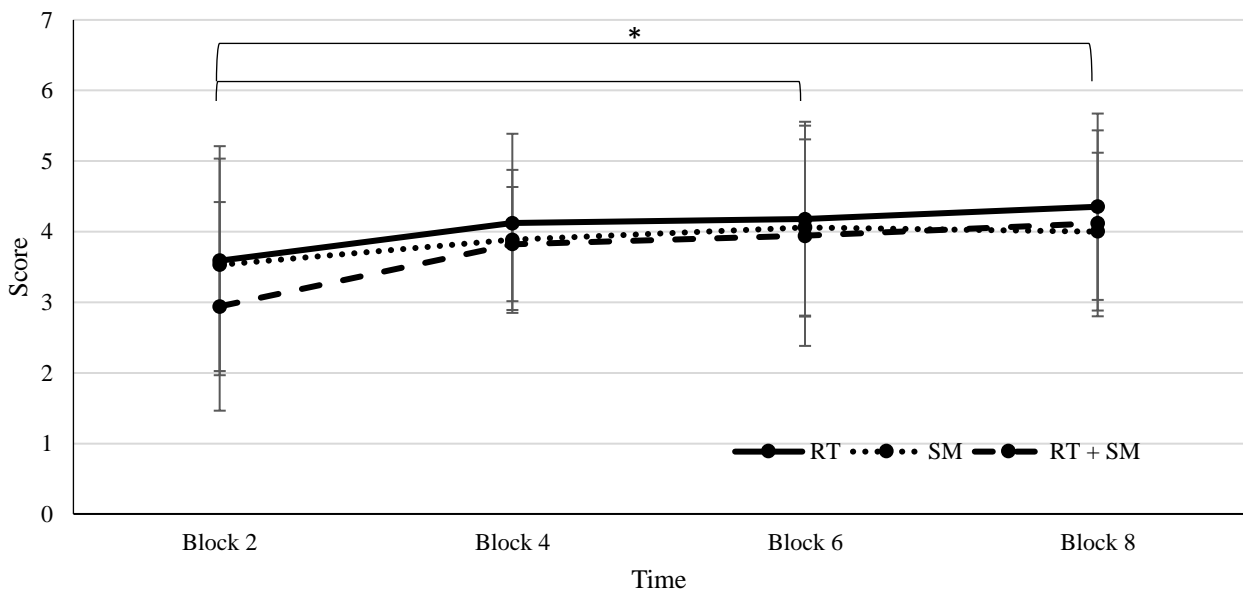


Figure 5. Average accuracy scores across acquisition for the error decision score of the forced-choice assessment for the three groups (RT = Real-Time, SM = Slow-motion, RT + SM = Real-time + Slow-motion). * denotes significance at $p < .05$. Note. Maximum score of 8.

Physical performance. The physical performance acquisition data was analyzed using a 3 Group (RT, SM, RT-SM) x 4 Time (Block 2, 4, 6, 8) two-way ANOVA with repeated measures on the last factor. Figure 6 provides an overview of the data obtained. There was a significant main effect of Time $F(2.824, 135.54) = 14.01, p < .001, \eta_p^2 = .226$. Post-hoc comparisons revealed that participants' scores were significantly higher at block 6 ($M = 4.23$ (1.70) points) and block 8 ($M = 4.56$ (1.50) points) compared to block 2 ($M = 3.40$ (1.13) points).

Additionally, scores in block 8 were significantly higher than scores in block 4 ($M = 3.84$ (1.06) points) $p = .006$, while no other comparisons were significant. No significant main effect for Group $F(2, 48) = 0.53$, $p = .949$, $\eta_p^2 = .002$ or interaction was obtained $F(5.65, 135.54) = .734$, $p = .615$, $\eta_p^2 = .030$.

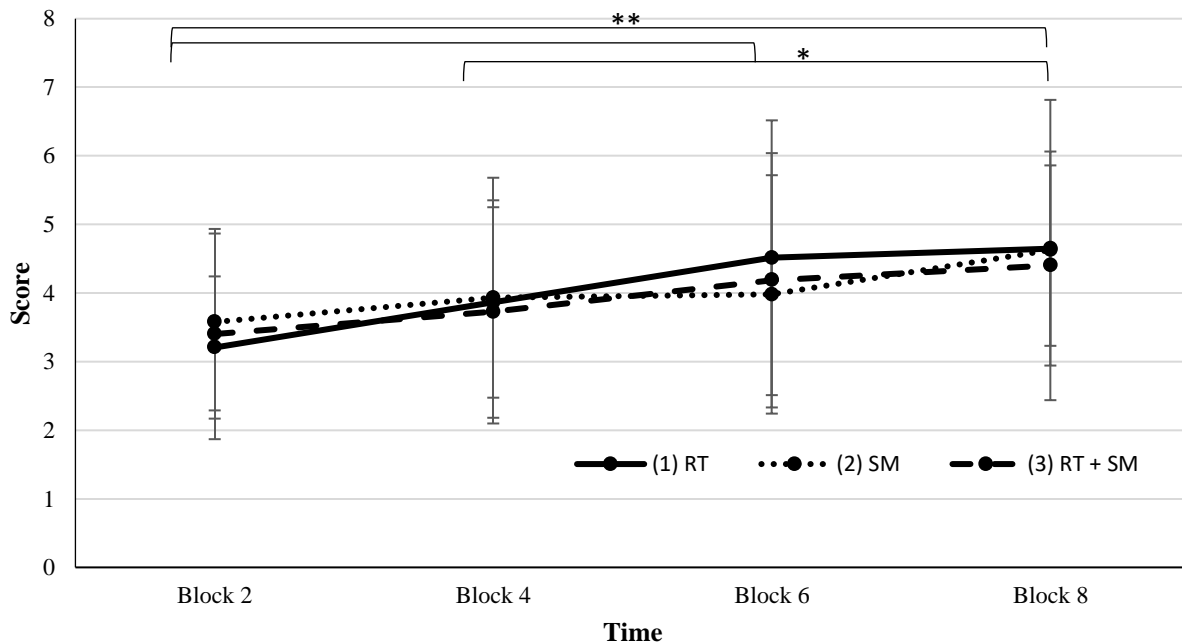


Figure 6. Average physical performance scores during acquisition, for each group (RT = Real-Time, SM = Slow-motion, RT + SM = Real-time + Slow-motion). Error bars denote the standard deviation. ** denotes significance at $p < .001$; * denotes significance at $p < .05$. *Note.* Maximum score of 13.

Learning

Cognitive representation. The learning data for the error decision score of the forced-choice cognitive representation assessment is represented in Figure 7 and was analyzed using a 3 Group (RT, SM, RT-SM) x 2 Time (pre, post) two-way mixed ANOVA with repeated measures on the last factor. There was a significant main effect of Time $F(1, 48) = 73.78$, $p < .001$, $\eta_p^2 = .606$. Scores at post-test ($M = 4.20$ (1.22) points) were significantly higher than at pre-test ($M =$

2.57 (1.46) points). No significant main effect for Group $F(2, 48) = .093, p = .911, \eta_p^2 = .004$ or interaction $F(2, 48) = 0.11, p = .989, \eta_p^2 = .00$ was obtained.

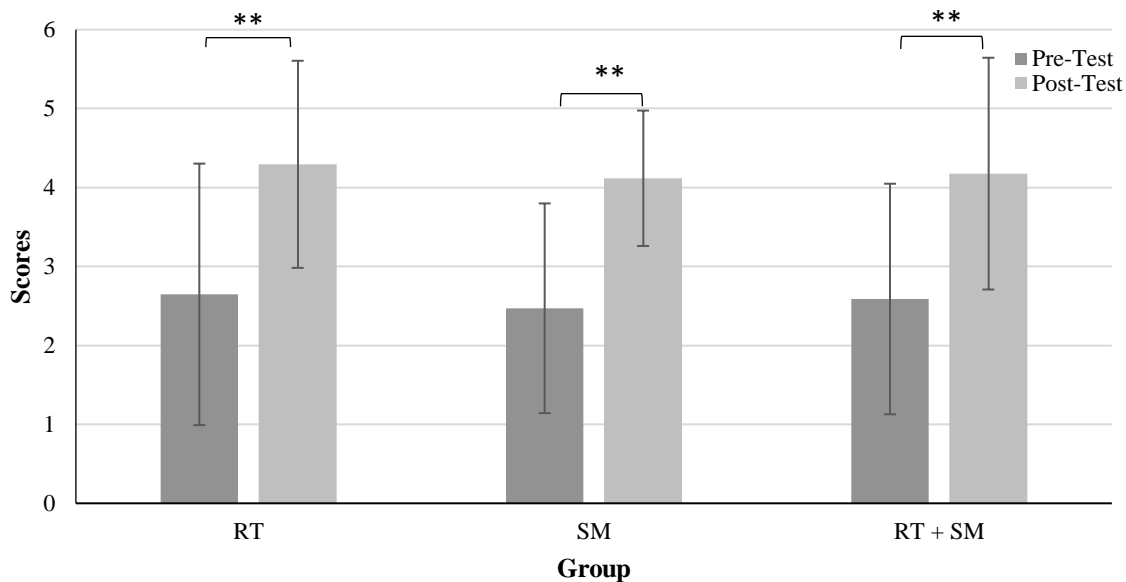


Figure 7. Average accuracy scores of the error decision score of the forced-choice cognitive representation assessment at pre- and post-tests of all of the experimental groups (RT = Real-time, SM = Slow-motion, RT + SM = Real-time + Slow-motion). Error bars denote the standard deviation. ** denotes significance at $p < .001$. *Note.* Maximum score of 8.

Physical performance. The physical performance learning data was analyzed using a 3 Group (RT, SM, RT-SM) x 2 Time (pre, post) two-way mixed ANOVA with repeated measures on the last factor. There was a significant main effect of Time $F(1, 48) = 55.77, p < .001, \eta_p^2 = .54$. Scores at post-test ($M = 4.35$ (1.30) points) were significantly higher than at pre-test ($M = 2.79$ (1.25) points), $p < .001$. No significant main effect for Group $F(2, 48) = .811, p = .45, \eta_p^2 = .033$ or interaction was obtained $F(2, 48) = .274, p = .762, \eta_p^2 = .011$ (see Figure 8).

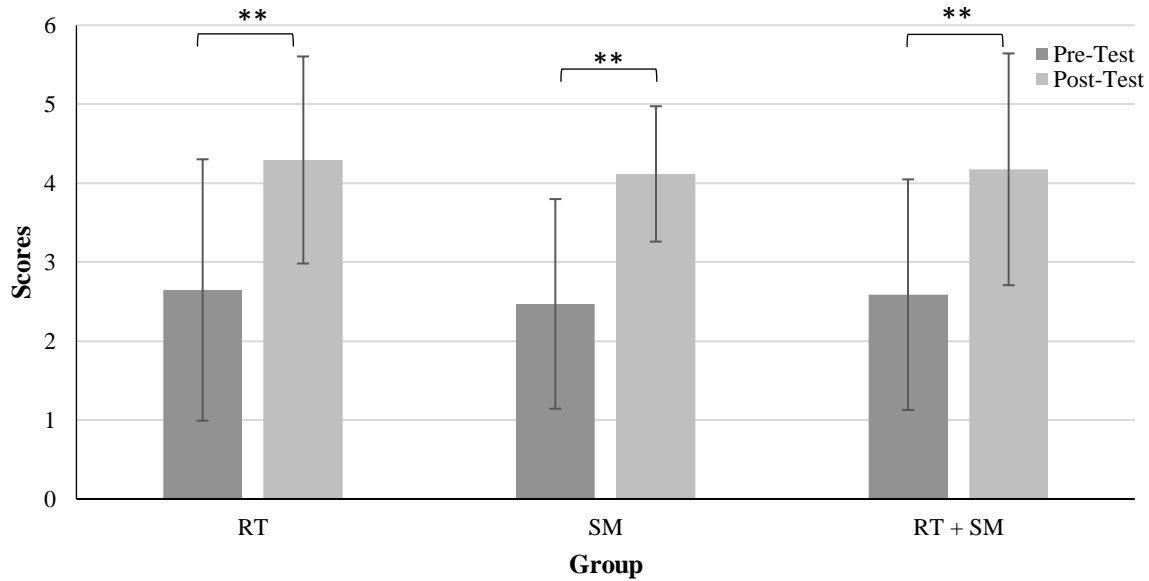


Figure 8. Average scores on the physical performance assessment at pre- and post-tests of the experimental groups. RT = Real-time, SM = Slow-motion, RT + SM = Real-time + Slow-motion. Error bars denote the standard deviation. ** denotes significance at $p < .001$. *Note.* Maximum score of 13 points.

Correlation

A Pearson's correlation was performed between the physical performance scores and the error decision scores of the forced-choice cognitive representation assessment, with a focus on both dependent measures at the same time point, and $n + 2$. For example, the error decision score of block 2 were compared to the physical performance scores of both block 2 and block 4 (the next time point that was measured). Table 2 shows the results for the relevant Pearson's correlation coefficients.

Table 2.

Pearson's correlation coefficients of error decision and physical performance scores

	Block 2	Block 4	Block 6	Block 8
Physical Performance				
Block 2	.309 ^a			
Block 4	.062	.165		
Block 6		.155	.365 ^b	
Block 8			.283 ^a	.279 ^a
Post-Test				.174

^a is significant at $p < .05$

^b is significant at $p < .01$

Chapter 4: Discussion

The use of observation as a learning tool is one that extends into a variety of settings, and thus it remains relevant to have a better understanding of the characteristics of an effective observation intervention. One factor that has limited empirical evidence is related to the video speed of a demonstration. In addition to this limited empirical evidence, there are indications that researchers are currently implementing this into their methodology without having a full understanding of the role of slow-motion video speed demonstration (Amara et al., 2015; Bang et al., 2013; Bertram et al., 2007; Post et al., 2016). Moreover, those who advertise online teaching tools or programs for sport enthusiasts also advocate for the use of slow-motion video (e.g. Golf, 2011; AllSportSystems, 2015). Consequently, the research here was designed to examine the question “under mixed-modeling conditions, with the use of a skilled model and self-observation, what is the influence of video speed demonstration on the learning of a novel complex motor skill?” Two hypotheses were forwarded. First, based on the observation and imagery literature, it was anticipated that the combined observation of the mixed-model demonstration in real-time and slow-motion speeds would result in the greatest amount of learning. Secondly, in following Bandura’s (1986) reasoning, it was expected that there would be a strong correlation between the physical performance and the cognitive representation scores measured both within the same acquisition block, as well as the $n+2$ block, as the cognitive representation is said to guide overt physical reproduction.

Effects on Acquisition

To better understand whether an intervention is having an effect on motor learning, it is important to determine that changes in performance are occurring across acquisition. In this light, the acquisition data provided insight into the changes in the cognitive representation and physical performance that occurred across the practice blocks. In terms of the cognitive

representation data, there was a significant main effect for Time (Figure 5), which provided evidence for an improvement in accuracy at detecting errors in performance. Specifically, scores at block 6 and block 8 were significantly higher than those at block 2, demonstrating an increase in accuracy over the first four blocks that remained until the end of acquisition. Noted though is that the final cognitive representation scores were still quite low (4.15/8).

Regarding the physical performance scores, there was once again a significant main effect of Time (Figure 6). This main effect also demonstrated a continuous improvement over the acquisition session. The scores of both block 6 and block 8 were significantly more accurate than those of block 2. As well, block 8 was significantly more accurate than block 4. Taken together, these results highlight a gradual improvement over the acquisition blocks, with continued learning occurring after block 4, which was measured halfway through acquisition. Overall, similar to the cognitive representation data, these physical performance scores were still fairly low in comparison to the maximal score that could be attained (4.56/13), and thus one can question whether additional acquisition sessions would have been worthwhile.

During acquisition, there was no main effect of Group for either dependent measure, suggesting that the speed of the mixed-model demonstration did not impact performance as all groups performed similarly over time. Taken together, the results over the acquisition session suggest that regardless of demonstration speed, participants' showed evidence of the development of a cognitive representation of the skill, as well positive changes in physical performance.

Correlations between Cognitive Representation and Physical Performance Assessments

We were also interested in whether there would be a correlation between the cognitive representation and physical performance measures at the same time point in acquisition and the

subsequent time points. The results of the correlation analysis demonstrated that at the same time point, the measures were significantly correlated at blocks 2, 6 and 8 (see Table 1), but not within block 4. Additionally, only one of the correlations for the CR and PP+2 blocks was significantly correlated, specifically CR block 6 was significantly correlated with PP block 8. None of the other PP+2 correlations yielded significance. As a whole, the correlation results only partially support Bandura's theory. While there were significant correlations between the same time points, albeit not as strong as anticipated, the cognitive representation scores were not generally predictive of physical performance scores at the subsequent time point measured (i.e., after 18 more trials of observational and physical practice). Bandura's postulation that the cognitive representation develops first led to the prediction that both of the correlations of the analyses performed would be significant, as has been shown in previous research (Carroll & Bandura, 1987; Laguna, 1991; St. Germain et al., 2019).

Of particular interest, for a comparison between these correlation results, and those of others, is the research conducted by St. Germain et al. (2019). That data set is of the most relevance because the same task and cognitive representation assessment were used, thus providing the most similar methodology for comparison. Even though these similarities existed, there were methodological differences between the current experiment and the research conducted by St. Germain et al., which may explain why the results here do not show the same significant correlations. Specifically, St. Germain et al., incorporated two cognitive representation assessments into their methodology, one of which was the same as that used in this experiment and another that had participants examine 36 still images of the pirouette. This image selection test occurred three times for one minute following each block of acquisition. Thus, a possible hypothesis is that the process of studying these still images may have

contributed to the difference in correlation results, specifically the stronger correlation found by St Germain et al.

Effects on Learning

While the acquisition data provides information regarding the changes in performance, these changes may be transient and depend on immediate factors in the practice environment. For this reason, a retention interval of approximately 24-hours was introduced and the post-test performance was used to infer the learning accrued, as it is said that these delayed retention, or post-tests, provide insight into the relatively permanent changes of the motor skill (Kantak & Winstein, 2012). Our first hypothesis, which proposed that a combination of both slow-motion and real-time video speed demonstrations would provide additional learning benefits over either speed alone, was not supported by the results. There was no main effect for Group for either dependent measure, highlighting once again that all video demonstration speeds facilitated the same amount of learning. The lack of group differences demonstrates that the inclusion of slow-motion video speed demonstration for a dance skill, under mixed-modeling conditions does not facilitate increased learning. This aligns with research in the imagery domain, which found that the speed at which participants imaged (real-time or slow-motion) did not moderate learning or changes in self-efficacy for a golf-putting task (Forlenza, Weinberg, & Horn, 2013). Similar to the present experiment, all groups in that research demonstrated did not demonstrate a significant difference in the amount of learning.

In contrast, the results of this experiment conflict with previous research which has examined video speed demonstration within an observation intervention. Of the previous literature that examined the effect of video speed demonstration, Al-Abood et al., (2001) had the strongest experimental design to date, and thus, our focus will be on the comparison of the

present results to those of Al-Abood and colleagues. More specifically, in that research, they found that slow-motion demonstration was detrimental to the learning of some dependent measures (coordination, movement outcome score), while other dependent measures demonstrated no difference between groups (elbow release angle, velocity, movement time). Here, the use of the different video speeds did not prove detrimental to performance or learning of either dependent measure. The differences seen between the two experiments may be a function of task complexity. The task used in Al-Abood and colleagues' research was that of a modified underarm dart throwing motion, which had a performance outcome goal and could also be considered less complex than the current task. Previous research has demonstrated that task outcomes have been shown to moderate observational learning outcomes (Hodges, Hayes, Eaves, Horn, & Williams, 2006; Ste-Marie et al., 2012). Specifically, Hodges et al., found that the addition of a goal-based constraint to a soccer kick with low-level soccer players lead to greater learning of the movement compared to the group without this added goal. Within the present experiment, and in contrast to that of Al-Abood et al., there was no specified goal-based constraint, which may explain the differing results regarding the effectiveness of video speed demonstration with novices.

Another factor that merits discussion concerns the main effect of Time. The results revealed that the accuracy of both the physical performance and error decision scores improved from pre- to post-test (Figure 7; Figure 8), thus suggesting some learning of the pirouette en dehors occurred within the protocol delivered. Although this main effect occurred, it was still unexpected that after eight blocks of acquisition, which included five physical trials and four observation trials for a total of 72 trials, that all groups learned to physically perform less than half of the key elements accurately and only half of the errors were identified by post-test. This

was unexpected because, as previously mentioned, this task had been used by St. Germain, et al. (2019) and their participants showed similarly low levels of learning, but those participants were only provided the skilled model demonstration and limited verbal feedback. The participants here, however, were provided a mixed-modeling experience. The mixed-model was expected to facilitate greater learning of the skill because of the combination of the two model types. The observation of the self was expected to aid in the development of the error detection and correction mechanism (Franks & Maile, 1991), while the skilled model was anticipated to provide a reference of correctness which the learner could use to compare their performance (Rohbanfard & Proteau, 2011). Indeed, research has shown this combination to be beneficial for learning over either single model alone (Robertson et al., 2018). It is possible that not as much learning occurred as expected because the present experiment featured novice learners, whereas Robertson et al. found the mixed-model to be beneficial with experienced gymnasts.

Overall, as the cognitive representation scores and the physical performance scores showed limited gains across the intervention, such findings could be considered in the context of Fitts and Posner's model (1967). This model suggests three stages of learning: (1) the cognitive stage, (2) the associative stage, and (3) the autonomous stage. The first stage of learning, the cognitive stage, is characterized by inconsistent performance, and it is suggested that learners in this stage need information about the task, guidance and sufficient time before they move into the next stage of the model (Huber, 2013). The associative stage is characterized by a more stable performance, smaller gains in performance change, and conscious effort is used to perform the skill. Finally, the autonomous stage reflects a movement that is accurate, efficient and performed unconsciously, or in an automated fashion. As the present results highlight little mastery or learning of all of the key elements of the skill, and an inconsistent performance, it is

proposed that the participants likely remained in the cognitive stage of learning. Based on this conclusion, it leads one to question whether a longer acquisition period may have facilitated greater learning of the skill, and perhaps slow-motion video speed, while it does not impact learning at the cognitive stage, may have an impact at later stages of learning.

Limitation and Delimitations

Of importance for any research is the discussion of both the limitations and delimitations of the current experiment. Operationally, a limitation is defined as a weakness or restriction, which is out of the researcher's control and often related to the methodology applied, while a delimitation is established by the researcher themselves through the choices they make with the experimental design (Theofanidis & Fountouki, 2018). A first limitation to note arises from the inclusion of the motivation measure, specifically the use a subscale of the IMI, which relied on self-reported data. Inherent with any self-report questionnaire is the possibility of biases in participants' answers, such as a social desirability bias in which participants attempt to craft their answers to respond in a socially desirable manner (Demetriou, Özer, & Essau, 2015). While steps were taken to reduce bias by instructing participants not to write their name on the questionnaires, thus creating the perception of the anonymity of their responses, it is recognized that there is still the bias risk associated with the use of the IMI. Additionally, a Pearson's correlation analysis was used to analyze the strength of the relationship between the two main dependent measures. This statistical test can only determine if a relationship exists between the two measures, and thus, does not express causation (Joly, 2017). The inclusion of this statistical test limited the interpretation of the results, as it cannot be concluded that increases in cognitive representation scores caused increases in physical performance scores.

There were also several notable delimitations to be addressed. First, subjective assessments were used to score the physical performance data, as there was not an objective assessment available. Further, the physical performance score was generated by only one judge, as opposed to multiple judges. Understanding these delimitations, experimental rigor was implemented in two ways for the physical performance scores. First, training of the judge occurred by ensuring that her scores aligned with those generated by two dance judges that had previously used the same scoring system. The inter-rater reliability scores were high at the conclusion of this training. Moreover, an intra-rater reliability process was also used to establish that the judge was being consistent in the manner in which she employed the scoring system. Based on these inter-rater and intra-rater reliability tests performed, there is confidence in the physical performance scores attained from the single judge as an indicator of performance changes.

Also to consider is that the cognitive representation and physical performance assessments during acquisition were administered every two blocks, with 18 trials in between each assessment. Had these tests been administered after every block, more insight into the changes in these measures during the acquisition session may have been captured. From a feasibility standpoint, however, the physical performance assessments were not conducted more frequently to limit the amount of videos which would need to be assessed, as this was a barrier to obtaining a judge to score each trial. A third delimitation of the current experiment was the short acquisition session. Indeed, the learning scores for both dependent measures were quite low, and the performance data did not appear to reach a plateau. Both of these indicators suggest that additional acquisition sessions may have allowed participants more time to learn the complex task and for examination of the possible impact of video speed across varied stages of learning.

The chosen length of the acquisition session, however, was prompted by feasibility constraints, such as the willingness of participants to agree to participate when the experimental protocol extends more than two days and requires more time

Future Research

Although the present experiment yielded the same amount of learning, regardless of the speed of the video demonstration, the value of examining this feature of *how* should not be disregarded. First, we recommend continued future research with some modification, such as the inclusion of a longer acquisition phase and cueing provided to the learner during their self-observation trials. More broadly, the applied model for the use of observation forwarded by Ste-Marie et al. (2012) highlights the importance of considering the moderating effects of both the task and observer characteristics, all of which could not be examined within the present methodology. Speaking to the task characteristics, we recommend further examination into the influence of video speed demonstration, specifically the incorporation of slow-motion, on an array of tasks, ranging from simple to complex, with and without the inclusion of a goal-based constraint. The results of the available literature are conflicting, as the present experiment found no learning differences with the inclusion of slow-motion, while Al-Abood et al., (2001), found slow-motion to be detrimental to the learning of certain measures. These conflicting results warrant further examination into the incorporation of slow-motion, as the tasks in the experiments were different, with one using a simpler task characterised by a performance outcome goal (throwing task) and this one with a more complex and action-goal driven task (pirouette en dehors). The measures of interest were also different, speaking to the need to examine video demonstration speeds for a variety of spatial and temporal measures to gain a thorough understanding. Moreover, the use of slow-motion with experienced athletes has only

been used in the imagery literature, and thus it is recommended that exploration into its role with mastering and refining existing skills (i.e., those in the associative stage of Fitts and Posners' model (1967) could be useful.

Another element from the applied model to consider in future research regards the functions of observational learning. Cumming, et al. (2005) proposed three functions of observation: (1) skill, (2) strategy, and (3) performance. The majority of all observation research, however, is focused on the skill function, and others have called for more research into the other two functions (Ste-Marie, et al., 2012). In light of this, it may be of interest to extend the examination of the potential influence of slow-motion video demonstration to that of learning strategies (i.e. slow-motion replay of a soccer game) and/or on psychological outcomes (e.g. self-efficacy). For example, imagery research has suggested that athletes use slow-motion imagery to increase confidence (O & Hall, 2013) and perhaps slow-motion observation would have similar psychological outcomes. Indeed, anecdotally speaking, participants did give indications of being overwhelmed and not understanding how to correct their errors, even when they were aware they were doing something wrong. Measures which tap into these concepts could be of interest and future research is encouraged to consider psychological measures, such as self-efficacy and motivation.

Conclusion

Overall, the speed of the demonstration did not influence the results, as there were no differences between groups for the learning of the pirouette en dehors. Thus, it can be concluded that under mixed-modeling conditions, both slow-motion, real-time and a combination of the two speeds of video demonstration lead to similar learning gains for this dance skill when physical practice was interspersed with observation trials.

These results can be used to inform the practices currently being adopted in settings such as sport and rehabilitation. Although the accessibility of technology allows for the inclusion of slow-motion video speed demonstration, it is not necessary to facilitate learning in novices. If an athlete however, were to request to see themselves performing a skill, without a goal constraint, in slow-motion during practice, it would not be detrimental based on our measures to incorporate the athlete's preference into the observation intervention. Similarly, these results could be extended to a rehabilitation setting, where patients requesting slow-motion video feedback of themselves, or of a skilled model performing a skill, could be incorporated to allow choice to the patient, without causing performance or learning detriments. In sum, while it cannot be advocated that practitioners use slow-motion demonstration speed within observation interventions, it would not necessarily be actively discouraged for skills similar to that used here, and that the preference of the learner could be considered. Indeed, the self-controlled learning literature has shown advantages associated with providing learners choice (e.g., St. Germain et al., 2019) and the speed of demonstration may well be one in which choice could be provided.

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Appendix A

Université d'Ottawa

Bureau d'éthique et d'intégrité de la recherche

University of Ottawa

Office of Research Ethics and Integrity

H-12-18-1504 - REG-1504 - Certificat d'approbation éthique / Certificate of Ethics Approval*(English message follows)*

Cher/Chère Natasha Lelievre,

Veuillez trouver ci-joint le certificat d'approbation éthique pour le projet intitulé «Influence of Video Speed Demonstration Under Mixed-Modelling Conditions on the Learning of a Complex Dance Skill».

Le certificat est valide jusqu'au : 17-12-2019

Recherche financée : veuillez faire suivre une copie du certificat au [Service de gestion de la recherche](#).Si vous avez des questions, n'hésitez pas à communiquer avec le Bureau d'éthique à ethique@uottawa.ca ou en composant le 613-562-5387.Vous pouvez voir votre demande en vous connectant à votre compte [eReviews](#).

Cordialement,

Riana Marcotte
Responsable d'éthique en recherche*Ceci est une réponse automatisée, merci de ne pas répondre à ce courriel.*

Dear Natasha Lelievre,

Please find attached the certificate of ethics approval for your research project titled "Influence of Video Speed Demonstration Under Mixed-Modelling Conditions on the Learning of a Complex Dance Skill".

This certificate is valid until: 17-12-2019

Funded research: A reminder that you must provide a copy of this certificate to [Research Management Services](#).If you have any questions, please contact the Ethics Office at ethics@uottawa.ca or by telephone at 613-562-5387.You can view your project at any time by logging into [eReviews](#).

Best regards,

Riana Marcotte
Protocol Officer*This is an automated message. Please do not reply directly to this email.***Attachement(s) / Attachment(s)**[approvalLetter1545170123651.pdf](#)550, rue Cumberland, pièce 154 550 Cumberland Street, Room 154
Ottawa (Ontario) K1N 6N5 Canada Ottawa, Ontario K1N 6N5 Canada613-562-5387 • 613-562-5338 • ethique@uOttawa.ca / ethics@uOttawa.ca
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Appendix B

Key Element Study Sheet

You will be evaluated on the following 13 criteria:

- i) Beginning arm position
 - i. Keep your right arm straight and in front of your body at shoulder height
 - ii. Keep your left arm straight and 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, with the right knee pointing forward
- 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) Landing leg position
 - i. Land by stepping onto a bent right leg, left foot pointed to side, and left leg bent
- x) Landing arm position
 - i. Arms down by sides
- xi) Make sure to complete the pirouette on the longitudinal axis, with a controlled landing

Appendix C

Verbal Description of the Pirouette en Dehors

Let's get started. You will be learning a pirouette en dehors which is a movement in the dance repertoire. It consists of doing a 360-degree rotation on one leg. *Show the first photo* Your arms will start with your right arm in front of your right shoulder, and your left arm beside your left shoulder. Your left foot will begin in front of the body, and the right foot behind the body. *Show the second photo* During the turn, your arms will 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. *Show the third photo* At the end of the turn, you will end with your weight on your right foot and your arms down beside your body.

Now we will have you sit here and watch a video of a dancer performing the pirouette with no errors. You will get to watch the video three times, and before watching the video each time we will be giving you some instructions about where to focus your attention.

- [Video 1]: At the beginning position, pay attention to the positions of the arms, legs, and head
- [Video 2]: During the turn, pay attention to the positions of the arms, legs, and head
- [Video 3]: Finally, at the end position of the turn pay attention to the positions of the arms, legs and head

Appendix D

Motivation Questionnaire (Subset of IMI - Task Interest/Enjoyment)

Pre-Test

For each of the following statements, please indicate how true it is for you, using the following scale:

1	2	3	4	5	6	7
not at all			somewhat			very
true			true			true

1. I will enjoy doing this activity very much: _____
2. This activity will be fun to do: _____
3. I think this will be a boring activity: _____
4. This activity will not hold my attention at all: _____
5. I would describe this activity as very interesting: _____
6. I think this activity will be quite enjoyable: _____
7. While I am doing this activity, I will be thinking about how much I am enjoying it: _____

Post-Test

For each of the following statements, please indicate how true it is for you, using the following scale:

1	2	3	4	5	6	7
not at all			somewhat			very
true			true			true

1. I will enjoy doing this activity very much: _____
2. This activity will be fun to do: _____
3. I think this will be a boring activity: _____
4. This activity will not hold my attention at all: _____
5. I would describe this activity as very interesting: _____
6. I think this activity will be quite enjoyable: _____
7. While I am doing this activity, I will be thinking about how much I am enjoying it: _____

Appendix E

Breakdown of Key Elements for the Judge

i) Arms straight in fourth position

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

i. Right arm straight and 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), OR having arm in front of body but too low, OR crossed in front of body (but no more than one)
3. 0 points for arm more than 45° away from midline or meeting both criteria for 2 or having arms in completely wrong position

ii. Left arm straight and 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) OR arm to side but too low (but not both)
3. 0 points for arm more than 45° away from side, winding up shoulders,

ii) Feet in parallel fourth position

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.

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 foot, leg bent, and with the heel raised (1 point)

1. 1 point for right foot parallel, in the back, bent leg, and heel raised
2. 0.5 points for right foot to the side/diagonal (somewhere other than it should be) with the heel raised, OR for right foot in the back but heel on the ground, OR right foot behind with heel raised but straight leg (but no more than one)
3. 0 points for more than one criterion in number 2, or anything else

iii) Left leg straightens with pulled up hamstrings and quadriceps (1 point)

1. 1 point for completely straight supporting leg
2. 0.5 points for kink in supporting knee
3. 0 points for anything more than a kink

iv) 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, or if heel touches ground during turn

- v) 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 retiré position), OR for turned out retiré with the toes attached to the knee, OR hooked behind knee but at proper height (but no more than one)
 - 3. 0 points for foot not attached to leg, or for left leg lifted
- vi) 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
- vii) 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, OR proper height but too close into the body, OR correct position but with fingertips touching (but no more than one)
 - 3. 0 points for more than one criterion in 2 or anything else
- viii) 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 (look at position of shoulders for rotation) (but not both)
 - 3. 0 points for both in 2 or anything else (including a hop)
- ix) Rock position (1 point)
 - i. Arms
 - 1. 1 point for arms down to side, slightly away from body (proper position)
 - 2. 0.5 points for arms down to sides but touching body, OR having one arm in front of body and one behind body
 - 3. 0 points for both from 2, or anything else
 - ii. Legs
 - 1. 1 point for having weight on right leg, left leg to the side with no weight, and both legs bent
 - 2. 0.5 for having one or both legs straight, OR having weight on wrong foot, OR having left leg to the back instead of to the side (no more than one)
 - 3. 0 points for more than 1 of any criterion in number 2, or for having weight on both legs, or anything else

- x) 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 (including dropping raised foot quickly), OR for rotating off axis (including bending at the hips) (but not both)
 - 3. 0 points for both in 2 or anything else
- b. ***If body is straight but pirouette is very uncontrolled they should still get 0.5**

Appendix F

Sample Physical Performance Marking Grid

Participant:

Video:

Key Elements	Trial 1	Trial 2	Trial 3
1a) Arms in fourth position – right arm			
1b) Arms in fourth position – left arm			
2a) Feet in fourth position – left foot			
2b) Feet in fourth position – right foot			
3) Pulled up supporting leg			
4) High relevé			
5) Retiré position			
6) Spot			
7) Arms in first position			
8) Full right pirouette en dehors			
9a) Finish in rock position – arms			
9b) Finish in rock position - legs			
10) Controlled landing, pirouette on longitudinal axis			

Each element is given a score of 0, 0.5, or 1.