LEARNER-ADAPTED MOTOR SKILL ACQUISITION

EXAMINING THE EFFECTS OF LEARNER-ADAPTED PRACTICE ON MOTOR SKILL ACQUISITION

By

Kinga Laura Eliasz, B.Kin.

A Thesis

Submitted to the School of Graduate Studies

In Partial Fulfillment of the Requirements

For the Degree

Master of Science

McMaster University

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MASTER OF SCIENCE (2011) **McMaster University**
(Human Biodynamics) **Hamilton, Ontario**

TITLE: Examining the effects of learner-adapted practice on motor skill acquisition

AUTHOR: Kinga Laura Eliasz, B.Kin. (Brock University)

SUPERVISORS: Drs. Timothy D. Lee and Laurie R. Wishart

NUMBER OF PAGES: ix, 157

ABSTRACT

Two studies were conducted to examine the effects of learner-adapted practice on the self-efficacy beliefs, acquisition and retention of a motor task. Through a discovery process all participants learned to perform several keypress patterns, with the goal of completing each sequence as fast and accurate as possible. The first experiment had learners practice the keypress sequences in one of two adaptive schedules, which utilized either a ‘WinSwitch’ or ‘WinRepeat’ task switching algorithm, or follow a pre-determined order of tasks (two yoked-control groups). The purpose of this experiment was to determine if adaptive schedules were effective because they were tailored to a learner’s performance characteristics or due to the nature of the contextual interference employed by the switching algorithm when the 'winning' criterion was satisfied. To examine the psychological factors involved in adaptive practice, the second experiment had all groups practice in a ‘WinSwitch Adaptive’ schedule and manipulated the social-comparative feedback that was provided (positive, negative or control). Together these studies revealed that the effectiveness of adaptive schedules may not necessarily be due to the fact that they are tailored to a learner's performance characteristics. They also suggest that learning is facilitated by a switching algorithm that involves some blocked practice towards the beginning and mostly random practice towards the end of acquisition (WinRepeat schedule). However, providing positive social-comparative feedback can override the negative effects of the opposite schedule (WinSwitch) and result in more effective learning and increases in self-efficacy beliefs. These findings are discussed in reference to contextual interference effects and the self-efficacy framework.

ACKNOWLEDGEMENTS

I have been extremely blessed to be surrounded by such wonderful people and I have many to thank.

First and foremost, thank you to my wonderful co-supervisors, Tim and Laurie. I think you are both brilliant and it has been such an honor to be under your supervision. My deepest gratitude goes to you for all of your insight and support as well as all of the valuable learning opportunities you have provided me with - I really cannot thank you enough! I owe another big thank you to my committee member and future PhD supervisor, Jim. I am really looking forward to working with you for the next few years and developing my scholarly skill set under your supervision. I would also like to thank my external examiner, Kelly. Thank you for sharing your expertise and for all of your insightful comments. Ramesh, it has been an amazing opportunity to learn and work in your state-of-the-art Sensorimotor Neuroscience Lab. I feel very privileged and I really appreciate everything you have taught me. I would also like to thank all the faculty and staff in the Kinesiology department. In all, I am very proud to be continuing my education among such highly regarded intellectuals.

Next, I'd like to thank all of my colleagues and friends in the grad program and especially those in the SN, MB, and HF Labs. Thank you for always being there. I really value your friendship, input and expertise. We make a great team and I look forward to future collaborations! A very special thanks to Dave- for his programming brilliance and Brian- for being such a technical guru.

Thank you to all my family and friends for always supporting everything I do. I really appreciate it. To my mother, I'd like to thank you from the bottom of my heart. You have sacrificed so much for us and I hope to always make you proud. Kamila, I am so lucky to be able to call you my sister and best friend. We have such a strong bond and I truly thank you for everything.

To my prince charming, your unconditional love and support makes me feel like I can conquer anything. Thank you for always believing in me Nick.

Dad, you were always so proud of our education. I dedicate this document to you - may you always rest in peace (*March 1950-July 2011*).

Love has no limits of time, space or distance ♥

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CHAPTER I: INTRODUCTION AND REVIEW OF THE LITERATURE

1.1 Statement of the Problem

A major direction of research in motor learning has been aimed at determining optimal practice schedules for learners (Schmidt & Lee, 2011). In the last few decades, numerous studies have provided insight into practice schedules that either facilitate performance (during acquisition) and/or learning (during retention) (Lee & Wishart, 2005). A problem is that few schedules produce both effective performance as well as learning. As a consequence, this leaves it up to the learner to make the difficult decision of whether they want to be successful at the motor task(s) *now* or in the *future*. The advantage of practice schedules that result in optimal performance and learning is that the learner is more likely to be motivated to practice. In order to learn new skills, learners need to repeat the to-be-learned skill many times. Therefore, research is needed to establish the best practice conditions to optimize both performance and learning.

1.1.1 Aim of the Research

The aim of this research is to investigate practice schedules that may facilitate both performance *and* learning. One promising avenue is to use adaptive practice schedules which are tailored to a learner's performance characteristics (Choi, Qi, Gordon, & Schweighofer, 2008; Marchal-Crespo & Reinkensmeyer, 2008). Preliminary results from studies on adaptive schedules suggest that these types of schedules are effective for performance and learning. However due to a lack of research, their effectiveness and underlying mechanisms remain unclear.

One explanation for these positive results could be the fact that they are tailored to a learner's performance characteristics. Another reason for the benefits of adaptive practice could be related to the ordering of the trials/tasks in these types of schedules (i.e., when a learner switches tasks). A third explanation could be related to learners' self-efficacy beliefs and their influence on learning. The role of learners' self-efficacy beliefs has been largely overlooked in the motor learning literature. If self-efficacy affects behaviour and willingness to continue future practice, it is worthwhile to explore practice schedules that may enhance self-efficacy beliefs and therefore encourage positive cognitive appraisals (Bandura, 1997). A combination of a practice schedule that efficiently and effectively helps learners retain motor tasks *and* a schedule that enhances self-efficacy beliefs would benefit motor skill acquisition and have practical implications in the field.

GENERAL OUTLINE FOR CHAPTER I

The overall purpose of this chapter is to review the literature on various types of practice schedules while examining their combined effectiveness on performance and learning, as well as on self-efficacy beliefs. The importance of reviewing the seminal literature on this topic is to determine where the gaps lie in this research and to help develop a better understanding of which variables during the motor learning process could be combined to try and optimize both performance and learning. After distinguishing between performance and learning, this chapter begins by addressing some of the practice variables that impact motor skill acquisition and then outlines common practice schedules, alternative schedules and learner-controlled schedules. Next the chapter addresses the learning estimation illusions (i.e., learners' metacognitions) that some of these types of schedules can potentially create. One method that is suggested to address these metacognitive illusions is to use learner-adaptive practice schedules which don't rely on subjective cognitive appraisals. The remainder of the chapter presents a discussion on how augmented feedback may also affect metacognitions as well as impact other psychological factors such as self-efficacy and in turn influence learning.

1.2 Practice Makes 'Perfect'

Motor performance is the observed behaviour of a voluntary action, whereas motor learning is usually defined as a relatively permanent change in an individual's capability to perform a skill and is typically inferred through performance on retention tests (Schmidt & Lee, 2011; Schmidt & Wrisberg, 2008). To improve, learn and be able to retain most motor skills, some amount of practice has to be undertaken by the learner. The amount of practice needed depends on the complexity of the task and how much expertise is needed. Some research has even proposed that specific motor skill expertise is gained through accumulating an average of 10,000 practice hours (i.e., typically 10 years) (Ericsson, Krampe, & Tesch-Romer, 1993). Unfortunately, most teachers as well as learners cannot realistically dedicate this much time to learning several motor skills. In learning environments a major concern is often a limited amount of time. As a result, it is important to make sure that learners are maximizing the efficiency of their practice time. In addition, in most everyday learning situations, individuals are learning more than one set of skills. Therefore, the manner in which practice is structured becomes critical for maximizing learning effectiveness and efficiency.

1.3 Practice Structure

Practice structure is related to how task variations are organized during practice. Trial order is one of the most important practice variables to consider when simultaneously learning more than one motor skill. The way that practice is structured can influence not only how well the tasks are performed but also how well the tasks can be retained after practice has ceased (Lee & Simon, 2004; Shea & Morgan, 1979). In general, the two most frequently-studied practice structures are blocked and random schedules. A blocked practice schedule is characterized as being predictable and consists of rehearsing the same task until all of the trials for that particular task are exhausted before switching to the next task (i.e., AAA…BBB…CCC…) (Schmidt & Lee, 2011; Schmidt & Wrisberg, 2008; Shea & Morgan, 1979). On the other hand, a random practice schedule frequently switches from one task to another, such that, in contrast to blocked practice, repetitions on any single task are minimized (i.e., ABCACBCAB…) (Schmidt & Lee, 2011; Schmidt & Wrisberg, 2008; Shea & Morgan, 1979). Therefore, even though these schedules offer the learner the exact same amount of practice time and trials, it is simply the *order* of these trials (blocked or random) that differentially influences performance and learning.

1.3.1 Contextual Interference

The effects of blocked and random practice are frequently investigated as a means to understand a learning paradox, the contextual interference (CI) effect (Battig, 1972; Lee & Simon, 2004; Shea & Morgan, 1979). CI refers to the interference that results when performing different variations of a skill in a practice environment (Magill & Hall, 1990). This concept of CI was first examined in a verbal learning domain by Battig (1972) and then by Shea and Morgan (1979) in a motor learning domain.

The intensity of the CI effect can be manipulated by how a practice session is organized (i.e., how much blocked or random practice is present). Participants who practice in a blocked schedule (low CI) typically exhibit better performance during acquisition (initial practice) compared to those who practice in a random schedule (high CI) (Lee & Simon, 2004; Lee, Wishart, Cunningham, & Carnahan, 1997; Shea & Morgan, 1979). However, in most cases practicing tasks in a random-practice schedule elicits better performance on a retention test, and thus better learning, compared to a blocked schedule (Battig, 1979; Lee & Magill, 1983; Lee et al., 1997; Shea & Morgan, 1979). In general, if the learner's desire is to effectively learn a motor skill set, then it is more favorable to engage in a random rather than blocked practice schedule.

There are two main theoretical explanations for the CI effect: the Elaboration-Distinctiveness view and the Forgetting-Reconstruction view (Lee & Magill, 1983, 1985; Shea & Morgan, 1979; Shea & Zimny, 1983). The Elaboration-Distinctiveness explanation states that random practice (high CI) offers the learner more opportunities to compare and contrast the tasks and thus increasing the meaningfulness/distinctiveness of the tasks (Shea & Morgan, 1979; Shea & Zimny, 1983). As a result, the memories of the learners engaged in random practice are more readily accessible. In contrast, the Forgetting-Reconstruction explanation states that the benefits of random practice are due to the spacing or forgetting and re-creating of the action plan in working memory (Lee & Magill, 1983, 1985). Lee and Magill (1983, 1985) suggest that it is the extensive retrieval practice that the random schedule offers which is responsible for the retention test (learning) advantage. Although these hypotheses remain relatively different, both offer a view that is based on some aspect of working memory and cognitive processing to explain the CI effect (Lee & Simon, 2004).

1.4 Alternative Practice Schedules

Strictly blocking or randomizing acquisition task order offers counterintuitive effects on performance and learning which may not be ideal in most learning environments. Since blocked and random practice schedules offer only ‘extreme’ forms of CI, Lee and Wishart (2005) proposed that alternative practice schedules should be considered in future research. There has been evidence to suggest that mixed practice schedules, which offer both blocked and random practice, have a promising future since they fall between the CI continuum (low and high CI) and offer the learner a moderate amount of CI (Hebert, Landin, & Solomon, 1996; Landin & Hebert, 1997; Porter & Magill, 2010, Porter & Saemi, 2010). However, more research needs to determine whether the learning effects resulting from these mixed practice schedules are solely due to this moderate amount of CI that is offered to the learner.

Another alternative to how task variations can be scheduled during practice is by systematically increasing the level of CI, such that learners begin with blocked, then serial and finally end practice with random trials (Porter & Magill, 2010; Porter & Saemi, 2010). Practicing in this type of schedule has been found to be more effective for learning compared to just practicing in a strictly blocked or random schedule (Porter & Magill, 2010; Porter & Saemi, 2010). However, the success of this type of schedule cannot be fully attributed to the systematic increases in CI since the authors did not compare this type of progressive schedule to one that just consists of blocked followed by random trials. As a result, it is unclear whether it was the increasing in CI (i.e., the portion of serial practice offering medium CI) that enhanced learning or because learners engaged in blocked trials towards the beginning and random trials towards the end of practice.

Other motor learning schedules include massed and distributed practice. These practice schedules are typically used when one motor skill (as opposed to multiple) is being learned. In general, massed practice refers to practice that is either ‘unspaced’ or offers relatively little 'rest' time (i.e., rest period is less than the practice time), whereas distributed practice (‘spaced’ practice) is characterized as having equal or longer rest periods (i.e., spacings) between practice time (Schmidt & Lee, 2011). It is well established in the literature that distributed practice is more beneficial for learning compared to massed practice, and including more rest periods during acquisition results in better performance and learning of that skill (Baddeley & Longman, 1978; Dempster, 1988; Schmidt & Lee, 2011). However, since some of these schedules span several days/weeks, one of their biggest flaws is their efficiency (i.e., time and effectiveness) (Lee & Wishart, 2005; Schmidt & Lee, 2011).

One of the biggest criticisms of these practice schedules is that they are all experimenter-controlled and do not consider the individual or the individual skill progression as important variables in the learning environment. Allowing the learner to be an active part of their own learning environment could help tailor the schedule to their needs as well as provide the necessary encouragement to continue practice.

1.5 Learner-Controlled Schedules

Allowing learners to have control over some aspect of their own practice schedule (i.e., self-regulating) has been demonstrated to generally enhance their learning process compared to learners who are not given this opportunity. Self-regulating certain practice variables has been investigated using several circumstances and a variety of skills. For example, self-regulation has been studied in the context of the trial/task order (Titzer, Shea, & Romack, 1993; Wu & Magill, 2004; Wu, Magill, & Foto, 2005), when learners want to receive augmented feedback (Chiviacowsky & Wulf, 2002, 2005; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Janelle, Kim, & Singer, 1995), or when they choose to receive physical guidance from an assistive device (Wulf & Toole, 1999).

The benefits of having control over trial order were first investigated by Titzer et al. (1993) where they used a barrier knock-down task involving three movement patterns, to compare self-regulated practice to blocked and random practice conditions. The self-regulation group generated their own practice schedule (i.e., by controlling the trial order of the three movement patterns). They found that the self-regulated group had improved during acquisition (performed similar to the blocked condition) *and* retention (performed similar to the random condition). However, the study failed to include a yoked condition – a control condition that would follow the same schedule as the self-regulated group, though in the absence of choice (i.e., pre-determined by the experimenter). As a result, the authors could not conclude whether allowing participants to self-regulate was beneficial because they were given the opportunity to choose their trial order or whether it was because the trial order they chose resembled a mixed schedule of blocked and random practice. Regardless of the actual mechanism of self-regulation, these results were interesting enough to begin a series of self-regulation experiments in the motor skill learning domain. Wu and Magill (2004) followed up on the results of the Titzer et al. (1993) study and included a group which was yoked to a self-regulated group that was able to choose their trial order on a golf putting task. Wu and Magill found that self-regulating practice did enhance motor learning compared to the yoked group. However, when a keypressing task was utilized, Wu et al. (2005) did not show any significant differences between the self-regulated and yoked groups. Interestingly, when further examining the self-regulated group's chosen acquisition schedule due to the lack of group differences, the authors noted that the self-regulated participants chose a schedule that was similar to blocked practice (low CI). This study suggested that giving learners control to choose their schedules did not necessarily mean that their learning would be facilitated especially when the schedules they chose (i.e., performance-rewarding blocked schedules) were not optimal for learning (CI effect).

Researchers have also found that learning is enhanced when learners are given the opportunity to self-regulate their feedback (i.e., choose when they receive augmented feedback) (Chiviacowsky & Wulf, 2002; Janelle et al., 1997; Janelle et al., 1995). Chiviacowsky and Wulf (2002, 2005, 2007) have suggested that self-regulated learners seem to tailor their performance feedback to when they either prefer it or believe that they need it. More specifically, they established that learners not only prefer to receive feedback after good trials but that their learning is also enhanced when they receive feedback following good rather than poor practice trials (Chiviacowsky & Wulf, 2002, 2005, 2007). The suggestion is that learners take on a more ‘active’ role in their learning and, as a result, try to receive feedback to confirm correct performance, which could in turn increase their motivation to perform better (Chiviacowsky & Wulf, 2002, 2005, 2007; Janelle et al., 1997; Zimmerman, 1989, 1990). Another study further explored this idea of self-regulators having an ‘active’ role in their learning environment by examining whether preference for what was being controlled in a practice schedule (e.g., feedback schedule, instruction mode) influenced learning and the learner’s self-efficacy beliefs (Bund & Wiemeyer, 2004). Prior to group randomization, Bund and Wiemeyer (2004) used a questionnaire in which they determined that learners preferred to control the instruction schedule compared to the variability of practice. Additionally, their results indicated that the self-regulation groups outperformed the yoked-controls on the table tennis forehand task *and* had greater perceived self-efficacy ratings regardless of whether the opportunity to self-regulate was for a preferred (i.e., video instruction schedule) or non-preferred (i.e., variability of practice) aspect of the practice schedule.

Based on the study by Bund and Wiemeyer (2004) and other research conducted by Keetch and Lee (2007), it seems that it is the self-regulation *per se* that is beneficial for learning and not the opportunity to control a specific aspect of a practice schedule. Therefore, self-regulated practice regimes in general seem favorable for learning and self-efficacy beliefs; however, it remains unclear how much control the learner should be permitted given that they may be unaware of what type of practice schedule may optimize their learning.

1.6 Metacognitive Judgments of Learning

During motor skill acquisition, learners will often estimate learning through their metacognitions. Research has suggested that it is not only physical factors such as practice order but also psychological factors such as subjective judgments of learning (JOL) that can influence motor learning strategies (Bjork, 1999; Lee & Wishart, 2005; Simon & Bjork, 2001, 2002). For example, individuals who practiced in a blocked condition (superior performance) had predicted that they would perform better on the retention test compared to those in the random condition (Simon & Bjork, 2001). These illusions of competence continued into a delayed retention test (24 hours later), despite the fact that participants in the blocked condition performed significantly worse than their random counterparts. Similar results were found for a study which used a distributed or massed type of practice schedule (two variations of each schedule) to train postal workers to use a typewriter (Baddeley & Longman, 1978). In this study, Baddeley and Longman (1978) found that distributing practice led to more effective learning compared to massed practice, however, subjective ratings indicated that participants preferred the massed schedule better than the distributed schedule (i.e., the schedule that was most effective for learning). This mismatch between subjective and objective measures of learning suggests that individuals may not always be accurate at metacognitively judging their actual level of learning.

These metacognitive illusions especially become a concern for self-regulation research since allowing learners to have control over their practice environment could actually be detrimental to overall learning if their self-regulatory processes are combined with their inaccurate JOLs. The predicament becomes how much control during practice should a learner have before it becomes detrimental to their learning? This is a concern since incorrect JOLs used interchangeably with certain practice schedules could modify how much effort learners allot to learning the motor skills and potentially amplify a less effective learning process.

1.7 Adaptive Practice Schedules

Lee and Wishart (2005) have suggested that it is worthwhile to explore alternatives to the traditional random and distributed practice schedules. One reason is that these practice schedules have not always produced consistent and effective learning environments and more importantly, because they do not seem to be favored by learners themselves (Baddeley & Longman, 1978; Lee & Wishart, 2005; Simon & Bjork, 2001). Alternatively, self-controlled schedules have been noted by some to be a promising new research avenue. However, the major concern lies in the fact that learners may not always have the knowledge or motivation to choose optimal learning schedules (Bandura, 1997; Wu et al., 2005). Theoretically and practically, self-controlled schedules hold considerable promise but are not always ideal because they involve highly variable and potentially illusive individual perceptions (Wu & Magill, 2004; Wu et al., 2005). On the other hand, it is still important to include the learner as a major part of the learning environment but to adjust what they are allowed to ‘control’ so that their *choices* are not detrimental to their learning.

To focus more on the learner as an individual, Guadagnoli and Lee (2004) developed a framework which proposes that learning is maximized when the learner faces an optimal level of challenge. They suggested that this level is individualistic and results from an optimal interaction between skill level, the actual practice conditions and task complexity. Using this type of framework, a promising avenue of research is the idea of learner-adaptive practices schedules which are a compromise between traditional experimenter-imposed schedules and self-controlled schedules.

Recent studies have found that learning is facilitated when practice schedules are adapted to a learner's performance characteristics, compared to equivalent amounts of random practice (Choi et al., 2008; Marchal-Crespo & Reinkensmeyer, 2008). These practice schedules are determined by the learner's actual performance and do not rely on their metacognitive judgments, which have been demonstrated to be unreliable (Baddeley & Longman, 1978; Simon & Bjork, 2001). Thus, these schedules can be structured so they adapt to when the learner is actually ready to move onto the next task (based on their performance and skill level) and not when the learner perceive themselves to have mastered the task (Simon & Bjork, 2001; Simon, Cullen, & Lee, 2002; Simon, Lee, & Cullen, 2008).

One promising performance-adaptive schedule is the 'win-switch, lose-repeat' paradigm, where the learner switches tasks contingent upon their performance (Simon et al., 2002; Simon et al., 2008). For example, when a learner in this schedule achieves success (i.e., a 'win') they would switch to a different pattern; failure to 'win' would result in immediate repetition of the same pattern (Simon et al., 2002; Simon et al., 2008). The idea is that this type of a tailored schedule (i.e., switching when successful) would elicit superior performance during acquisition (similar to blocked practice) and superior learning during a retention test (similar to random practice). Therefore, learner-adapted practice would address both the physical (practice schedule) and psychological factors (metacognitive illusions) involved in motor learning and perhaps help to motivate the learner during motor skill acquisition.

1.8 Augmented Feedback as a Source of Motivation during Practice

In addition to the appropriate design of a practice schedule, the type and amount of augmented feedback a learner receives can also play a valuable role in how motor tasks are retained. There are two general types of augmented feedback: knowledge of performance and knowledge of results. Augmented feedback that is provided about an individual's own movements is termed knowledge of performance (KP) (Salmoni, Schmidt, & Walter, 1984; Swinnen, 1996). For example, KP after unsuccessfully performing a computer sequence task could be 'you pressed the left key too slowly'. In contrast, augmented feedback that provides response-produced information to the individual about their success in meeting the goal is termed knowledge of results (KR) (Salmoni et al., 1984; Swinnen, 1996). For example, KR after unsuccessfully performing a computer sequence task with a goal of 10 seconds could be 'your movement time was 12.5 seconds'. Both KP and KR feedback in these examples are informing the individual that he/she unsuccessfully performed the task. Nevertheless, the majority of motor learning studies provide KR feedback to learners.

Traditionally, augmented feedback such as KR has been considered to be essential information in accurately judging personal improvements (Salmoni et al., 1984; Swinnen, 1996). However, more recently the augmented feedback that learners receive during practice is also thought to have a motivational influence on an individual's actual performance (Bund & Wiemeyer, 2004; Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008). More specifically, this feedback is considered to have motivational properties by providing a person with a greater sense of confidence, encouragement, and help minimize boredom (Bund & Wiemeyer, 2004; Dweck & Leggett, 1988; Schmidt & Lee, 2011).

Until recently, this area of research has been widely ignored in the motor learning domain since motivation was thought to only solicit temporary effects on performance (Schmidt & Lee, 2011). However, recent motor learning studies have revealed that motivational feedback does have a direct impact on motor learning (examined through delayed retention tests without feedback) (Chiviacowsky & Wulf, 2007; Lewthwaite & Wulf, 2010; Wulf, Chiviacowsky, & Lewthwaite, 2010). Lewthwaite and Wulf (2010) have demonstrated that providing motivational feedback *during* practice influences learning, however, these authors have also found that providing motivational information *prior* to practice can have a positive effect on learning (Wulf & Lewthwaite, 2009). Studies using a balance task (Lewthwaite & Wulf, 2010) and a sequence keypressing task (Wulf et al., 2010) have also demonstrated that the type of motivational feedback received during practice can influence learning. One type of motivational information that influences learning is social-comparative feedback, which provides the learner with group norms (i.e., group performance average) in addition to his/her performance feedback (Lewthwaite & Wulf, 2010). More specifically, learners receiving false positive social-comparative feedback experience a facilitatory effect on motor learning compared to receiving negative social-comparative feedback and/or a control condition (Lewthwaite & Wulf, 2010; Wulf et al., 2010). These studies suggest that there is a link between motivation and the use of various cognitive strategies (Chiviacowsky & Wulf, 2007; Lewthwaite & Wulf, 2010; Wulf et al., 2010; Wulf & Lewthwaite, 2009). However, due to the limited amount of studies, this linkage as well as the timing and the type of motivational informational that should be provided to enhance learning remains unclear.

1.9 Self-Efficacy

A more specific form of motivation is examined in the *social cognitive theory*, which addresses both the development of competencies and the regulation of action (Bandura, 1986). The central component of Bandura's (1986, 1997) social cognitive theory is self-efficacy. Unlike efficacy, which is the capability to produce an outcome, self-efficacy is an individual's belief in their own capability to execute a behaviour relative to a specific activity (Bandura, 1986, 1997). The stronger an individual's belief in their capabilities, the more persistent their efforts will be and the greater the chance of accomplishment (Bandura, 1989). In contrast, lower self-efficacy beliefs are expected to also influence behaviour but result in a tendency to want to avoid those tasks, regardless of actual skill (Schunk, 1990). Although a mismatch between perceptions and actual behaviour can occur, having an individual's self-efficacy at a greater level than what they may be capable of doing is always more beneficial rather than the opposite (Bandura & Cervone, 1983). In addition, when self-efficacy is high and performance dissatisfaction is high then there is a greater amount of effort expenditure (Bandura, 1986; Bandura &

Cervone, 1986; Schunk, 1990). Since self-efficacy beliefs have been shown to influence behaviour, examining these beliefs during the motor learning process is necessary in determining which practice variables may maintain or increase self-efficacy and if they affect the actual learning process.

1.9.1 Sources of Information

Level of motivation and actions are based more on what individuals believe (subjectively) than what is actually (objectively) true, and these efficacy beliefs can directly influence performance (Bandura, 1997). In addition, cognitive guidance to help form these appraisals is especially influential in the early stages of skill development (Bandura, 1997).

Not all sources of information influence self-efficacy beliefs in the same way. There are four determinants of self-efficacy (a situation-specific form of self-confidence): previous (mastery) experiences, vicarious experience, social (verbal) persuasion, and physiological/emotional states (Bandura, 1986, 1997). The best source for influencing self-efficacy beliefs is through mastery (previous) experience, which is highly resistant and predictable (Bandura, 1997). Successful (mastery) experiences increase one's efficacy beliefs, while frequent failures (especially in the early phase of competency development) tend to decrease self-efficacy in future performance (Bandura, 1997, 2010). The second determinant of self-efficacy is vicarious experience, which is acquiring information from knowledge of others through social comparisons and thus changing personal experience by using someone else's experience (observational learning) (Bandura, 1997). The more similar the individual is to the model, the more their personal self-efficacy beliefs will increase when the model experiences mastery/success. The third source of self-efficacy is social/verbal persuasion, which is feedback that a social source would provide usually in the form of verbal judgments (Bandura, 1997, 2010). One reason that verbal persuasion does not have as strong an impact on self-efficacy beliefs is because the judgment outcome is not witnessed as directly by the individual as it is through vicarious experience and instead relies on the credibility of the persuader. The weakest and final determinant of self-efficacy is physiological/emotional states. These physical or psychological states, such as perceived fatigue while performing a task, can be used as an indicator of low physical capability (Bandura, 1997). Although these four sources of information do not establish self-efficacy beliefs, they do (depending on strength of the source) influence cognitive beliefs associated with one's self-efficacy.

1.9.2 Self-Efficacy Sources and Motor Behaviour

Although the source and level of self-efficacy can vary, the more situation-specific the source is, the better it will predict self-efficacy (Bandura, 1997). In relation to motor behaviour, having goals and performance feedback, compared to just goals or feedback alone, have been found to have the greatest effect on performance and self-efficacy to attain the goal (Bandura & Cervone, 1983). Also, having positive social comparisons not only strengthens self-efficacy beliefs but also improves performance, while negative social comparisons can degrade performance (Bandura & Jourden, 1991). In all, the self-efficacy framework suggests that changes in self-efficacy beliefs (perceptions) may actually influence behaviour. If this is true then this framework could have major implications in motor learning research. One of these implications may be how practice needs to be scheduled in order to not only maximize learning but to also increase/maintain a learner's self-efficacy beliefs during the entire learning process.

1.10 Summary

Previous research suggests that some of the most common practice schedules either do not provide enough learner involvement (i.e., traditional experimenter-controlled schedules) or they provide learner involvement/control (i.e., self-controlled schedules) that could inherently degrade learning (Shea & Morgan, 1979; Wu et al., 2005). Adaptive practice schedules may offer a balance between these two ‘extreme’ forms of learner involvement. These schedules are learner-adapted, which means that they still take into account the individual’s own skill and performance (i.e., they still involve the learner) but they do not provide individuals with the ability to control variables that if controlled incorrectly, may be detrimental to their learning (i.e., choosing mostly blocked practice when provided with control over trial order). Also, the augmented feedback that learners receive during practice may not only influence learning directly but also psychological factors such as self-efficacy. According to the self-efficacy framework, greater self-efficacy beliefs can enhance behaviour. If psychological manipulations can alter actual behaviour, research should explore how practice schedules, such as learner-adapted acquisition, should be created to take this into account.

Therefore, the overall purpose of this research will be to investigate the influence of learner-adapted practice schedules on motor performance and learning, as well as on self-efficacy beliefs (i.e., perceived learning confidence). More specifically, Experiment 1 will examine if adaptive schedules are effective because they are tailored to a learner’s performance characteristics or due to the nature of the contextual interference that is employed by the switching algorithm when learners satisfy the task goal. Experiment 2 will build on these results and manipulate the social-comparative feedback that learners receive in order to examine the psychological factors that may be involved in adaptive practice. These experiments will add to the emergent literature on learner-adapted practice and explore potential psychological factors that may be involved when tailoring practice to the learner's needs.

CHAPTER II: THE ROLE OF LEARNER-ADAPTIVE SCHEDULES IN MOTOR LEARNING

2.1 Introduction and Rationale

The CI literature suggests that random practice leads to poorer acquisition performance but better retention and transfer performance compared to blocked practice (Battig, 1979; Lee & Magill, 1983; Lee et al., 1997; Shea & Morgan, 1979). Although random practice is generally demonstrated to be the superior learning schedule, it is often not considered by researchers to be the most optimal type of schedule and has been plagued with concerns (Lee & Wishart, 2005). One concern is that learning is an individualistic process and this type of schedule does not take into account the learner's performance or changes in performance (Guadagnoli & Lee, 2004). Another concern is that learners typically do not enjoy this type of practice and are not usually aware of the learning benefits of random practice (Simon & Bjork, 2001). As a result of these concerns, random practice could even discourage practice adherence.

One way to encourage learners to continue practice is to give them control over their practice schedules and actively involve them in creating the learning environment. Allowing learners to control the way they practice has been shown to be beneficial for performance and learning compared to yoked-controls who are not provided with this opportunity (Pinard, 1992; Titzer et al., 1993; Wu & Magill, 2004; Wulf & Toole, 1999; Zimmerman, 1989). One of the explanations for why this may be so, is that having personal control over something could elicit motivational processes. However, giving learners the responsibility to decide how they will undertake practice does not necessarily mean that they will be capable of choosing an optimal practice schedule that *will* enhance their learning (not just their performance). Furthermore, Simon and Bjork (2001) have suggested that learners are subject to inaccurate judgements of learning (JOLs) and thus the practice schedules they choose during a self-regulation condition may be effective during performance but not result in learning advantages.

Alternative schedules have been proposed to address the concerns of strictly using random practice (experimenter-controlled) or self-regulation practice (learner-controlled). Recent studies have found that learning is facilitated when practice schedules are adapted to a learner's performance characteristics, compared to equivalent amounts of random practice (Choi et al., 2008; Marchal-Crespo & Reinkensmeyer, 2008). These practice schedules are objectively determined by the learner's actual performance and therefore do not rely on their metacognitive judgments which have been demonstrated to be unreliable (Simon & Bjork, 2001). One of these performance-adaptive schedules is the 'win-switch, lose-repeat' paradigm, where the learner's task switching during practice is performance-contingent (Simon et al., 2002; Simon et al., 2008). The idea is that this personally-tailored schedule (i.e., switching when successful) would not only cater to the learner's performance characteristics, but also elicit superior performance during acquisition (like blocked practice would) and superior learning during a retention test (like random practice would). One explanation for these positive results could be the fact that they are tailored to a learner's performance characteristics. Another reason for the benefits of adaptive practice could be related to the ordering of the trials/tasks in these types of schedules (i.e., when a learner switches tasks). Even though the current literature on learner-adaptive schedules (not controlled by learner) is very limited, offering these types of schedules which are a compromise between traditional experimenter-imposed schedules and self-controlled schedules is an area of research that seems promising and warrants further investigation.

2.2 Purpose and Hypotheses

2.2.1 Purpose

The general purpose of Experiment 1 was to explore the influence of learner-adaptive schedules (i.e., performance-contingent) on performance and learning. The specific purpose was to determine if the effectiveness of these types of schedules could be for the reason that they are tailored to the learner's performance characteristics or due to the nature of the contextual interference that they provide to learners during practice. This purpose was explored in two ways: a) employing two different performance-contingent algorithms (to explore the nature of the CI) and b) including yoked conditions (to explore practice schedules which are adapted to a learner's performance characteristics).

2.2.2 Hypotheses

Based on the review of the literature, the following predictions were made:

1) Learners in the adaptive schedules would have more effective learning as measured by lower MTs and fewer errors compared to the yoked-controls (adapting to their performance characteristics).
2) Due to the CI effect, the nature of the switching algorithm would result in superior learning as measured by lower MTs and fewer errors for the WinRepeat

groups (mostly random practice) compared to the WinSwitch groups (mostly blocked practice).

2.3 Methods

2.3.1 Participants

Participants were recruited from the McMaster University campus and surrounding area. The exclusion criteria included color-blindness and any condition that may have interfered with completing a computer keypressing task. Each participant provided written consent to the experimental procedures that were approved by the McMaster University Research Ethics Board (MREB # 2009-130).

Forty-one healthy young adults (mean (M) ± standard deviation (SD) = 22.8 ± 3.2 years, 44.2 seconds on Trail Making test; 16 males; 38 right-hand dominant) volunteered to participate in Experiment 1. The Trail Making test (part B) is a timed paper test where participants use a task switching paradigm (connecting the circles in alternating sequence between a set of numbers and letters) and how quickly it is completed infers cognitive flexibility (Arbuthnott & Frank, 2000). This Trail Making test was completed at the end of the experiment by all participants but it was used strictly as a demographic and not screening measure. The reason it was chosen was because both the experimental task and this test included a memory *and* motor component.

This study required participants to use a standard computer keyboard. The goal was to learn and perform four spatially distinct computer keypress patterns as quickly and accurately as possible. The criterion for task switching/'winning' during practice was manipulated between groups. Prior to acquisition, participants were randomly assigned to one of four practice conditions: Win-Switch/Lose-Repeat Adaptive (WinSwitch ADAPTIVE) (n = 10), Win-Repeat/Lose-Switch Adaptive (WinRepeat ADAPTIVE) (n = 10), Win-Switch/Lose-Repeat Yoked Control (WinSwitch YOKED) (n = 10), or Win-Repeat/Lose-Switch Yoked Control (WinRepeat YOKED) (n = 11). The WinRepeat YOKED group included 11 participants because one of the yoked schedules had to be provided to two participants (opposed to one) as a result of a technical difficulty.

Participants came in for two consecutive days of testing. On *Day 1* all participants performed an acquisition session, followed by an immediate retention test and on *Day 2* they all completed a delayed retention test. Each participant was compensated 15 (CAD) dollars upon study completion (*Day 1* and *Day 2*) and best performance was awarded an additional 15 (CAD) dollars. Based on the delayed retention test, a total score for each participant was calculated to determine who best retained the motor tasks on *Day 2* (i.e., best score). For the adaptive groups, WinSwitch and WinRepeat ADAPTIVE, one participant (out of 20) was paid an additional 15 dollars and for the yoked-control groups, WinSwitch and WinRepeat YOKED, one participant (out of 21) was paid an additional 15 dollars for best score. This score was based on the average of the lowest movement times (MT) in milliseconds (ms) for each of the four patterns practiced in acquisition (i.e., the average of: the lowest red pattern MT, blue pattern MT, green pattern MT, and orange pattern MT) plus five ms added onto this average for each error (incorrect keypress) made during all 16 delayed retention trials. The score was calculated this way to ensure that participants focused on both completing the pattern as fast as possible while minimizing their errors. For example, if the participant's average of their lowest

MT for each of the four patterns was 620 ms and they made a total of four errors (adding an additional 20 ms to their average) then their final delayed retention score would be calculated as 640 ms.

2.3.2 Apparatus

Participants sat in front of a 16” wide computer screen (LG model) and a modified keyboard (Microsoft model), which were placed on a standard table. All of the keys on the numeric keypad of the were removed, with the exception of the keys corresponding to '2', '4', '6' and '8', which were used as the input device during the entire experiment. A small white paper square was attached to the top of each of these four keys and labeled with a left, right, up or down black arrow symbol. The remaining keys on this numeric keypad were removed and covered with black paper to reduce input errors during the keypressing task (Figure 1). The software tool E-prime, version 2.0, was used to program the instructions and task, as well as record the dependent measures of interest (MT and error). Several brief questionnaires were also presented to the participants; however, these will be addressed in more detail in the procedures section.

2.3.3 Procedures

Day 1

Participants arrived at the Motor Behaviour Laboratory where they provided informed consent and filled out demographic information (Appendix B-1). The instructions were specified on the computer screen and any remaining questions were answered prior to data collection. The experimental task required all participants to use the modified keypad to learn different computer keypress patterns.

For each pattern, a 3x3 grid was presented on the computer screen with the starting position of a colored square filled in among the rest of the black squares (Figure 1). Through a discovery process, the participant's task was to move the colored square to the next location in the sequence by pressing the appropriate arrow key (e.g., pressing the "down" arrow key to move from the currently colored square to the next key in the sequence). If the correct step was achieved (i.e., correct keypress) then the colored square moved to the new location on the grid and the previous square turned black, like all the other grid squares. If an incorrect key was pressed, the colored square remained in the same location. The same process occurred for the rest of the sequence until all five correct keypress steps were discovered. The final colored square in a sequence included the word 'end,' to indicate the end of the pattern.

Before beginning the acquisition (practice) session, participants were given three practice trials of a unique pattern to orient them to the task. After these trials were completed, participants were asked to rate how confident (i.e., baseline measure) they were, on a scale of 0 (not confident at all) to 100% (completely confident), that they could successfully learn the upcoming patterns in acquisition and be able to later reproduce them (Appendix B-2).

During the acquisition session, participants used a discovery process involving their non-dominant index finger to acquire knowledge of the four spatially distinct patterns (Figure 2 - blue, red, green, orange patterns). Participants held a small rolled piece of high-density foam while completing the task to ensure that only their index finger was being used. The acquisition session included a total of 160 trials (40 trials of each color pattern). Trial order depended on the group to which the participant was assigned.

Participants were provided with MT feedback following each acquisition trial, so their goal (‘winning criterion’) was to always try and beat their personal best MT (ms) for each specific pattern. Before the starting square of a pattern was displayed, a separate screen would alert the participant of the upcoming color pattern and what their time to beat (ms) was for that specific pattern (e.g., RED pattern time to beat is: 700 ms). After the pattern was completed (all five correct keypresses were discovered), a new screen showed their actual MT for that trial as well as a goal time for the next time another trial of the same pattern was presented. If their actual MT was faster than their time to beat (e.g., participant’s actual MT was 850 ms versus their ‘time to beat’ being 920 ms), then this became their new personal best time for that pattern (i.e., 850 ms) and the participant achieved success (i.e., a ‘win’) since they had satisfied the ‘winning criterion'. If their actual MT was slower than their time to beat (e.g., participant’s actual MT is 987 ms versus their ‘time to beat’ being 920 ms), then their goal time remained the same until it was beat (i.e., 920 ms) and as a result the participant ‘lost’ since they were not successful at satisfying the ‘winning criterion’.

In the adaptive conditions, task switching was performance-contingent and dependent on the algorithm employed (i.e., WinSwitch or WinRepeat ADAPTIVE). For example, when a participant in the WinSwitch ADAPTIVE schedule achieved the task goal (i.e., a 'win'), they were rewarded with a switch to a different pattern on the next trial; failure to beat their best MT (i.e., a 'loss') resulted in immediate repetition of the same pattern. The opposite contingency was used in the WinRepeat ADAPTIVE schedule. In the case of a task switch, the computer program would switch to the pattern with the greatest number of trials left until each pattern was exhausted (all 40 trials completed). The yoked-controls (WinSwitch and WinRepeat YOKED), regardless of their performance, were each matched to a participant in their counterpart adaptive condition and as a result followed a pre-determined practice schedule.

In addition to receiving MT feedback, for the first eight trials of acquisition, participants were also verbally told if they ‘won’ or ‘lost’ so that they did not misunderstand the task or the consequences of reaching/not reaching the goal criterion. After the eighth trial, participants were expected to interpret their own performance results and were not explicitly notified if they 'won' or 'lost', however, all participants were encouraged to always try to 'win' (i.e., beat their best MT in acquisition trials). In addition, unlike their yoked counterparts, participants in the adaptive conditions also experienced the consequence of 'winning' or 'losing' due to the performance-contingent task switching.

After acquisition, participants were given a 10 minute break where they completed the *Day 1 Pattern Questionnaire*, which assessed their perceived learning confidence (i.e., self-efficacy) and perceived task difficulty for each separate pattern on a scale of 0-100% (Appendix B-3). The remaining time was used to complete a spatially interfering task (i.e., a Sudoku puzzle) (Appendix B-4). The experimenter also used this time to explain the details of the $15 dollar bonus. Following the break, all participants completed the immediate retention test (same-day retention) using only their non-dominant index finger. This test consisted of 16 total trials (four trials of each pattern) presented in a random order without any goal information (i.e., 'time to beat') or performance (i.e., actual MT) feedback. Participants were instructed to continue to complete each trial as fast and accurate as possible. Following this test, participants provided another rating of their perceived learning confidence on a scale of 0 (not confident at all) to 100% (completely confident) for each separate pattern (Appendix B-5) and were invited to return the following day at approximately the same time.

Day 2

When participants returned to the lab 24 hours later, they used the same scale to once again rate their perceived learning confidence on a scale of 0 to 100% for each separate pattern (Appendix B-5). Next, they completed a cued recall test for each separate pattern (Appendix B-6). For this test they were presented with a paper illustration of the grid with the starting square cued for each pattern and instructed to draw the five arrows corresponding to how they remembered that square moving throughout the grid. Participants then completed the delayed retention test (next-day retention) with their non-dominant index finger, which was identical to the immediate retention test they completed the day before. Following the test, participants completed the modified version (part B) of the *Trail Making test*, where they were timed while connecting the circles in alternating sequence between a set of numbers and letters without lifting their pen off the paper (i.e., 1-A-2-B-3-C, etc…) (Appendix B-7). This test was used strictly as a demographic descriptor and not a screening tool. Participants were then debriefed, paid and thanked for their participation.

2.4 Dependent Measures

Dependent measures were collected on *Day 1* and *Day 2* and will be discussed under the following categories: Psychological Measures, Performance Measures, and Cognitive Memory Measure.

2.4.1 Self-Reported Psychological Measures

Perceived Learning Confidence (self-efficacy measure) was assessed at several time points during the experiment (Bandura, 1997). A baseline measure of perceived learning confidence was taken before the start of the acquisition session. During this time, participants reported how confident they were on a scale of 0 (not confident at all) to 100% (completely confident) that they *could* successfully learn the acquisition patterns and reproduce them at a later time (Appendix B-2). After the acquisition session and immediate retention test, and before the delayed retention test, participants reported how confident they were that they successfully *learned* each pattern on a scale of 0 (not confident at all) to 100% (completely confident) (Appendix B-3 and -5). The perceived learning confidence rating for each of the four color patterns was averaged together to provide an estimate of overall perceived learning confidence.

Following acquisition, a measure of perceived task difficulty was taken for each color pattern. For this measure, participants were asked to report the how difficult they perceived each color pattern to be on a scale of 0 (not difficult at all) to 100% (completely difficult) (Appendix B-3). This measure was taken to ensure that following acquisition, participants perceived all of the patterns to be approximately equal in their level of difficulty (i.e., one pattern was not more difficult than another).

2.4.2 Performance Measures

The E-prime computer software program (version 2.0) was used to record MT and Keypress Errors during acquisition, and the immediate and delayed retention tests. MT was measured as the time in ms lapsed from the first to the last button press for each color sequence/trial. Keypress Errors were measured as the total number of incorrect keypresses made during each trial.

In addition, after the acquisition data were collected, the number of task switches for each participant in the adaptive conditions was analyzed. This measure was taken to reflect how much CI was experienced during acquisition. A task switch occurred when two different patterns were performed on consecutive trials during the acquisition session. Task switches were not recorded for the yoked conditions since trial order was identical to their matched counterparts and using those data in an ANOVA would violate the assumption of independence.

2.4.3 Cognitive Memory Measure

A cued recall test was used to assess cognitive memory after a 24 hour period. For each pattern, participants were presented with a paper illustration of the grid and starting square (cued) and instructed to draw the five arrows corresponding to how they remembered that square moving throughout the grid (Appendix B-6). There was no time limit imposed during the test. Following the session, the experimenter scored each incorrect response on the grid as a recall error, for a potential maximum of 20 recall errors across all four color patterns.

2.5 Statistical Analysis

The acquisition data for MT and Keypress Errors were each analyzed using a 2 (condition: adaptive, yoked) x 2 (paradigm: WinSwitch, WinRepeat) x 10 (block: blocks of 16 trials, 4 trials of each color pattern) mixed analysis of variance (ANOVA) with repeated measures on the last factor.

The analysis of the acquisition data for task switches were conducted using a 2 (group: WinSwitch ADAPTIVE, WinRepeat ADAPTIVE) x 4 (block: blocks of 40 acquisition trials with 10 trials of each color pattern) mixed ANOVA with repeated measures on the last factor. This analysis only included the adaptive conditions (WinSwitch and WinRepeat ADAPTIVE) since the task switching that the yoked groups received was identical, and if included would violate the assumptions of an ANOVA (i.e., assumption of independence).

The retention data for MT and Keypress Errors were each analyzed using a 2 (condition: adaptive, yoked) x 2 (paradigm: WinSwitch, WinRepeat) x 3 (block: last acquisition block of 16 trials, immediate retention, delayed retention) mixed ANOVA with repeated measures on the last factor.

The learning confidence data were analyzed using a 2 (condition: adaptive, yoked) x 2 (paradigm: WinSwitch, WinRepeat) x 4 (test: baseline, post-acquisition, post-immediate retention, pre-delayed retention) mixed multivariate analysis of variance (MANOVA). The data were analyzed using a MANOVA since the wording and administration time (i.e., before or after the test) of the questionnaires differed enough such that a repeated measure ANOVA design was no longer appropriate to use. However, due to the sample size (not large enough for an appropriate MANOVA analysis), a 2 (condition: adaptive, yoked) x 2 (paradigm: WinSwitch, WinRepeat) x 4 (test: baseline, post-acquisition, post-immediate retention, pre-delayed retention) ANOVA with repeated measures on the last factor was also conducted.

Finally, the task difficulty and recall error data were each analyzed using a 2 (condition: adaptive, yoked) x 2 (paradigm: WinSwitch, WinRepeat) ANOVA.

All significant differences were determined by p values less than 0.05. Tukey HSD tests were conducted to parse out existing differences between means for significant F tests.

2.6 Results

2.6.1 Acquisition

Analysis of the MT acquisition data revealed a significant interaction between paradigm and block, F (9, 333) = 29.42, $p < .001$. Post-hoc analysis revealed that the WinRepeat groups outperformed (i.e., lower MT) the WinSwitch groups only during the first (M = 2554 ms compared to M = 4177 ms) and second (M = 1463 ms compared to M = 2189 ms) block of acquisition. No other main effects or interactions were found, suggesting that for the remainder of the acquisition session all groups were performing similarly. For a summary of the MT acquisition means, please see Figure 3 and Table 1.

Analysis of the Keypress Errors revealed a significant 3-way interaction between condition and paradigm and block, F (9, 333) = 2.85, $p < .01$. Post-hoc analysis revealed that the yoked conditions resulted in significantly fewer errors than the adaptive conditions during the first block of acquisition (M = 37.9 errors compared to M = 49.2

errors), and that the WinRepeat groups had significantly fewer errors than the WinSwitch groups during both the first block (M = 21.0 errors compared to M = 62.3 errors) and second block (M = 11.5 errors compared to M = 24.2 errors) of acquisition. For a summary of the Keypress Error acquisition means, please see Figure 6 and Table 2.

Analysis of the task switch data revealed a significant interaction between paradigm and block, F (3, 54) = 90.18, $p < .001$. Post-hoc analysis revealed that the WinRepeat groups had significantly fewer switches during the beginning of practice (Trials 1-40) and significantly more switches later in acquisition (Trials 41-80, Trials 81-120 and Trials 121-160) than those in the WinSwitch groups. Also, a main effect for paradigm, F (1, 18) = 225.84, $p < .001$ revealed that those in the WinRepeat groups were switching significantly more during acquisition than those in the WinSwitch groups. To put this finding into perspective, the WinRepeat groups engaged in more blocked practice than the WinSwitch groups early in acquisition, and engaged in more random practice than the WinSwitch groups later in acquisition. In addition, the WinRepeat groups also engaged in *more* task switching during acquisition compared to those in the WinSwitch groups as demonstrated by the main effect for paradigm. For a summary of the Task Switch means, please see Figure 9 and Table 3.

2.6.2 Retention

Analysis of the MT retention data revealed a significant interaction between condition and block, F (2, 74) = 4.50, $p < .05$. Post-hoc analysis revealed that the yoked conditions resulted in significantly lower MTs than the adaptive conditions during the immediate (M = 765 ms compared to M = 853 ms) and delayed (M = 724 ms compared to M = 866 ms) retention tests. During the last block of acquisition all groups were performing relatively similar which contributed to the significant interaction finding. In addition, there was also a significant interaction between paradigm and block, F (2, 74) = 4.43, $p < .05$, where post-hoc analysis revealed that the WinRepeat groups had significantly lower MTs than the WinSwitch groups during the immediate (M = 736 ms compared to M = 884 ms) and delayed (M = 709 ms compared to M = 882 ms) retention tests. Again, during the last block of acquisition all groups were performing relatively similar which contributed to the significant interaction finding. For a summary of the MT retention means, please see Figure 4 and Table 1. In addition, for an overall summary of the MT acquisition and retention means, please see Figure 5 and Table 1.

Analysis of the Keypress Errors retention data revealed a significant interaction between condition and block, F (2, 74) = 6.78, $p < .01$. Post-hoc analysis revealed that the yoked conditions had significantly fewer errors than the adaptive conditions during the immediate (M = 2.1 errors compared to M = 3.9 errors) and delayed (M = 1.8 errors compared to M = 4.3 errors) retention tests. During the last block of acquisition all groups were performing relatively similar which contributed to the significant interaction finding. In addition, there was also a significant interaction between paradigm and block, F (2, 74) = 5.34, $p < .01$, where post-hoc analysis revealed that the WinRepeat groups had significantly fewer errors than the WinSwitch groups during the immediate (M = 1.2 errors compared to M = 4.9 errors) and delayed (M = 1.2 errors compared to M = 4.9 errors) retention tests. Again, during the last block of acquisition all groups were performing relatively similar which contributed to the significant interaction finding. For a summary of the Keypress Error retention means, please see Figure 7 and Table 2. In addition, for an overall summary of the Keypress Error acquisition and retention means, please see Figure 8 and Table 2.

2.6.3 Learning Confidence

The MANOVA for learning confidence revealed a significant main effect for paradigm, Wilks' $\lambda = .720$, F (4, 34) = 3.31, $p < .05$. Separate post-hoc ANOVAs were conducted to further examine the source of existing differences. The results of these post-hoc analyses revealed that there was a significant main effect for paradigm following the immediate retention test, F (1, 37) = 103.74, $p < .05$, where the WinRepeat groups reported significantly greater self-efficacy beliefs (i.e., more confident) than the WinSwitch groups (M = 95.82 % compared to M = 87.69 %). A correlation analysis was conducted to examine the relationship between performance (MT) and self-efficacy. More specifically, this analysis was conducted to further investigate if the self-efficacy belief (i.e., learning confidence) ratings provided by the WinSwitch groups, specifically the WinSwitch ADAPTIVE group (after acquisition), were related to their performance on the immediate retention test. This analysis revealed a strong negative correlation, r = -0.86, which indicated that a lower self-efficacy rating following acquisition was related to greater MTs on the immediate retention test for the WinSwitch ADAPTIVE group. The Repeated Measures ANOVA for learning confidence revealed a significant main effect for block, F (3, 111) = 40.05, $p < .001$, where post-hoc analysis revealed that the learning confidence ratings, across all groups, significantly increased from the baseline rating to the rating taken after acquisition (M = 71.26 % compared to M = 88.18

%), and significantly decreased from the rating taken after the immediate retention test on *Day 1* to the rating taken before the delayed retention on (M = 91.75 % compared to M = 84.01 %). For a summary of the Learning Confidence means across testing blocks, please see Figure 10 and Table 5.

2.6.4 Task Difficulty

Analysis of the task difficulty data revealed no significant main effects or interactions between the groups. For a summary of the Task Difficulty means taken after acquisition, please see Table 4.

2.6.5 Recall Error

Analysis of the recall error data (cued recall test) revealed no significant main effects or interactions between the groups. For a summary of the Recall Error means taken on Day 2, please see and Table 6.

2.7 Discussion

The overall purpose to Experiment 1 was to examine how learned-adaptive acquisition schedules (i.e., performance-contingent) influenced performance and learning. All participants had to learn four spatially-distinct keypress patterns with the instruction to perform each sequence as quickly and accurately as possible. Following each acquisition trial, all participants received MT feedback and their goal was to always try and beat their best MT for each color pattern. Using this protocol and task, the purpose of this experiment was two-fold.

2.7.1 Does the Nature of the Contextual Interference in Adaptive Schedules Matter?

The first purpose of Experiment 1 was to determine whether it was the nature of the adaptive schedule that influenced performance and learning. This purpose was examined by using two opposing performance-contingent task switching schedules. One performance-contingent paradigm, WinRepeat, had learners repeat the same pattern if they were successful at achieving the task goal (i.e., beating best MT). Failure to beat their best MT in the WinRepeat schedule resulted in an immediate task switch. The opposite algorithm, WinSwitch, resulted in a task switch if the goal was achieved and a task repetition if the goal was not achieved. Since the goal was to always beat one's personal best MT, achieving the performance criterion (i.e., 'a win') would be much easier early in practice than later in practice. As revealed in the analysis of the switch data (Figure 9), this meant that in a WinRepeat schedule, the beginning of practice involved some blocked practice and the remainder of acquisition would result in mostly random practice (due to losing); the opposite contingency would result in the WinSwitch paradigm. Based on the CI literature, it was expected that more task switching (WinRepeat) would reveal superior learning compared to the opposite contingency (WinSwitch) and this hypothesis was confirmed. This experiment extends the work that has been done on the CI effect which demonstrates that high contextual interference (i.e., more random practice due to the task switching algorithm of WinRepeat) facilitates learning (Battig, 1972; Lee & Simon, 2004; Shea & Morgan, 1979). This study adds a significant new finding that it is not only the *amount* of overall task switching that is important, but also *when* this task switching occurs. These results also provide support for 'mixed' practice schedules which have been shown to enhance learning by varying the CI levels with different amounts of blocked and random practice (Hebert et al., 1996; Landin & Hebert, 1997; Porter & Magill, 2010, Porter & Saemi, 2010). Thus, the findings of this experiment do suggest that the nature of the contextual interference in adaptive practice may explain why one task switching algorithm was better for learning than the other.

2.7.2 Does Learner-Adaptive Practice Facilitate Learning?

The second purpose of Experiment 1 was to determine if adaptive schedules were effective because the practice was tailored to the performance characteristics of the learner. This question was examined by assigning learners to either an adaptive practice condition or a yoked-control condition. Each time those in the adaptive conditions (WinSwitch ADAPTIVE or WinRepeat ADAPTIVE) succeeded or failed to achieve the task goal of beating their personal best MT, they faced a consequence of their action (either a task switch or repetition, depending on the algorithm). As a result, the learners in the two adaptive schedules had their achievements or failures emphasized since they were always aware of the consequences of 'winning' and 'losing'. In contrast, the yoked-controls (WinSwitch YOKED or WinRepeat YOKED) were matched to those in the adaptive conditions and therefore followed a pre-determined switching schedule. Unlike the adaptive conditions, task switching/repeating in the yoked-controls was dissociated from their actual performance.

Since adaptive schedules are tailored to individual differences and, based on the literature suggesting that adaptive practice facilitates learning, it was expected that the adaptive conditions would have superior learning, as measured by lower MTs and fewer errors, compared to the yoked-controls (Choi et al., 2008; Marchal-Crespo & Reinkensmeyer, 2008). Contrary to expectation, the second hypothesis was not supported – the yoked conditions had more effective learning (i.e., significantly lower MTs and fewer errors) compared to their counterparts in the adaptive conditions. These results suggest that the success of adaptive schedules may not be due to the fact that they are tailored to the learner's performance characteristics. However, this outcome may not be truly representative since the psychological factors associated with 'losing' may have influenced these results. Since the goal was to always beat personal best MTs, it became increasingly difficult to succeed (i.e., 'win') towards the end of acquisition, meaning that for most of practice, learners were 'losing'. In addition, those in the adaptive conditions faced direct consequences of losing (immediate task switch/repetition) so their losses were further emphasized unlike their yoked counterparts whose trial order was dissociated from their performance. Further emphasizing the consequence of 'losing' could have had psychological repercussions that may have influenced how well the task was performed/learned. The consequence of repeated losing may not have been as pronounced in the WinRepeat ADAPTIVE schedule (mostly random practice) since losing resulted in a task switch and forced the learner to focus on a brand new task (i.e., pattern). The learner was allowed to forget the tasks they failed (i.e., 'lost'). However, in the WinSwitch contingency (mostly blocked practice), losing resulted in an immediate task repetition which forced the learner to try and focus on the same task they just failed. It was predicted that repeated losing in the WinSwitch ADAPTIVE schedule could have lowered their perceived self-efficacy to do the task (more than their yoked counterparts), and therefore resulted in detriments to their actual learning (as suggested by the strong negative relationship between a lower self-efficacy rating after acquisition and greater MTs in the immediate retention test, $r = -0.86$ for the WinSwitch ADAPTIVE group). In addition, the emphasis of 'losing' may have also been interfering with the way that learners were processing the information during task repetitions (perhaps focusing less on the actual task). This may be a possible explanation for why such poor learning occurred in the one adaptive group (i.e., WinSwitch ADAPTIVE). More specifically, this particular group's lower self-efficacy ratings (i.e., perceived learning confidence) offer some support for this explanation. The finding was surprising since this group was engaging in mostly blocked practice, which is usually a schedule that is preferred by learners since it is easier (not as cognitively engaging as random practice) (Simon & Bjork, 2001). In order to further investigate this explanation, the influences of self-efficacy (i.e., perceived learning confidence) on learning in this particular adaptive schedule (WinSwitch ADAPTIVE) were explored in Experiment 2.

2.8 Limitations

One of the main limitations of Experiment 1 was the administration time of the self-efficacy ratings (before and after tests) as well as the wording of these self-report questionnaires. Experiment 2 addressed this by modifying the wording of these questionnaires to more accurately depict self-efficacy beliefs as a predictor of behaviour (Bandura, 1997).

Another limitation of Experiment 1 was related to the design. Some of the instructions and feedback/interpretations were verbally provided to participants. For example, towards the beginning of acquisition (for the first eight trials) the experimenter verbally told participants based on the MT feedback they were receiving if they 'won' or 'lost' before they were responsible to interpret this information on their own. Verbal instructions could bias (e.g., the tone in the experimenter's voice) the participant to behave in a specific manner. In addition, participants could have invested more cognitive effort to interpret the feedback (since it wasn't provided) rather than invest this effort into the task itself. Experiment 2 addressed this design limitation by providing more written information, and thus limiting the amount of experimenter involvement and leaving less for participants to have to interpret on their own. For example, in Experiment 1 participants were provided with MT feedback following each acquisition trial, however, they were expected to interpret whether they ‘won’ or ‘lost’ on their own (except for the first eight trials where the experimenter provided this information in the form of additional verbal feedback). To limit direct experimenter involvement and discrepancy in a participant's interpretation of the feedback, the design for Experiment 2 was changed such that after each trial participants were provided with information on the screen indicating whether they ‘won’ or ‘lost’.

2.9 Conclusion

In summary, Experiment 1 used task switching variations in the learner-adapted practice schedule (two adaptive schedules and two matched yoked-control schedules) to investigate the influence of learner-adaptive schedules (i.e., performance-contingent) on performance and learning. The specific purpose was to determine if the effectiveness of these types of schedules could be because they were tailored to the learner's performance characteristics or due to the nature of the contextual interference that they provide to learners during practice. The results of this experiment suggest that a switching algorithm (i.e., WinRepeat) that incorporates not only more switching (i.e., random practice) but includes this task switching/random practice towards the end of acquisition has a facilitatory effect on learning. Contrary to expectation, the experiment also suggests that the success of adaptive schedules may not be due to the fact that they are tailored to the learner's performance characteristics since the yoked conditions had more effective learning (i.e., significantly lower MTs and fewer errors) compared to their counterparts in the adaptive conditions. However, this outcome may not be truly representative since the psychological factors associated with ‘losing’ may have influenced these results. As a result, Experiment 2 will further explore these potential psychological factors and how they may influence practice and learning in learner-adapted practice.

CHAPTER III: THE INFLUENCE OF SELF-EFFICACY IN ADAPTIVE PRACTICE SCHEDULES (EXPERIMENT 2)

3.1 Introduction and Rationale

The overall purpose of this research (Experiment 1 and 2) is to investigate the influence of learner-adapted practice schedules on motor performance and learning, as well as on self-efficacy beliefs (i.e., perceived learning confidence). Moreover, research has stressed the importance of considering how practice structure (trial order, augmented feedback, etc.) influences motor skill acquisition in order to create more effective and efficient practice schedules. Since it has been demonstrated that adaptive schedules have potential to facilitate learning, it is worthwhile to examine which factors in this type of schedule are influencing learning.

Experiment 1 demonstrated that the nature of CI was important in learner-adapted practice (i.e., WinRepeat groups had more effective learning than WinSwitch groups) and that the effectiveness of adaptive schedules may not be because they are tailored to the learner's performance characteristics since the yoked conditions experienced more effective learning. More specifically, this study demonstrated that the WinSwitch ADAPTIVE group learned less effectively compared to the WinRepeat groups and their counterpart, the WinSwitch YOKED group. One reason for this finding is that this group not only engaged in mostly blocked practice (because they mostly 'lost') but their 'losing' was also emphasized when they had to keep repeating the same pattern. The emphasis on their losing seemed to have lowered their perceived self-efficacy to do the task (more than their yoked counterparts), which could have ultimately contributed to their learning detriments (as suggested by the strong negative relationship between a lower self-efficacy rating after acquisition and greater MTs in the immediate retention test, $r = -0.86$ for the WinSwitch ADAPTIVE group). As a result, this possibility will be further explored in Experiment 2 by using fabricated social-comparative feedback to alter (raise or weaken) learners' self-efficacy beliefs prior to and during practice (in a WinSwitch ADAPTIVE schedule) and examine their influence on motor skill acquisition. If receiving further negative social-comparative feedback (i.e., in the 'bad' feedback group) leads to even worse performance and learning compared to the 'control' and 'good' feedback groups, then this would lend support to the suggestion that the self-efficacy decreases in the WinSwitch ADAPTIVE group (due to the emphasized 'losing') were responsible for the learning decrements in Experiment 1.

3.2 Purpose and Hypotheses

3.2.1 Purpose and Objectives

The general purpose of this study was to examine the effects of altering self-efficacy beliefs, through social-comparative feedback (i.e., positive, negative, control), on the performance and learning of a motor sequence task. More specifically, the purpose of this study was to investigate whether it was the repeated 'losing' later in practice (in Experiment 1) that was responsible for lowering self-efficacy beliefs in the WinSwitch ADAPTIVE group and in turn negatively influencing their learning. This purpose will be explored by using Bandura's self-efficacy framework (from the social cognitive theory) to explain the findings of the first experiment and to further examine the influence of these psychological factors on motor skill acquisition (Bandura, 1986, 1997). Self-efficacy beliefs will be manipulated through social-comparative feedback prior to and during practice to examine their effects on motor learning. Prior to practice (in the capability/pre-acquisition test), self-efficacy will be manipulated (once) by using fabricated social-comparative feedback (i.e., performance results) to alter one's perceived capability of successfully completing the task. During practice (acquisition) self-efficacy will be manipulated (four times) by using fabricated social-comparative feedback (performance displayed relative to group performance results) to alter the learner's mindset (i.e., change how the learner believes he/she is performing the task). Each participant will be assigned to one of three combinations of this information: positive social-comparative feedback prior to and positive social-comparative feedback during practice (i.e., 'good' feedback group), negative social-comparative feedback prior to and negative social-comparative feedback during practice (i.e., 'bad' feedback group), no fabricated feedback prior to and during practice (i.e., 'control' feedback group).

3.2.2 Hypotheses

Based on the review of the literature, the following predictions were made:

1) Receiving positive social-comparative feedback was expected to result in self-efficacy belief increases and better performance and learning (i.e., lower MTs and fewer errors). Receiving negative social-comparative feedback was expected to result in a decrease in self-efficacy beliefs and poorer performance and learning (i.e., greater MTs and errors) (Bandura, 1986, 1997).
2) It was expected that the participants in the 'good' feedback group would have higher self-efficacy ratings than both the 'control' and 'bad' feedback groups. Also,

it was predicted that the 'bad' feedback group would have lower self-efficacy ratings than the 'control' group.

3) It was expected that the participants in the 'good' feedback group would have the most task switches (i.e., 'winning') during acquisition and the 'bad' feedback group would have the least. It was also expected that more task switching (i.e., more 'winning') would enhance learning as measured by lower MTs and fewer errors.

3.3 Methods

3.3.1 Participants

Participants were recruited from the McMaster University campus and surrounding area. The exclusion criteria included color-blindness and any condition that may have interfered with completing a computer keypressing task. Each participant provided written consent to the experimental procedures that were approved by the McMaster University Research Ethics Board (MREB # 2011-126).

Thirty-three healthy young adults volunteered to participate in Experiment 2. Three participants (one male) were excluded from data analyses due to a technical problem in the computer program (one participant in the control group) or because the manipulation was not believed (two participants in the bad feedback group reported that did not believe the fabricated social-comparative feedback). As a result, thirty healthy young adults were used in the final study analyses (mean (M) ± standard deviation (SD) = 22.8 ± 2.8 years, 49.4 seconds on Trail Making test; 15 males; 28 right-hand dominant). The Trail Making test was once again used as a demographic tool and completed at the end of the experiment.

The Experiment 2 protocol was similar to Experiment 1, and as a result redundant methodology-specific details will be omitted. Experiment 2 required participants to use the modified keypad to learn and perform, as quickly and accurately as possible, several spatially distinct computer keypress patterns. For this experiment, the task switching criterion was not manipulated between groups, as all participants engaged in a WinSwitch ADAPTIVE practice schedule. However, this experiment did manipulate self-efficacy (i.e., learning confidence) by administering fabricated social-comparative feedback before and during practice (i.e., positive for the Good Feedback group, negative for the Bad Feedback group or no social-comparative feedback for the Control Feedback group). A control group was added to this experiment to try and eliminate alternate explanations of the experimental results. Significant results would then suggest that altering the learner's mindset (i.e., self-efficacy) through social-comparative feedback influenced performance and/or learning. Prior to the first experimental task, participants were randomly assigned to one of three practice conditions (10 participants per group): Good Feedback (GF) group (n = 10), Bad Feedback (BF) group (n = 10), or Control Feedback (CF) group (n = 10).

Participants came in for two consecutive days of testing. On *Day 1* all participants performed a capability test and an acquisition session, followed by an immediate retention test and on *Day 2* they all completed delayed retention and transfer tests. Each participant was compensated 15 (CAD) dollars upon study completion (*Day 1* and *Day 2*). Based on the delayed retention test, a total score for each participant was calculated to determine who best retained the motor tasks on *Day 2* and one participant from each group (GF, BF and CF) with the best score was paid an additional 15 (CAD) dollars. The score was determined in the same way as in Experiment 1. In addition, the same apparatus was also used for this experiment (please see Experiment 1 Apparatus section for details).

3.3.2 Procedures

Day 1

Participants arrived at the Motor Behaviour Laboratory where they provided informed consent and filled out demographic information (Appendix E-1). The instructions were specified on the computer screen and any remaining questions were answered prior to data collection. All the patterns used in this experiment were either the same as Experiment 1, or similar in construction (two additional patterns included).

Before beginning the first experimental task, participants were given three practice trials of a unique pattern to make sure that they understood the task (same as Experiment 1). Following this, participants were asked to rate how confident they were that they *could* successfully learn the upcoming pattern on a scale of 0 (not confident at all) to 100% (completely confident) and that they *could* successfully reproduce and perform it as fast and accurate as possible at a later time (Appendix E-2).

The first experimental task required all participants to complete the 'capability test', which consisted of trying to learn one, five-keypress spatially distinct pattern over the course of 16 trials using only their non-dominant index finger (Figure 11 - purple pattern, separate from the patterns used during acquisition). To ensure that only their index finger was being used, participants were required to hold a small rolled piece of high-density foam while completing this task, as well as the remaining computer tasks in Experiment 2. Augmented feedback was not provided during the test and they were instructed to perform all 16 trials as quickly and accurately as possible. After completing the 16 trials, participants in the GF and BF groups were shown a bonus information screen which provided them with fabricated social-comparative feedback regarding their performance on the task. Participants in the GF group were informed that: 'based on other people who have completed this test, your predicted capability to successfully learn the upcoming patterns is: 84%'. Those in the BF group were informed that based on their test performance they were predicted to be 16% capable to successfully learn the upcoming patterns and those in the CF group were not provided with any social-comparative feedback. Most research that uses fabricated social-comparative feedback provides performance feedback that is either calculated based on the participant’s actual score (either $\pm$ 20 %) or informs the participant that they are in the top/bottom percentile (e.g., top/bottom 10^{th} percentile) based on their age and gender for a particular task (Hutchinson et al., 2008; Lewthwaite & Wulf, 2010). However, due to the nature of this test, a fabricated score had to be provided to the learner (to keep this consistent across participants). These specific scores (i.e., 84% and 16% as opposed to rounded numbers or more unrealistic scores such as 90% and 10%) were chosen to try and ensure that participants believed the feedback manipulation. This fabricated 'capability' test was designed to manipulate a learner's self-efficacy beliefs by altering their mindset (i.e., *perceived capability*) through social-comparative feedback (positive, negative or no feedback). For example, based on the self-efficacy framework, it would be expected that providing a learner with positive social-comparative feedback would increase his/her perceived capability and in turn influence performance in acquisition/retention (Bandura, 1997). As a manipulation check, following this test and/or after receiving this feedback, participants were asked to rate how confident they were that they *had* successfully learned the (purple) pattern on a scale of 0 (not confident at all) to 100% (completely confident) and that they *could* successfully reproduce and perform it as fast and accurate as possible at a later time (Appendix E-3).

Next, participants completed the same acquisition (practice) session that was used in Experiment 1 (Figure 2 - blue, red, green, orange patterns). However, three major changes were made to the design of the acquisition session for this experiment. The first change compared to Experiment 1 was that all participants engaged in the same practice schedule, WinSwitch ADAPTIVE (no task switching contingency manipulation) and therefore all had the same 'winning' criterion. This meant that when participants ‘won’ (i.e., beat their best MT), they experienced a task (pattern) switch and if they ‘lost’ (i.e., did not beat their best MT), they practiced the same pattern again. In order to address one of the limitations of Experiment 1 (amount of experimenter involvement and participant interpretation), this experiment modified the acquisition program so that following each trial during acquisition, right below their MT feedback, participants were also informed if they ‘won’ or ‘lost’ on that trial (i.e., beat/not beat their best MT for that color). The third variation to the acquisition session was the addition of the fabricated social-comparative feedback (positive or negative), which was presented to only participants in the GF and BF groups. Participants in the GF group were always provided with positive social-comparative feedback, while those in the BF group were always provided with negative social-comparative feedback. Participants in these two groups were presented with fabricated visual summary graphs that indicated how they were performing relative to the (hypothetical) group average at different time points during acquisition. A fabricated cumulative summary graph was presented every 38 trials (i.e., after the 38th, 76th, 114th, 152nd trial). Each of the four fabricated graphs illustrated a 'Learning Score %' as a function of performance time. A dark grey bar was used to illustrate the participant's performance after 'x' amount of trials, and a dotted red line was used to indicate the group's performance after the same amount of trials. To make the graphs look as realistic as possible, the group average (red dotted line) was set at progressive 'learning score %' increments of 40%, 65%, 77% and 81%. The GF group was visually informed that they were always performing and learning better than their peers, as their performance (grey bar) was calculated and shown as performing 20% above the group learning score average (red dotted line) (see Figure 12 for an example of the GF graph). The BF group was visually informed that they were never performing and learning as well as their peers, since their performance (grey bar) was calculated and shown as performing 20% below the group learning score average (red dotted line) (see Figure 13 for an example of the BF graph). Participants in the CF group did not receive any social-comparative feedback (e.g., fabricated performance summary graphs).

Following acquisition, participants were given a 10 minute break where they completed a Sudoku puzzle (Appendix E-4). The experimenter also used this time to explain the details of the $15 dollar bonus. Next, all participants completed the same immediate retention test as done in Experiment 1 and then were invited to return the following day at approximately the same time.

Day 2

When participants returned to the lab 24 hours later, they first rated their perceived learning confidence on a scale of 0 to 100% for the patterns that they had learned during *Day 1* acquisition (Appendix E-5). Next, they completed an uncued recall test for each separate pattern since the cued recall test in Experiment 1 did not seem challenging enough (Appendix E-6). For each pattern, participants were asked to mark an 'X' on a mini blank paper grid to illustrate the location of the starting colored square (Experiment 1 had this already illustrated) and then draw the five arrows corresponding to how they remembered that square moving throughout the grid. Participants then completed the delayed retention test (same as the immediate retention test done on *Day 1*). Following the test, participants were asked to complete a delayed transfer test, which was similar in construction to the first *Day 1* test (i.e., capability test/pre-acquisition), however no feedback was administered at the end. Participants again used their non-dominant index finger to complete 16 total trials of another unique pattern, as fast and accurate as possible, with no feedback present during or after the test (Figure 11 - yellow pattern). Finally, the last test that participants completed was the modified version of the timed (in seconds) Trail Making Test (Appendix E-7). In addition, a manipulation check was done to ensure that the fabricated feedback was believed by participants. Since mild deception was used, participants were debriefed on the true nature of the experiment as well as asked to re-consent to the experimental protocol (Appendix D). Participants were then paid and thanked for their participation.

3.4 Dependent Measures

Dependent measures were collected on *Day 1* and *Day 2* and will be discussed under the following categories: Psychological Measures, Performance Measures, and Cognitive Memory Measure.

3.4.1 Self-Reported Psychological Measures

Perceived Learning Confidence (self-efficacy) rating was used as a manipulation check to assess the impact of the fabricated social-comparative feedback on measures of self-efficacy. The wording of the questionnaire was modified so that it represented a better overall self-efficacy measure than Experiment 1 (i.e., adhering closer to Bandura's (1997) self-efficacy scale construction guidelines). Since the focus of Experiment 2 was to isolate self-efficacy, it was important to know when self-efficacy was in fact being altered and what type of augmented feedback was altering it. The first measure of perceived learning confidence (for one pattern) was taken prior to and following the 'capability test' (Appendix E-2 and -3). On *Day 2*, before the delayed retention test, all participants again reported how confident they were that they successfully learned the four patterns on a scale of 0 (not confident at all) to 100% (completely confident) and that they *could* successfully reproduce and perform them as fast and accurate as possible at a later time (Appendix E-5).

3.4.2 Performance Measures

The E-prime computer software program (version 2.0) was used to record MT and Keypress Errors during capability test, acquisition, immediate and delayed retention tests and delayed transfer test. MT was measured as the time in ms lapsed from the first to the last button press for each color sequence/trial. Keypress Errors were measured as the total number of incorrect keypresses made during each trial.

In addition, after the acquisition data was collected, the number of task switches for each participant in the adaptive conditions was analyzed. This measure was taken to assess how much CI was experienced during acquisition. A task switch occurred when two different patterns were performed on consecutive trials during the acquisition session.

3.4.3 Cognitive Memory Measure

The uncued recall test was used to assess cognitive memory after a 24 hour period. This particular recall test did not include the presentation of the starting square on the grid, since the cued task as measured by the amount of recall errors in Experiment 1 was not challenging enough (Table 6). For the uncued recall test, participants were presented with a paper illustration of the grid (blank) and instructed to mark the location of the starting square for each pattern with an 'X' and then draw the five arrows corresponding to how they remembered that square moving throughout the grid (Appendix E-6). There was no time limit imposed during the test. Following the session, the experimenter scored each incorrect response on the grid as a recall error, for a potential maximum of 20 recall errors across all four color patterns.

3.5 Statistical Analysis

The capability/pre-acquisition data for MT (ms) and Keypress Errors were each analyzed using a 3 (social-comparative feedback group: Good, Bad, Control) x 8 (delayed transfer test: last 8 trials of the test) mixed ANOVA with repeated measures on the last factor.

The analysis of the acquisition data for MT (ms) and Keypress Errors were each analyzed using a 3 (social-comparative feedback group: Good, Bad, Control) x 10 (block: each block has 16 trials, 4 trials of each pattern) mixed analysis of variance (ANOVA) with repeated measures on the last factor.

The analysis of the acquisition data for task switches were analyzed using a 3 (social-comparative feedback group: Good, Bad, Control) x 4 (block: each block has 40 trials with 10 trials of each pattern) mixed ANOVA with repeated measures on the last factor.

The retention data for MT (ms) and Keypress Errors were each analyzed using a 3 (social-comparative feedback group: Good, Bad, Control) x 2 (retention test: immediate, delayed) mixed ANOVA with repeated measures on the last factor.

The transfer data for MT (ms) and Keypress Errors were each analyzed using a 3 (social-comparative feedback group: Good, Bad, Control) x 16 (delayed transfer test: 16 trial test) mixed ANOVA with repeated measures on the last factor.

The self-efficacy (i.e., learning confidence) data were analyzed using a 3 (social-comparative feedback group: Good, Bad, Control) x 3 (test time: pre-capability test (baseline), post-capability test, pre-delayed retention) mixed ANOVA with repeated measures on the last factor.

The recall test data were analyzed using a 3-factor ANOVA (social-comparative feedback group: Good, Bad, Control).

All significant differences were determined by *p* values less than 0.05. If significant differences were present, then post-hoc Tukey HSD tests were conducted to parse out any existing differences.

3.6 Results

3.6.1 Capability/Pre-Acquisition Test

Analysis of the MT capability/pre-acquisition data (prior to any feedback manipulations) revealed a significant main effect for block, $F\ (7, 189) = 4.13$, $p < .001$. Post-hoc analysis revealed that participants performed the 12th trial in the capability/pre-acquisition test significantly faster (i.e., lower MT) compared to the 11th trial (M = 328 ms compared to M = 613 ms). No other main effects or interactions were found. For a summary of Capability/Pre-Acquisition Test MT means across testing trials, please see Table 10.

Analysis of the Error capability/pre-acquisition data (prior to any feedback manipulations) revealed no significant main effects or interactions. For a summary of Capability/Pre-Acquisition Test Error means across testing trials, please see Table 11.

These analyses were conducted to ensure that groups were not significantly different prior to the experimental manipulations (baseline).

3.6.2 Acquisition

To assess if the groups were performing similarly at the very beginning of acquisition for MT, a 3 (social-comparative feedback group: Good, Bad, Control) x 4 (first trial of each color pattern in acquisition – red, blue, green, orange) mixed ANOVA with repeated measures on the last factor was conducted. This analysis did not reveal a significant group difference for the first acquisition trial of each color pattern, F (2, 27) = 0.66, p = .52. Also, to ensure that groups were not performing significantly different from each other at the very beginning of acquisition for Keypress Errors, a 3 (social-comparative feedback group: Good, Bad, Control) x 4 (first trial of each color pattern in acquisition – red, blue, green, orange) mixed ANOVA with repeated measures on the last factor was conducted. This analysis did not reveal any significant group differences for the first acquisition trial (or any acquisition blocks) of each color pattern, F (2, 27) = 2.60, p = .09.

Analysis of the MT acquisition data revealed a significant interaction between group and block, F (18, 243) = 3.11, p < .001. Post-hoc analysis revealed that the GF group outperformed (i.e., lower MT) the BF and CF groups during the first (M = 2897 ms compared to M = 3991 ms and 4074 ms, respectively), second (M = 1107 ms compared to M = 1831 ms and 1955 ms, respectively) and third (M = 804 ms compared to M = 1340 ms and 1490 ms, respectively) block of acquisition. No other main effects or interactions were found, suggesting that for the remainder of the acquisition session all groups were performing similarly. These results suggest that the feedback manipulation(s) affected performance in the GF group early in practice (i.e., acquisition blocks 1-3) but not throughout the entire acquisition session. For a summary of the MT acquisition means, please see Figure 14 and Table 7.

Analysis of the Keypress Errors acquisition data revealed a significant main effect for block, F (9, 243) = 125.65, $p < .001$. Post-hoc analysis revealed that fewer errors were made over time (acquisition block). More specifically, significantly fewer errors were made by participants from the first to the second acquisition block (M = 39.7 errors compared to M = 5.9 errors), and from the second to the third acquisition block (M = 5.9 errors compared to M = 3.0 errors). No other main effects or interactions were found. For a summary of the Keypress Error acquisition means, please see Figure 18 and Table 8.

Analysis of the task switch data revealed a significant main effect for group, F (2, 27) = 3.80, $p < .05$. Post-hoc analysis revealed that the GF group had significantly fewer pattern switches during acquisition than the BF group (M = 10.4 switches compared to M = 12.6 switches). In addition, the task switch analysis also revealed a significant main effect for block, F (3, 81) = 301.28, $p < .001$. Post-hoc analysis revealed that the number of task switches decreased over acquisition blocks. More specifically, the second block had significantly fewer task switches than the first block (M = 11.7 switches compared to M = 25.0 switches), the third block had significantly fewer task switches than the second block (M = 5.8 switches compared to M = 11.7 switches), and the fourth block had significantly fewer task switches than the third acquisition block (M = 4.3 switches compared to M = 5.8 switches). Due to the WinSwitch algorithm this finding meant that towards the beginning of acquisition, participants engaged in mostly random practice and for the remainder of practice, they engaged in mostly blocked practice. For a summary of the Task Switch means, please see Figure 22 and Table 9.

3.6.3 Retention

Analysis of the MT retention data revealed a significant main effect for group, $F(2, 27) = 3.35$, $p < .05$. Post-hoc analysis revealed that the GF group had significantly lower MTs than the BF group during the retention tests (M = 751 ms compared to M = 985 ms). For a summary of the MT retention means, please see Figure 15 and Table 7. In addition, for an overall summary of the MT acquisition and retention means, please see Figure 16 and Table 7.

Analysis of the Keypress Errors retention data revealed no significant main effects or interactions. For a summary of the Keypress Error retention means, please see Figure 19 and Table 8. In addition, for an overall summary of the Keypress Error acquisition and retention means, please see Figure 20 and Table 8.

3.6.4 Delayed Transfer Test

Analysis of the MT transfer data revealed a significant main effect for block, $F(15, 405) = 74.19$, $p < .001$. Post-hoc analysis revealed that participants performed the second trial in the delayed transfer test significantly faster (i.e., lower MT) compared to the first trial (M = 1483 ms compared to M = 5438 ms). No other main effects or interactions were found. For a summary of the Delayed Transfer MT means across testing blocks, please see Figure 17 and Table 12.

Analysis of the Error transfer data revealed a significant main effect for block, $F(15, 405) = 56.18$, $p < .001$. Post-hoc analysis revealed that participants performed the second trial in the delayed transfer test with significantly fewer errors compared to the first trial (M = 0.3 errors compared to M = 4.5 errors). No other main effects or interactions were found. For a summary of the Delayed Transfer Error means across testing blocks, please see Figure 21 and Table 13.

3.6.5 Learning Confidence

Analysis of the learning confidence data revealed a significant main effect for group, F (2, 27) = 7.00, $p < .01$. Post-hoc analysis revealed that the BF group reported the lowest learning confidence (i.e., lower rating indicates lower confidence/self-efficacy) compared to the GF and CF groups (M = 72.0 % compared to M = 86.2 % and 86.1 %, respectively). At baseline (pre-capability test), groups did not significantly differ in their learning confidence ratings, F (2, 27) = 1.99, $p = .15$. For a summary of the Learning Confidence means across testing blocks, please see Figure 23 and Table 14.

3.6.6 Recall Error

Analysis of the recall error data revealed a significant main effect for group, F (2, 27) = 4.92, $p < .05$. Post-hoc analysis revealed that the GF group had fewer recall errors compared to the BF and CF groups (M = .2 recall errors compared to M = 4.1 recall errors and 3.6 recall errors, respectively). For a summary of the Recall Errors means across groups, please see Figure 24 and Table 15.

3.7 Discussion

The overall purpose to Experiment 2 was to use social-comparative feedback (i.e., positive or negative) to alter self-efficacy beliefs in a learner-adapted practice schedule and examine their influence on the performance and learning of a motor sequence task.

All participants engaged in the same adaptive schedule, WinSwitch ADAPTIVE. The same Experiment 1 task of learning several spatially-distinct keypress patterns was also used in Experiment 2. Using this protocol and task, along with some design changes, the purpose of this experiment was three-fold.

3.7.1 Did the Social-Comparative Feedback Influence Actual Performance and Learning?

The first purpose of this experiment was to examine whether providing fabricated social-comparative feedback (either positive or negative) would influence actual performance and learning. Based on the self-efficacy framework, it was expected that social-comparative feedback would alter self-efficacy beliefs and in turn actual performance and learning (Bandura, 1986, 1997). More specifically, it was predicted that the positive social-comparative feedback ('good' feedback group) would lead to more effective performance and learning (lower MTs and fewer errors) relative to the two other groups and that the negative social-comparative feedback (‘bad’ feedback group) would lead to less effective performance and learning (greater MTs and errors) relative to the two other groups. The results of this experiment revealed that positive social-comparative feedback enhanced actual performance (lower MTs) at the beginning of acquisition (temporarily) and learning during both retention tests compared to both the CF (no social-comparative feedback) and BF (negative social-comparative feedback) groups. The GF group did perform and learn the pattern sequences more effectively (as demonstrated by significantly lower acquisition and retention MTs and significantly fewer recall errors compared to the CF and BF groups). The BF group (received negative social-comparative feedback) had the slowest MTs during acquisition and retention compared to the CF group (e.g., M = 985 ms for both retention tests for BF group, compared to M = 896 ms for the CF group), however, this group difference was not statistically different and is therefore not necessarily repeatable. The high variability within the BF group could explain why no significant differences emerged when compared to the CF group (see Table 7 standard deviation values). Therefore, this experiment suggests that positive social-comparative feedback (GF group) influences performance *and* learning by providing a facilitatory effect on motor skill acquisition.

3.7.2 Did the Social-Comparative Feedback Influence Self-Efficacy Beliefs?

The second purpose of this experiment was to examine whether providing fabricated social-comparative feedback (either positive or negative) would influence self-efficacy beliefs (i.e., perceived learning confidence). Based on the self-efficacy framework, it was expected that providing social-comparative feedback (positive or negative) would alter self-efficacy beliefs if this determinant (i.e., social verbal persuasion) was perceived by the learners as an important/strong source of information (Bandura, 1986, 1997). The learning confidence data suggest that the initial 'capability' feedback manipulation was successful as the BF group *decreased* in self-reported learning confidence (M = 72.5% pre-test compared to M = 70.5% post-test) and the GF group *increased* in self-reported learning confidence (M = 81.5% pre-test compared to M = 89.5% post-test). However, these changes in self-efficacy were not statistically significant for both the BF and GF groups. In addition, the learning confidence rating for the CF group was not expected to change and did not statistically change, however, in the absence of receiving feedback following the pre-acquisition test, this group did report an increase in their self-efficacy beliefs (M = 83.0% pre-test compared to M = 89.8% post-test). One explanation for this self-efficacy increase in the CF group is the fact that they completed 16 trials of one pattern in a blocked trial order, so they essentially experienced a mastery experience (Bandura, 1997). These results may have been more exaggerated and approached significance (for the GF and BF groups, and *not* the CF group) if participants had completed fewer trials of this one pattern during the pre-acquisition test (i.e., four trials or less). Using fabricated social-comparative feedback, self-efficacy was also manipulated at four time points during acquisition; however self-efficacy ratings were not taken in order to confirm the success of these manipulations. The final self-efficacy measure was taken on Day 2 prior to the delayed retention test and was not significant for any of the three groups over time (e.g., not significant in terms of changes in the self-efficacy rating from the post-capability test to the rating taken prior to the delayed retention test).

When examining the combination of these three self-efficacy ratings together (i.e., pre-capability, post-capability, pre-delayed retention), the BF group did overall report significantly lower self-efficacy ratings compared to the GF and CF groups. The GF group overall reported significantly greater self-efficacy beliefs than the BF group but not the CF group. In addition, anecdotal reports from the participants in the GF and BF groups suggest that they were both affected by the feedback manipulations (see below). Please also note the variability in how some participants in the BF group took the negative feedback (some wanted to do better, others made excuses for poor performance).

Good Feedback (GF) group: *'confirmed that I was doing well', 'felt good to be performing well', 'I did better than most!', 'I had to prove that I could keep performing well', 'I was losing so much, but then I was shown that I was doing better than others, so it motivated me to keep going'*

Bad Feedback (BF) group: *'it was frustrating and bothering me all night', 'I didn't want to be worse than others', 'I felt I was doing poorly because I was always below the group average', 'I'm not good at video games', 'need to prove it to myself that I can do this and I had to do better', 'my bracelet's in the way, maybe that's why I'm not doing so well', '[feedback] made me try harder', 'I wanted to prove [the results] wrong but I just couldn't'*

Although the manipulation check suggests that self-efficacy was altered in the GF and BF groups, this self-efficacy increase/decrease between the pre- and post-capability test was not statistically significant. Anecdotal reports also suggest that self-efficacy (learning confidence) beliefs were manipulated in the GF and BF groups however these reports are to be viewed with caution. The general self-efficacy results (all three ratings) reveal that the BF group overall did report significantly lower self-efficacy ratings compared to the GF and CF groups, however, performance on the retention tests revealed that the BF group performed with significantly greater MTs than just the GF group and *not* the CF group. These results suggest that providing negative social-comparative feedback significantly influences self-efficacy reports but may not be potent enough to significantly affect performance and learning measures (the opposite is true for the GF group when compared to the CF group).

3.7.3 Did Task Switching Have an Influence on Learning?

The third purpose of Experiment 2 was to examine the task switches (i.e., 'winning') in the WinSwitch ADAPTIVE schedule. Based on the self-efficacy framework, it was expected that learners receiving positive social-comparative feedback (GF group) would have the most task switches/wins and that learners receiving negative social-comparative feedback (BF group) would have the least amount of task switches/wins. Based on the CI literature, it was predicted that more task switching (i.e., more random practice) would result in superior learning compared to less task switching (Battig, 1972; Lee & Simon, 2004; Shea & Morgan, 1979). Contrary to expectations, this hypothesis was not confirmed since the GF group had significantly fewer task switches during acquisition than the BF and CF groups. This also meant that the GF group was 'losing' significantly more than the other two groups (i.e., had considerable difficulty beating their best MT) and as a result was engaging in mostly blocked practice for the majority of acquisition. The enhanced positive information provided through social-comparative feedback seemed to override the switching effect from Experiment 1 (i.e., more task switching results in facilitated learning) and suggests that it may not be just the timing/amount of the task switching (i.e., random practice) that is contributing to effective learning. This experiment reveals that less task switching and *more* losing facilitated learning. Some proposed explanations for these data will be discussed in the general discussion (Chapter IV).

3.8 Limitations

One limitation to Experiment 2 was the absence of any manipulation checks for the self-efficacy alterations that were done during acquisition. These checks/questionnaires were not conducted in the interest of time and well as in the interest of not providing the learner with too many questionnaires. Therefore it is not possible to assess whether or not the fabricated social-comparative information in acquisition influenced actual self-efficacy beliefs and was the reason why performance differences occurred. It is also not possible to conclude which social-comparative feedback manipulation had a stronger effect on performance and learning (capability test manipulation/acquisition manipulations).

Another limitation of this design was the type of augmented feedback that was used (social-comparative feedback) to influence self-efficacy beliefs. Research has established that the strongest determinant of self-efficacy is mastery experience (not verbal persuasion) (Bandura, 1997). Maybe using a mastery experience manipulation would result in self-efficacy ratings that would reflect performance and learning more accurately when comparing these results to a control condition (i.e., CF group). Evidence to suggest that the social-comparative feedback was not the strongest determinant of self-efficacy was the fact that two participants in the BF group (not included in data analyses) reported that they did not believe the fabricated results. Therefore, most of the limitations in this experiment are in relation to the self-efficacy ratings. Future experiments should consider these points and seek alternative ways to measure and/or manipulate self-efficacy beliefs.

3.9 Conclusion

In summary, Experiment 2 used social-comparative feedback (i.e., positive or negative) to alter self-efficacy beliefs in a learner-adapted practice schedule to examine their influence on the performance and learning in a motor sequence task. In Experiment 2, all participants engaged in the same adaptive schedule, WinSwitch ADAPTIVE and the social-comparative feedback was manipulated in order to alter the learner's mindset (i.e., encourage them to believe that they were either performing better than the group average or worse regardless of their actual performance). The results of this experiment suggest that social-comparative feedback did influence self-efficacy beliefs. More specifically, providing negative social-comparative feedback revealed lower self-efficacy ratings in the BF group compared to the GF and CF groups and providing positive social-comparative feedback revealed higher self-efficacy ratings in the GF group compared to the BF group but not the CF group. In addition, social-comparative feedback influenced actual learning, where superior performance and learning were demonstrated in the GF group (received positive social-comparative feedback) compared to the BF and CF groups. Contrary to expectations, more task switching was not associated with facilitated learning when it was combined with positive social-comparative feedback. Instead, the GF group which received enhanced positive feedback had the fewest amount of task switches and greatest amount of 'losing', yet the most effective learning (i.e., performance on the retention tests) compared to the BF and CF groups. Furthermore, these results suggest that the positive social-comparative feedback may have overridden the switching effect that was found in Experiment 1.

CHAPTER IV: GENERAL DISCUSSION (EXPERIMENT 1 AND 2)

4.1 General Discussion

The overall purpose of this research was to investigate the influence of learner-adapted practice schedules on motor performance and learning, as well as on self-efficacy beliefs (i.e., perceived learning confidence). This chapter begins by summarizing the main findings from Experiment 1 and 2. This chapter then addresses the nature of CI in learner-adapted practice (i.e., the amount/timing of task switching). Next this chapter presents a discussion on the psychological consequences (i.e., self-efficacy beliefs) associated with 'losing' in adapted practice and how a further altered mindset, induced by either positive or negative social-comparative feedback, can potentially influence performance *and* learning. The remainder of the chapter presents a possible explanation related to attentional mechanisms for why providing positive social-comparative feedback may override a less effective learning schedule (e.g., blocked practice), and finally this chapter suggests future directions and implications of this work.

4.1.1 General Findings from Experiment 1 and 2

The general findings from these experiments (1 and 2) were:

1) WinRepeat schedule (more task switching/random practice) was more effective for learning than the WinSwitch schedule.
2) The effectiveness of adaptive practice may not be due to the fact that they are tailored to individual differences in skill and performance (yoked-controls learned more effectively).

3) Social-comparative feedback influenced self-efficacy beliefs (providing negative social-comparative feedback revealed lower self-efficacy ratings in the BF group compared to the GF and CF groups and providing positive social-comparative feedback revealed higher self-efficacy ratings in the GF group compared to the BF group but not the CF group).
4) Social-comparative feedback influenced learning (positive social-comparative feedback provided to the GF group revealed superior performance and learning compared to the BF and CF groups).
5) More task switching was not associated with facilitated learning when it was combined with social-comparative feedback (group with enhanced positive feedback had the fewest amount of task switches and greatest amount of 'losing'). The social-comparative feedback may have overridden the switching effect from Experiment 1.

4.1.2 The Nature of Contextual Interference in Learner-Adapted Practice?

Evidence for the CI effect was demonstrated in Experiment 1, where a greater amount of task switching (i.e., random practice) in the WinRepeat schedule seemed to facilitate learning (for both MT and Errors). This finding supports the CI literature and extends it to learner-adapted practice (Battig, 1972; Lee & Simon, 2004; Shea & Morgan, 1979). However, as demonstrated in Experiment 2, a greater amount of task switching (i.e., random practice) is not necessary to facilitate learning if learners are provided with positive social-comparative feedback.

Also, based on both task switching algorithms (WinRepeat and WinSwitch), adaptive practice seems to resemble a schedule that consists of a more moderate amount of interference (e.g., a mixed schedule). It is important to note that this 'mixed' blocked/random practice schedule does not result in performance decrements as does “true” random practice (Hebert et al., 1996; Landin & Hebert, 1997; Porter & Magill, 2010; Porter & Saemi, 2010).

4.1.3 Psychological Factors Involved in Adaptive Schedules

In both Experiment 1 and 2, the learner's goal was to always try and beat their personal best MT, however, the nature of task made it progressively more difficult to successfully attain this goal. As a result, all groups were progressively ‘losing’ more during acquisition. In Experiment 1, participants in the adaptive conditions (WinRepeat and WinSwitch) faced direct consequences when they failed to beat their best MT (the task goal). Emphasizing their ‘losing’ with a specific consequence (i.e., task switch/repetition) could have enhanced the negative feedback that they were already being provided with. As a result, emphasizing their losing may have altered their self-efficacy beliefs more so than the yoked-controls and in turn degraded their learning (i.e., as suggested by the strong negative relationship between a lower self-efficacy rating after acquisition and greater MTs in the immediate retention test, $r = -0.86$ for the WinSwitch ADAPTIVE group). In the WinRepeat paradigm, the losing (or its consequence) may not have been as detrimental for learning since it resulted in a task switch (more random practice) and there is strong evidence in the CI literature that task switching/random practice facilitates learning (Battig, 1972; Lee & Simon, 2004; Shea & Morgan, 1979). In the WinSwitch paradigm, losing (or its consequence) resulted in a task repetition (more blocked practice) and there is strong evidence to suggest that blocked practice is not as beneficial to learning as random practice (Lee & Simon, 2004). Therefore, the 'consequence of losing' (experiencing a task switch/repetition that is directly associated with performance) may have had more detrimental influences on learning (e.g., cumulative negative effects) than 'losing' alone (i.e., not beating personal best MT).

4.1.4 Consequences of Negative Feedback and Does Enhanced Positive Feedback Override 'Losing'?

In general, feedback is psychologically reassuring and people like to receive it, however, different variables could moderate how negative feedback is received. In Experiment 2 the consequence of 'losing' was further emphasized by having the BF group receive negative social-comparative feedback at several time points during the learning process (i.e., prior to and during practice). By providing this type of feedback, it was expected that the additional consequences of 'losing' would further degrade learning compared to the absence of this social-comparative feedback. For example, when a learner in the BF group did not beat their personal best MT (attain task goal), in addition to being informed that they 'lost' and having to face a consequence of their performance (i.e., task repetition consequence), they also were informed that they were performing below the group average during different time points in the learning process (false social-comparative feedback). The results revealed that although the negative feedback did affect the BF group's self-efficacy beliefs and their learning compared to the GF group, it did not significantly influence their performance and learning compared to the CF group.

Since people are often variable in how they use negative feedback, one reason for this insignificant result may be due to there being a lot of variability present within the BF group. There has been a lot of literature conducted on the effects of negative feedback and how individualistic differences, such as personality types (i.e., personality type-A or -B), can influence how people will receive negative feedback (Cooney & Zeichner, 1985; Kluger & DeNisi, 1996). For some individuals negative feedback can result in more effort, for others it may lead to directing their attention to the self and decreasing their performance quality (Ilgen & Davis, 2000; Kluger & DeNisi, 1996). Evidence for high variability among the BF group was also anecdotally revealed by some of the BF group participants. Furthermore, the psychological effects of enhanced negative feedback (i.e., negative social-comparative feedback) may have influenced learning in such a way that directed the learner's attention away from the primary task to instead focus on the emotional aspect of losing.

In contrast, it is possible that the enhanced positive feedback (i.e., positive social-comparative feedback) which was provided in Experiment 2 to the GF group was overriding the negative psychological effects of 'losing' that were demonstrated in Experiment 1. As a result, those in the GF group were losing more but maybe the enhanced positive feedback was encouraging them not to think about the losing as much their BF and CF counterparts (attention was instead directed to the primary task) (Bandura, 1986; Schunk, 1990).

4.1.5 Is Blocked Practice Really Detrimental To Learning?

Although Experiment 1 suggests that practice schedules involving a greater amount of blocked practice (less task switching) are not as effective for learning as those that include more random practice, Experiment 2 suggests that this task switching disadvantage can be overridden when combining a mostly blocked schedule with positive social-comparative feedback.

Research has demonstrated that feedback has the capacity to alter the locus of attention (Kluger & DeNisi, 1996). One hypothesis is that the positive social-comparative feedback motivated the learners to direct their full attention to the primary task and override the attention that was necessary to process the emphasized negative effects of losing, while the opposite was true for those receiving the negative social-comparative feedback (i.e., BF group). Moreover, the literature on *mind wandering* can support the results of Experiment 1 and 2. Mind wandering is a state of decoupled attention where the individual's ability to attend and therefore process relevant information becomes impaired (Smallwood, Fishman, & Schooler, 2007; Smallwood & Schooler, 2006). Tasks that require the deepest engagement (e.g., random practice) are the least susceptible to mind wandering and therefore attention is more likely to be dedicated to the primary task. In contrast, simple tasks (e.g., blocked practice) are the most susceptible to mind wandering (temporary attention lapses) since working memory becomes occupied with non-relevant information such as thoughts/feelings and attention is then taken away (decoupled) from the primary task (Smallwood et al., 2007; Smallwood & Schooler, 2006). It is possible that even the emotion of boredom could motivate an individual to cognitively escape from the task. In the motor learning literature, it has been suggested that blocked practice (low level of cognitive interference) requires less attentional demands whereas random practice (high level of cognitive interference) requires the learner to constantly redirect attention to the new task (Li & Wright, 2000; Stambaugh, 2011). Similar to a Forgetting-Reconstruction view: random practice 'forgets' about the losing and its consequences more than blocked practice (Lee & Magill, 1983, 1985). Thus, the attention issues (i.e., mind wandering, lower attentional demand) seem to lie mainly within blocked practice. If feedback can also alter attention, Experiment 2 suggests that the negative social-comparative feedback may have directed the learner's attention away from the primary task (focus became the emphasized losing as a result of the negative social-comparative feedback) while the positive social-comparative feedback in a mainly blocked schedule directed the learner's attention and focus to the primary task. By doing so, tasks presented in blocked trial-order became more cognitively engaging to the learner and perhaps overrode the negative learning effects of a blocked schedule.

4.1.6 What exactly is being 'adapted'?

These two experiments do not offer concrete answers as to what exactly is being adapted in learner-adaptive practice. Due to conflicting results, these data (Experiment 1 and 2) cannot confidently suggest that the effectiveness of learner-adapted practice is because they are tailored to individual differences. Future studies may benefit from using other types of adaptive schedules as well as different motor tasks to explore their influences on learning. However, more research needs to be conducted in order to specifically examine these variables.

4.2 Limitations and Future Directions

There are a number of limitations in both Experiment 1 and 2. The main limitation is due to the nature of the self-efficacy beliefs and the fact that they are subjective self-reported ratings. One problem with researchers using self-reported measures is that they rely on the participants to know and be able to accurately express their own perceptions. Extensive literature warns researchers not to rely solely on these subjective ratings and to instead supplement them with objective measures (Poulton, 1977; Schooler, 2002; Strahan, Spencer, & Zanna, 2002). Schooler (2002) suggests that people are not always capable of being able to accurately report their emotions and cognitions and that their appraisals may be distorted or not even reach consciousness. For example, research conducted on subliminal priming revealed that when participants were primed with words such as ‘thirst’ increased in their beverage consumption after a cookie-tasting test, however, no changes were demonstrated in their self-reported thirst (Strahan et al., 2002). Therefore, the subjective ratings taken in Experiment 1 and 2 do supplement the objective measures; however, they should still be taken with caution.

Another limitation may be related to the actual task (discrete and very memory-oriented) and a future experiment may want to use a continuous type of motor task instead. A final limitation is related to the goal used for both experiments. Since the goal was for participants to always beat their best MT, it inherently set participants up for failure since there were only so many times that their fastest MT could be beat until eventually they experienced a performance plateau.

Given that the goal in motor learning research is to always have learners be as independent as possible in their own learning process, future research should consider schedules that progressively give learners more control. It is important to try and educate learners about possible illusions of competence so that they are accurately aware of their actual learning progression. One way to approach this could be by having learners engage in adaptive practice (more experimenter-controlled) towards the beginning and then progressively fading the performance-contingency before providing learners with complete control over their task switching (task order). This type of schedule may encourage the continuation of future practice and solve the lack of task switching that self-controlled participants choose to engage.

4.3 Conclusion

These results of Experiment 1 and 2 have important implications for practice scheduling. These studies suggest that adaptive schedules may allow for learners to be able to more accurately judge their learning progression (based on self-efficacy ratings) and not be subject to metacognitive illusions (Simon & Bjork, 2001). Experiment 1 and 2 also suggest that more task switching benefits learning (Experiment 1), however the task switching effect can be overridden when combined with positive social-comparative feedback (Experiment 2). In contrast to the traditional view of blocked practice not being ideal for learning, the results of Experiment 2 suggest that when it is combined with positive social-comparative feedback, there are reliable learning advantages to using this type of practice schedule.

Since these experiments suggest that feedback can actually alter performance *and* learning, how and when feedback/instructions are provided becomes critical for researchers, coaches and health-care professionals. These studies recommend that learners be exposed to practice environments that will increase their self-efficacy beliefs. In addition, providing learners with positive social-comparative feedback will not degrade their learning but instead promote more effective learning. In contrast, since learners vary on how they react to negative feedback, the influence on their actual behaviour can also be highly variable. In summary, researchers should be cautious when providing learners with instructions and feedback, especially if they are negative in nature, since they have potential in influencing a learner's actual performance and learning. Further research needs to examine how enhanced (or subtle) this positive/negative social-comparative feedback has to be in order to influence actual behaviour.

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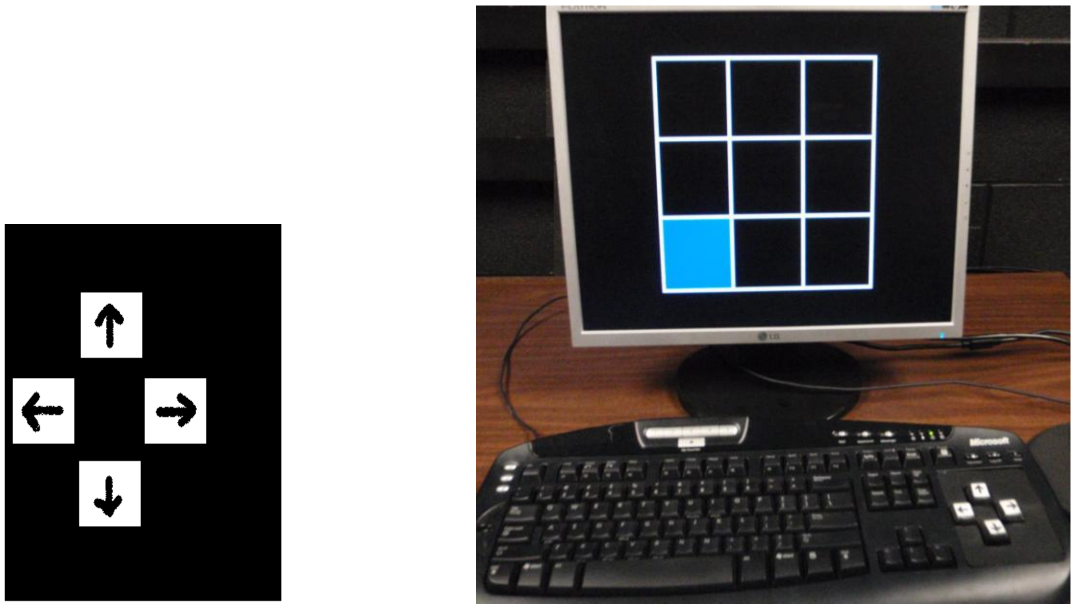
Appendices



(a) (b)

Figure 1. (a) Modified design of the numeric keypad (found on computer keyboard). All of the keys, with the exception of the keys corresponding to '2', '4', '8' and '6', were removed and covered with black paper to reduce input errors. The top of each of these four remaining keys were attached with a small white paper square and labeled with a left, right, up or down black arrow symbol. (b) Apparatus used for Experiment 1 and 2 (screen display illustrates the location of the starting square for the blue sequence on the 3x3 grid).

Acquisition Patterns:

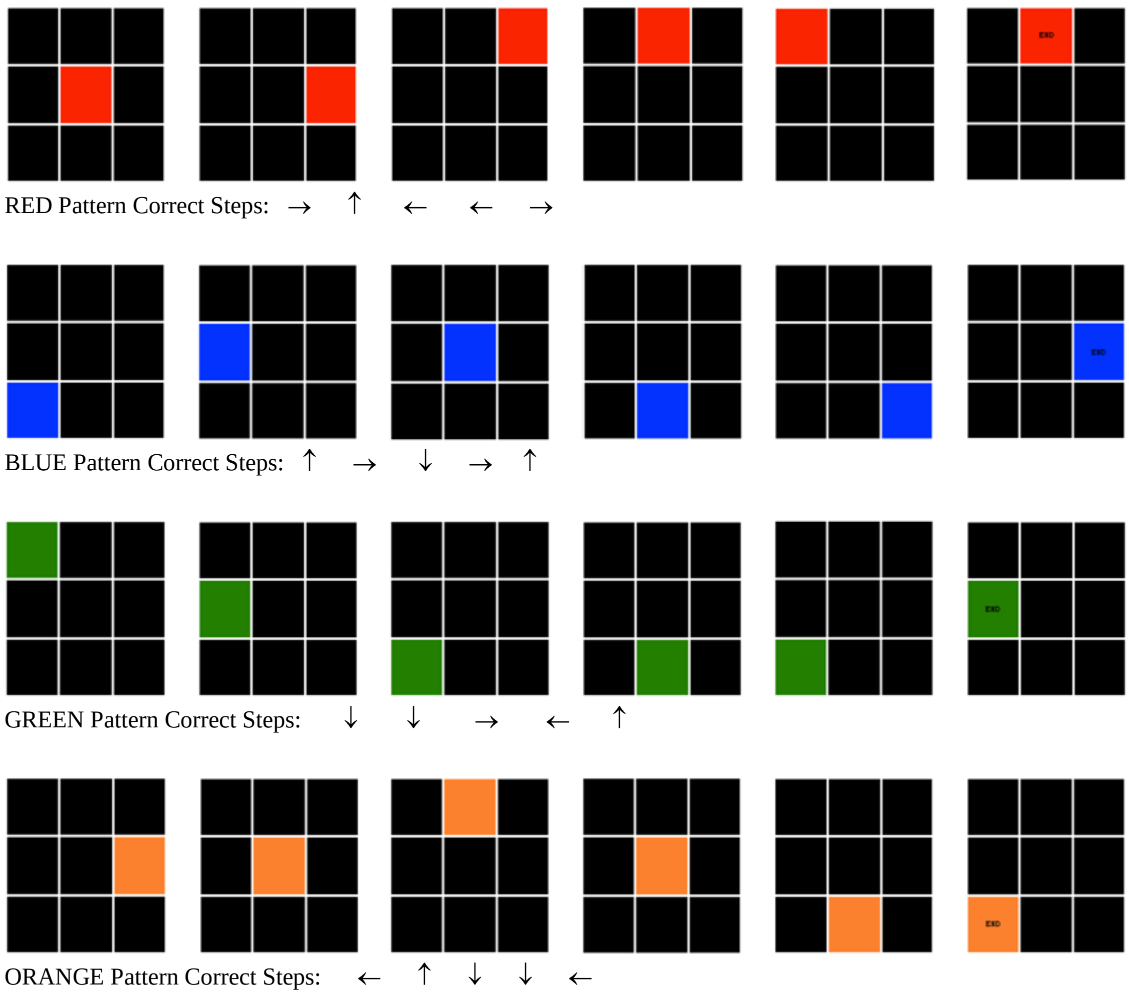


Figure 2. The correct keypress sequence for each of the four color patterns (red, blue, green, orange) used in Experiment 1.

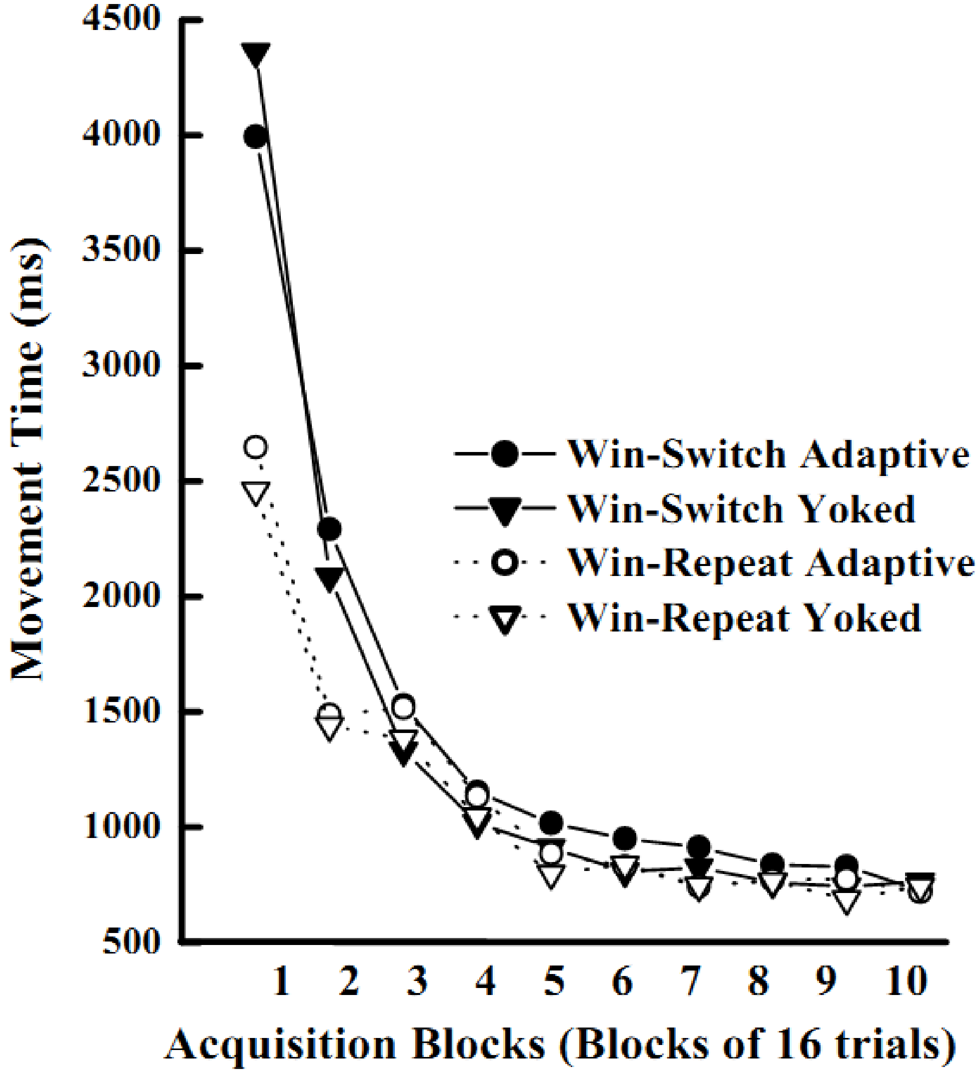


Figure 3. Movement Time (ms) for the WinSwitch Adaptive, WinSwitch Yoked, WinRepeat Adaptive, and WinRepeat Yoked groups across all 10 acquisition blocks (16 trials per block) in Experiment 1. Significant differences between paradigm (WinSwitch compared to WinRepeat) were found at blocks 1 and 2.

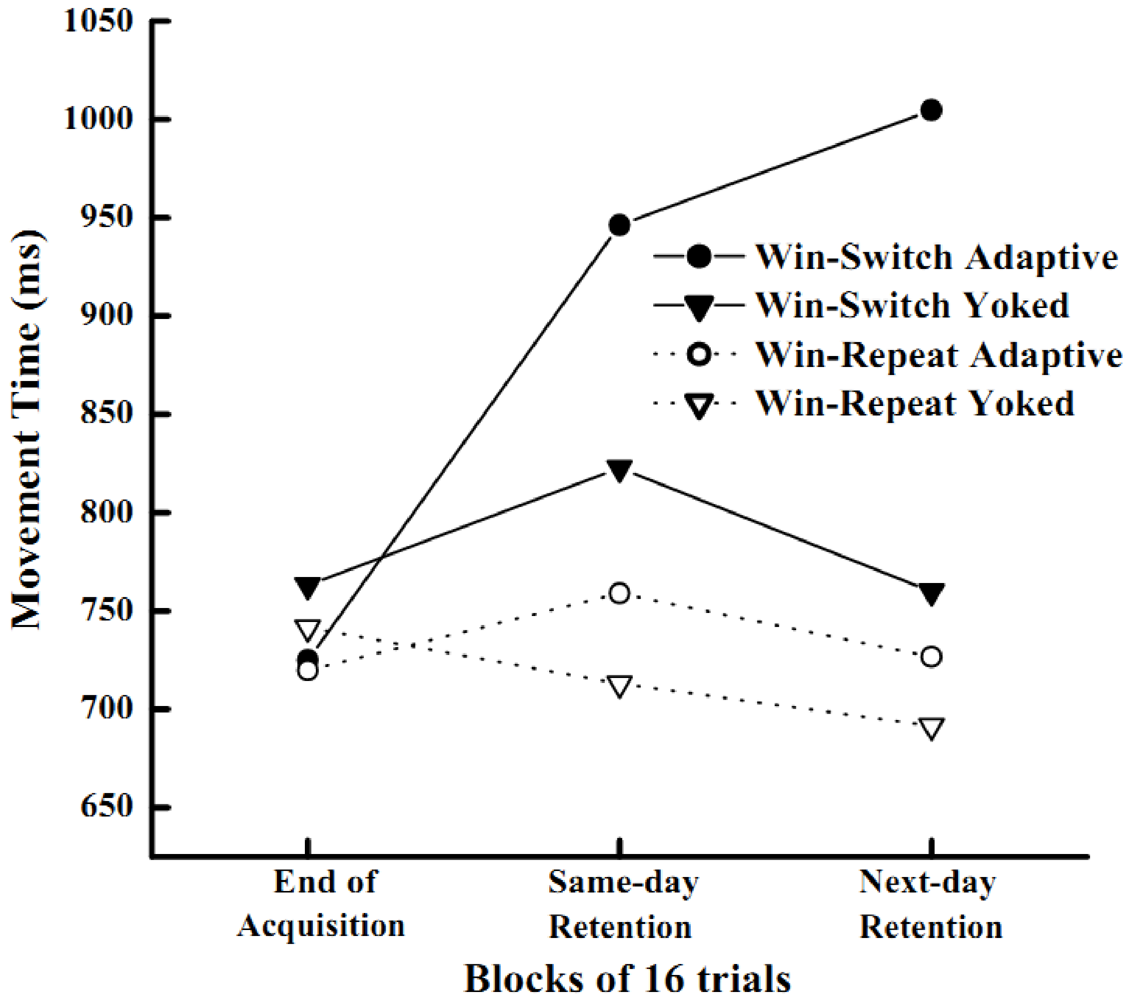


Figure 4. Movement Time (ms) for the WinSwitch Adaptive, WinSwitch Yoked, WinRepeat Adaptive, and WinRepeat Yoked groups across all test blocks (last block of acquisition, immediate (same-day) retention, delayed (next-day) retention) in Experiment 1. Significant differences between condition (Adaptive compared to Yoked) were found at same-day (immediate) retention and next-day (delayed) retention. Significant differences between paradigm (WinSwitch compared to WinRepeat) were found at same-day (immediate) retention and next-day (delayed) retention.

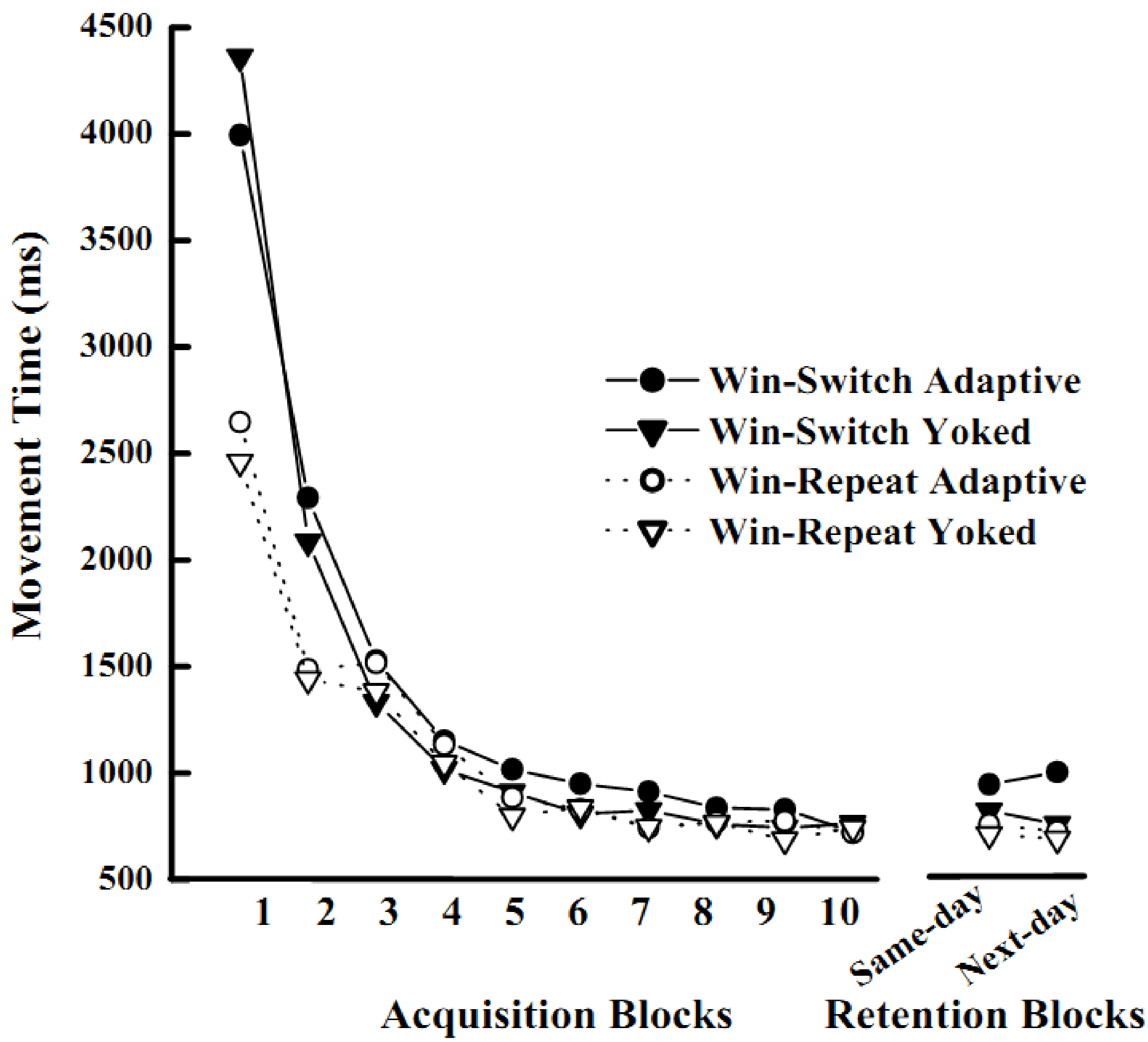


Figure 5. Overall summary graph of Movement Time (ms) for the WinSwitch Adaptive, WinSwitch Yoked, WinRepeat Adaptive, and WinRepeat Yoked groups across all acquisition and retention blocks, with each block consisting of 16 total trials in Experiment 1.

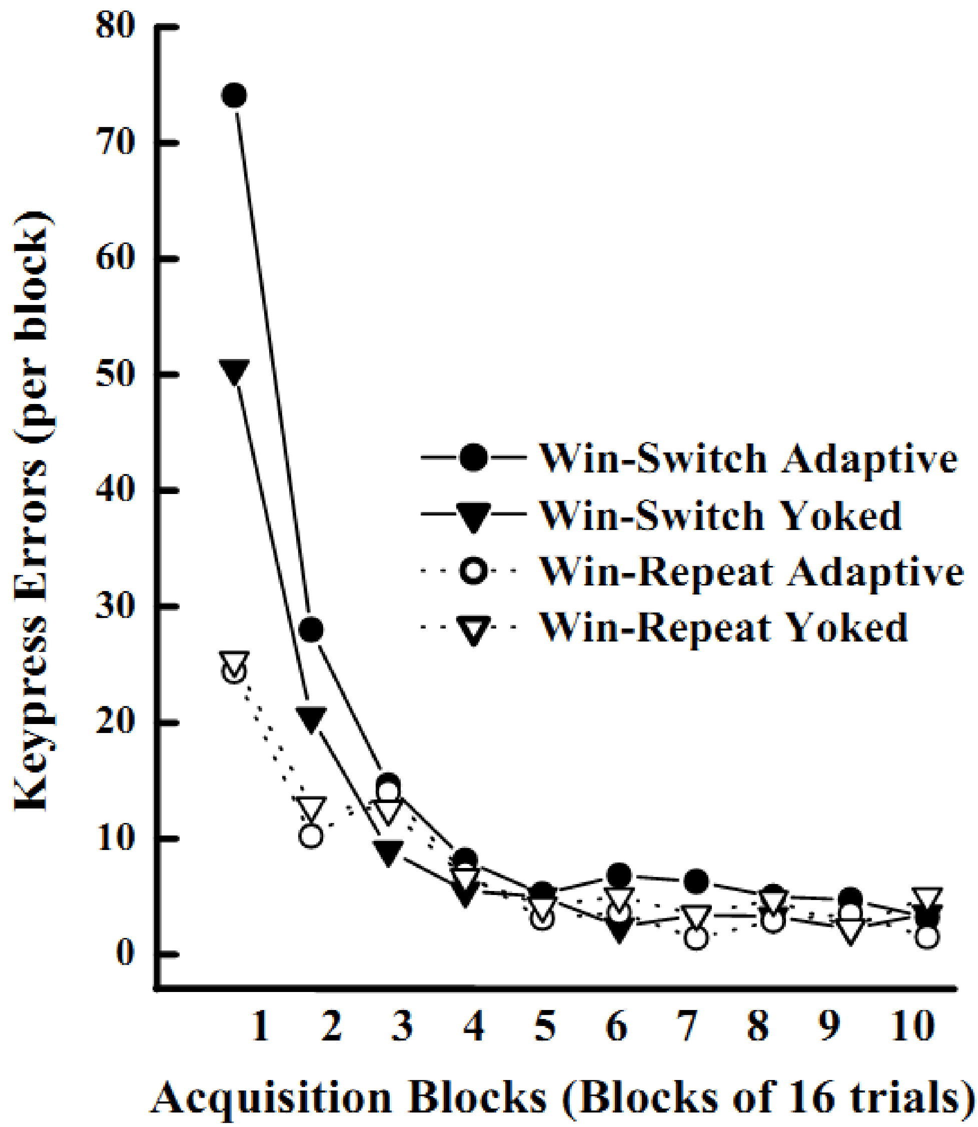


Figure 6. Keypress Errors for the WinSwitch Adaptive, WinSwitch Yoked, WinRepeat Adaptive, and WinRepeat Yoked groups across all 10 acquisition blocks (16 trials per block) in Experiment 1. Significant differences between condition (Adaptive compared to Yoked) were found at block 1. Significant differences between paradigm (WinSwitch compared to WinRepeat) were found at blocks 1 and 2.

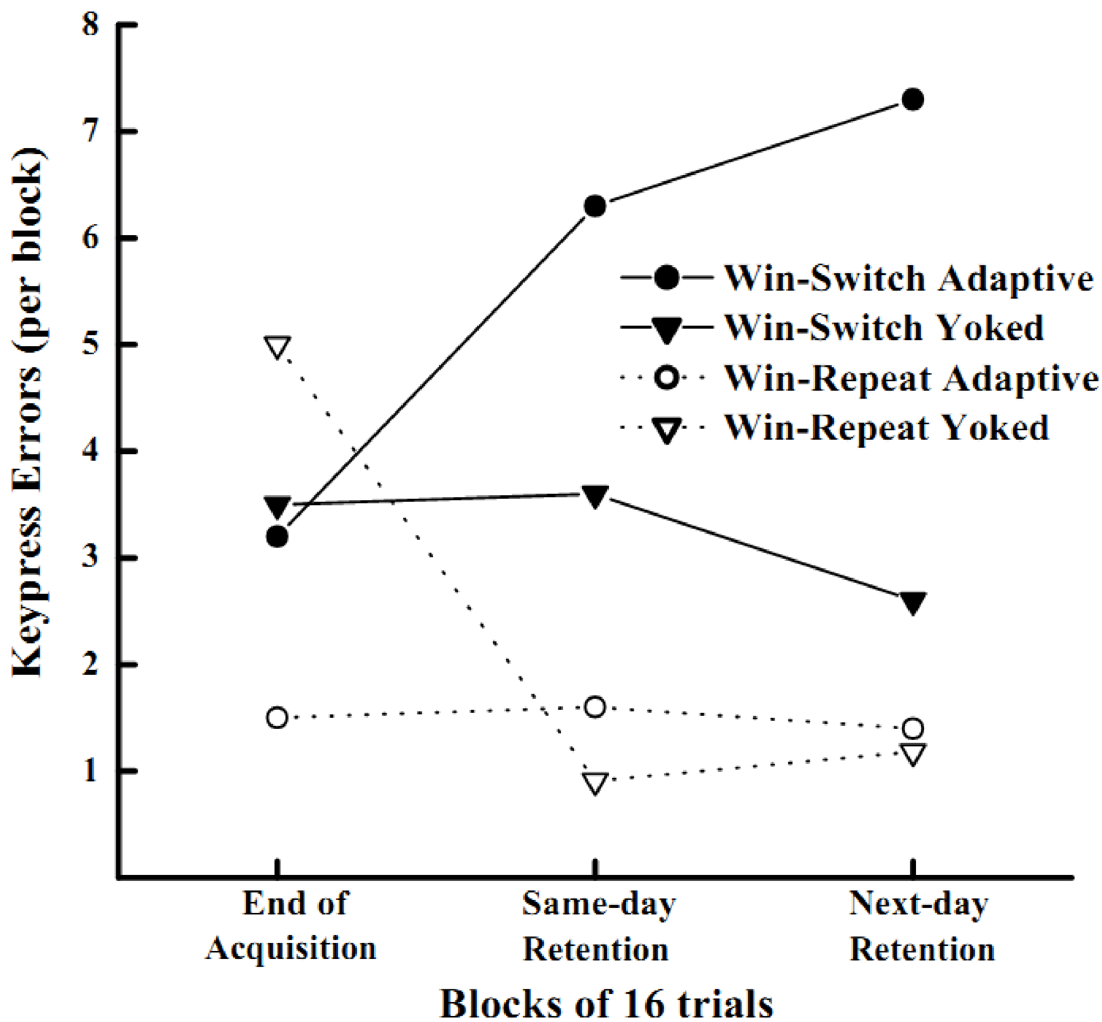


Figure 7. Keypress Errors for the WinSwitch Adaptive, WinSwitch Yoked, WinRepeat Adaptive, and WinRepeat Yoked groups across all test blocks (last block of acquisition, immediate (same-day) retention, delayed (next-day) retention) in Experiment 1. Significant differences between condition (Adaptive compared to Yoked) were found at same-day (immediate) retention and next-day (delayed) retention. Significant differences between paradigm (WinSwitch compared to WinRepeat) were found at same-day (immediate) retention and next-day (delayed) retention.

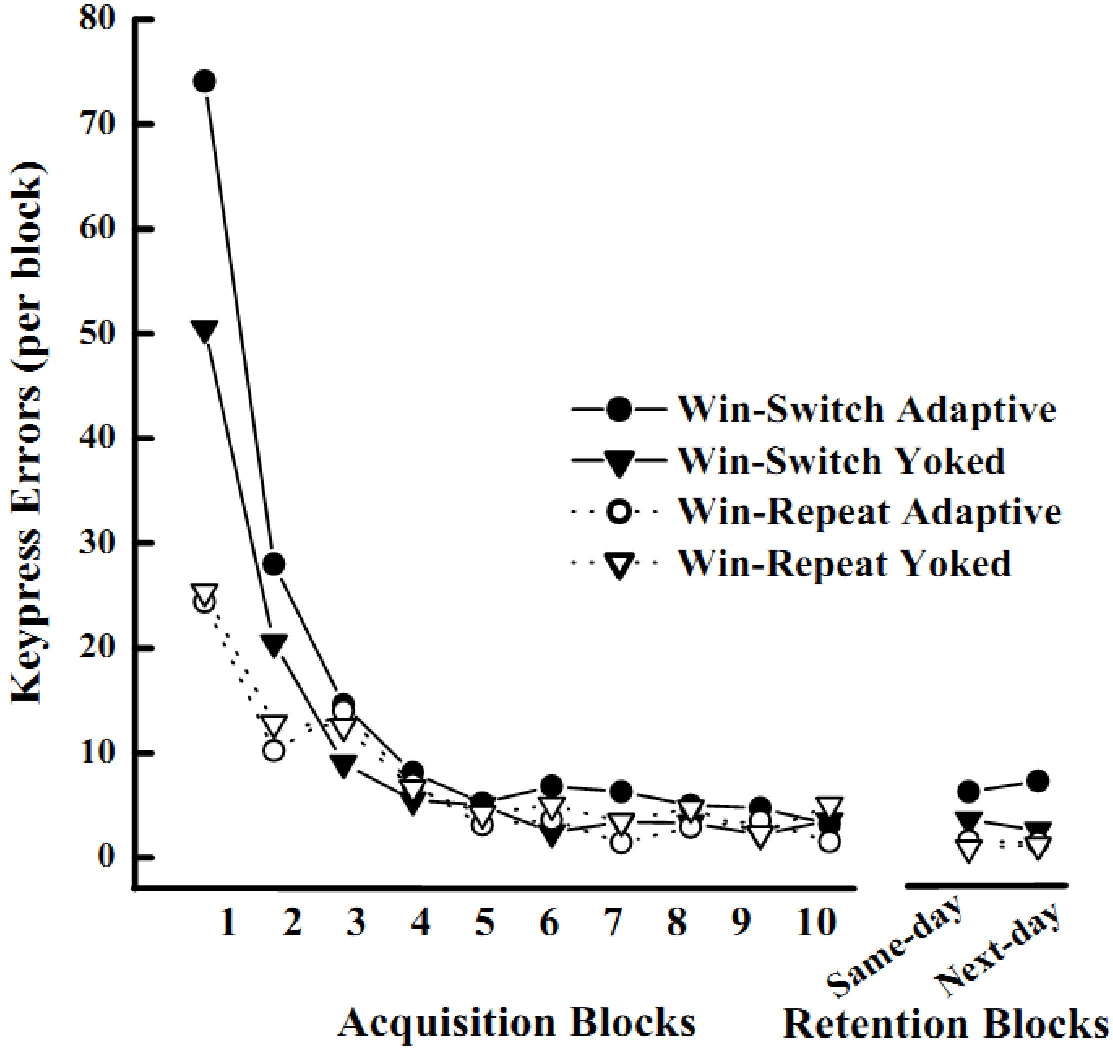


Figure 8. Overall summary graph of Keypress Errors for the WinSwitch Adaptive, WinSwitch Yoked, WinRepeat Adaptive, and WinRepeat Yoked groups across all acquisition and retention blocks, with each block consisting of 16 total trials in Experiment 1.

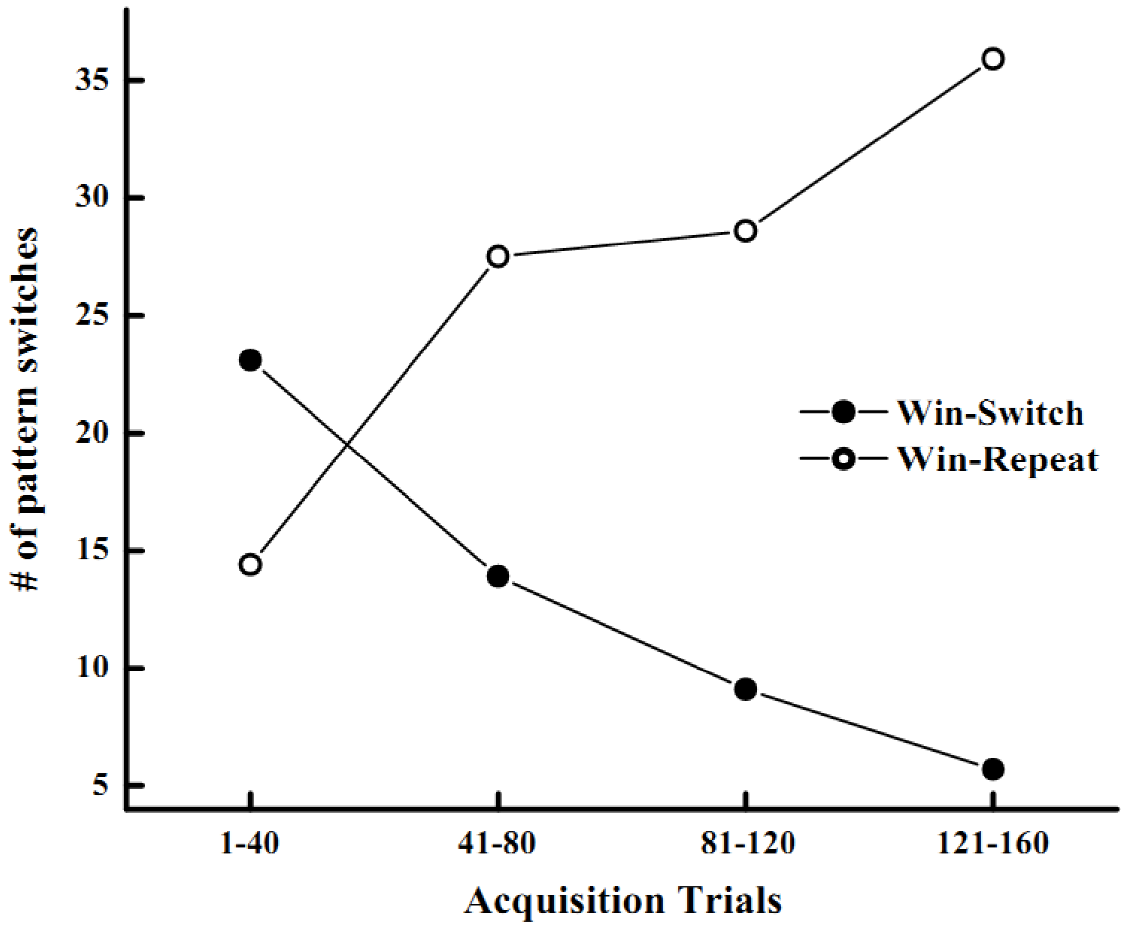


Figure 9. Mean Task (pattern) Switches for the WinSwitch and WinRepeat groups (excluding yoked) during acquisition in Experiment 1, with each of the four blocks consisting of 40 total trials. Significant differences between groups (WinSwitch compared to WinRepeat) were found at each Acquisition Trial Block, - Trials 1-40, 41-80, 81-120, and 121-160.

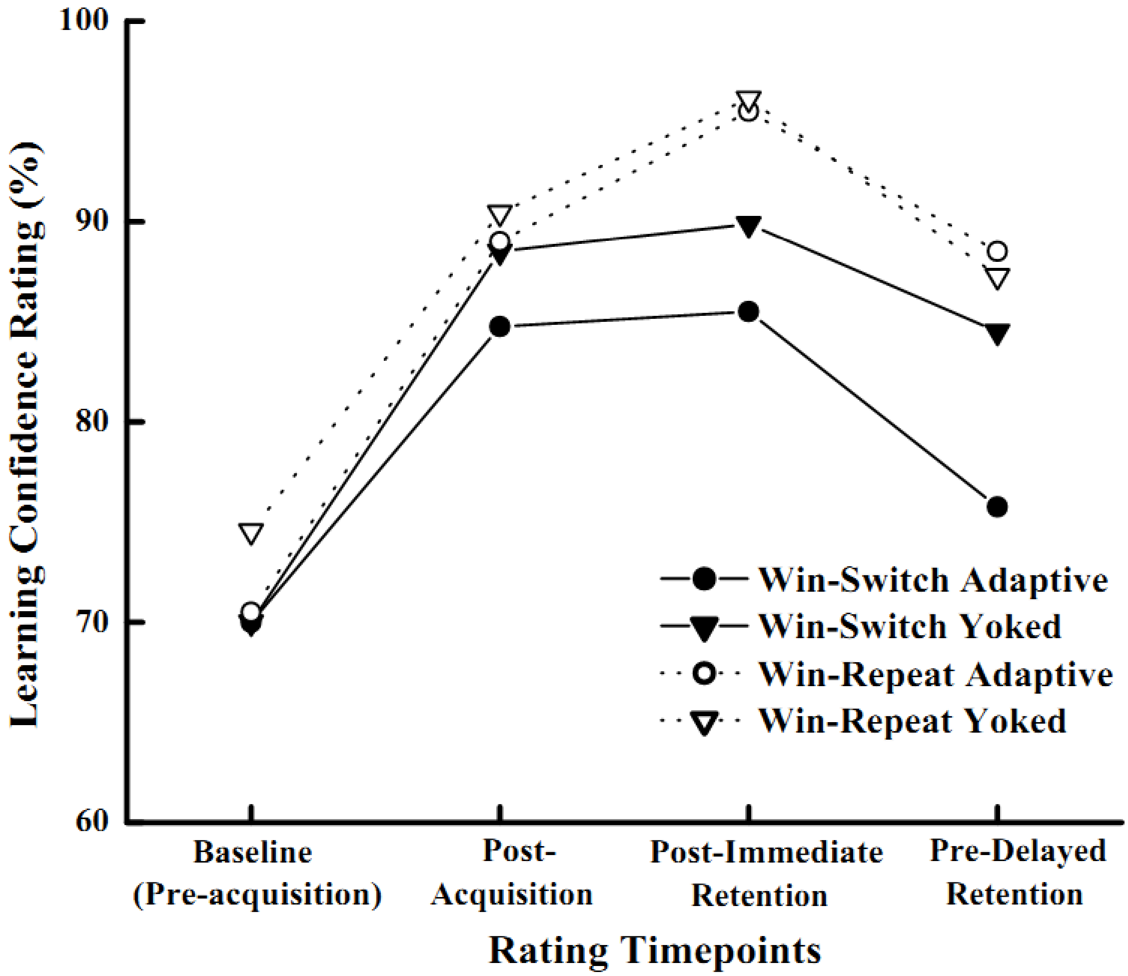
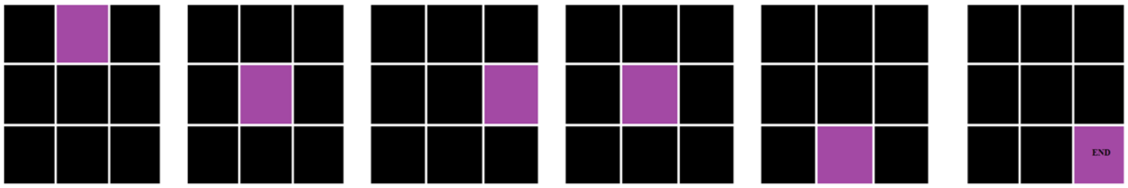


Figure 10. Mean Learning Confidence Ratings for the WinSwitch Adaptive, WinSwitch Yoked, WinRepeat Adaptive, and WinRepeat Yoked groups across testing block in Experiment 1. Self reported ratings were taken prior to acquisition (baseline measure), after acquisition, after immediate (same-day) retention and prior to delayed (next-day) retention. Significant differences between paradigm (WinSwitch compared to WinRepeat) were found following the immediate retention test.

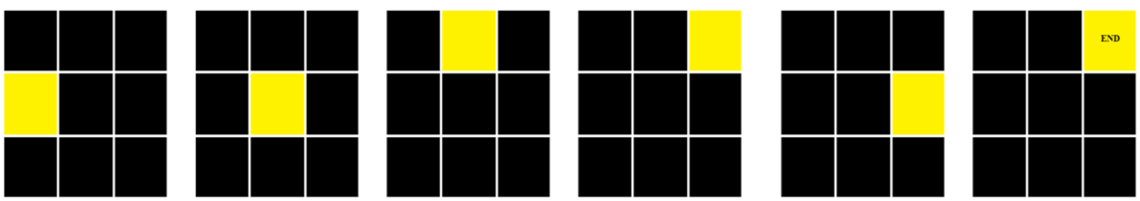
Capability (Pre-Acquisition) Test Pattern:



PURPLE Pattern Correct Steps: ↓ → ← ↓ →

Acquisition Patterns (same as shown in Figure 2):

Delayed Transfer Test Pattern:



YELLOW Pattern Correct Steps: → ↑ → ↓ ↑

Figure 11. The correct keypress sequence for the additional color patterns (purple, yellow) used in Experiment 2 (*note* in addition to the Experiment 1 color patterns).

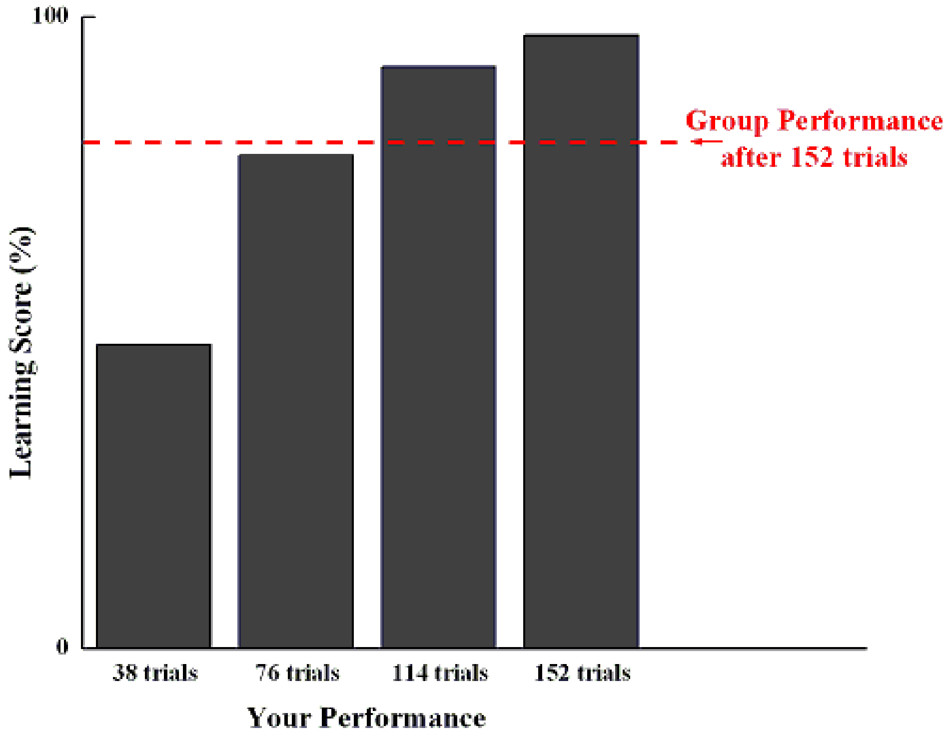


Figure 12. An example of the final (4th graph) summary feedback performance provided to participants in the 'good' practice feedback condition. This (fabricated) bar graph illustrates that the participant is learning more effectively (higher 'learning score %') than the (fabricated) group. A cumulative performance graph was displayed after the 38th, 76th, 114th and 152nd trial. The group performance average was always calculated/shown as 20% below the participant's performance average.

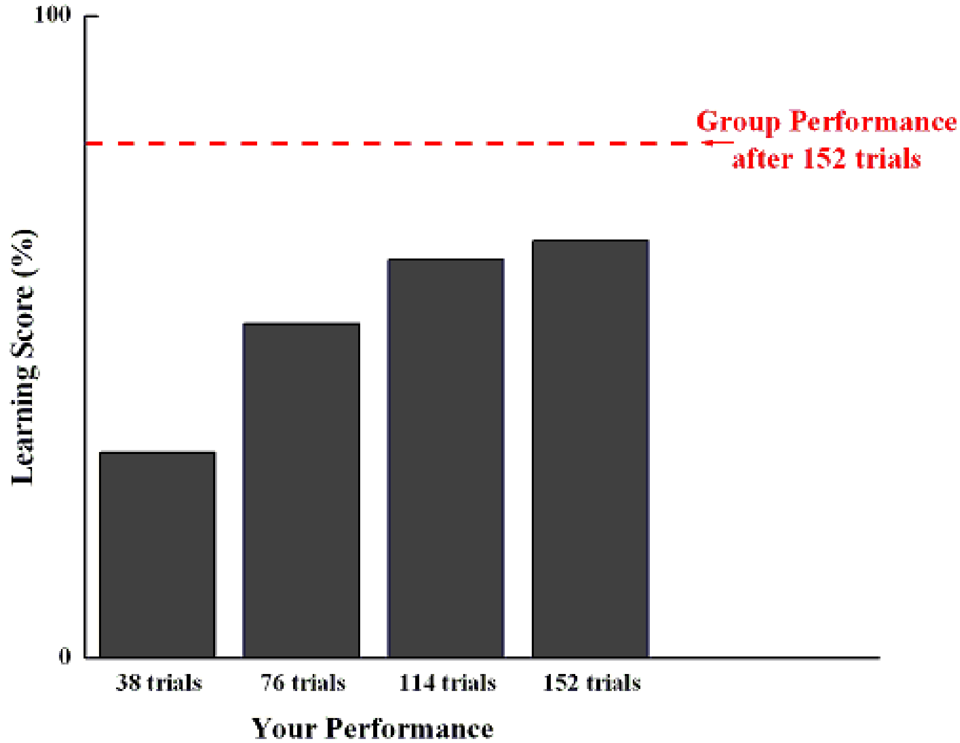


Figure 13. An example of the final (4th graph) summary feedback performance provided to participants in the 'bad' practice feedback condition. This (fabricated) bar graph illustrates that the participant is learning less effectively (lower 'learning score %') than the (fabricated) group. A cumulative performance graph was displayed after the 38th, 76th, 114th and 152nd trial. The group performance average was always calculated/shown as 20% above the participant's performance average.

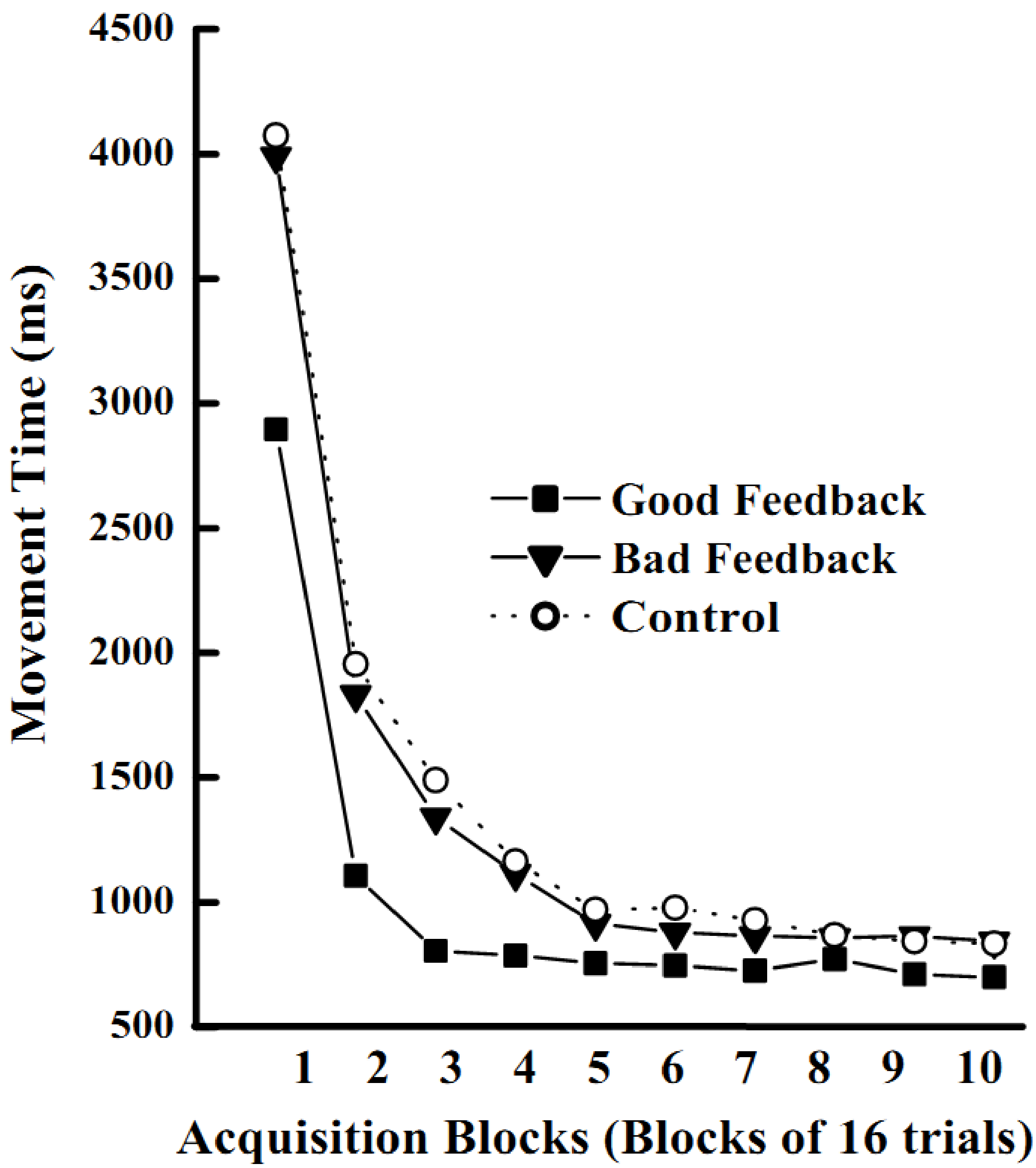


Figure 14. Movement Time (ms) for the Good Feedback, Bad Feedback, and Control groups across all 10 acquisition blocks (16 trials per block) in Experiment 2. Significant differences between group and block were found at blocks 1, 2 and 3.

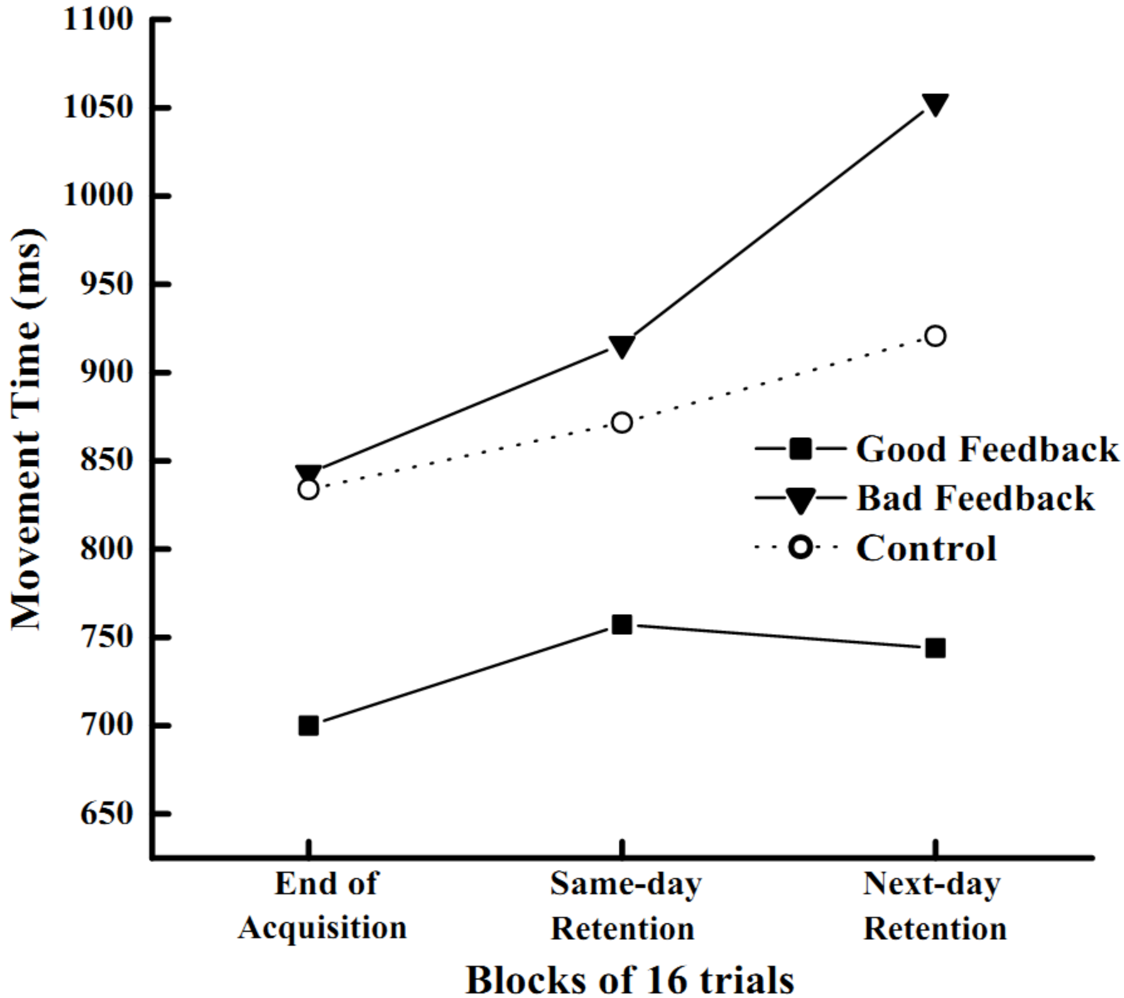


Figure 15. Movement Time (ms) for the Good Feedback, Bad Feedback, and Control groups across all test blocks (last block of acquisition, immediate (same-day) retention, delayed (next-day) retention) in Experiment 2. Significant differences between group (Good compared to Bad and Control) were found for the retention tests (same-day/immediate retention and next-day/delayed retention).

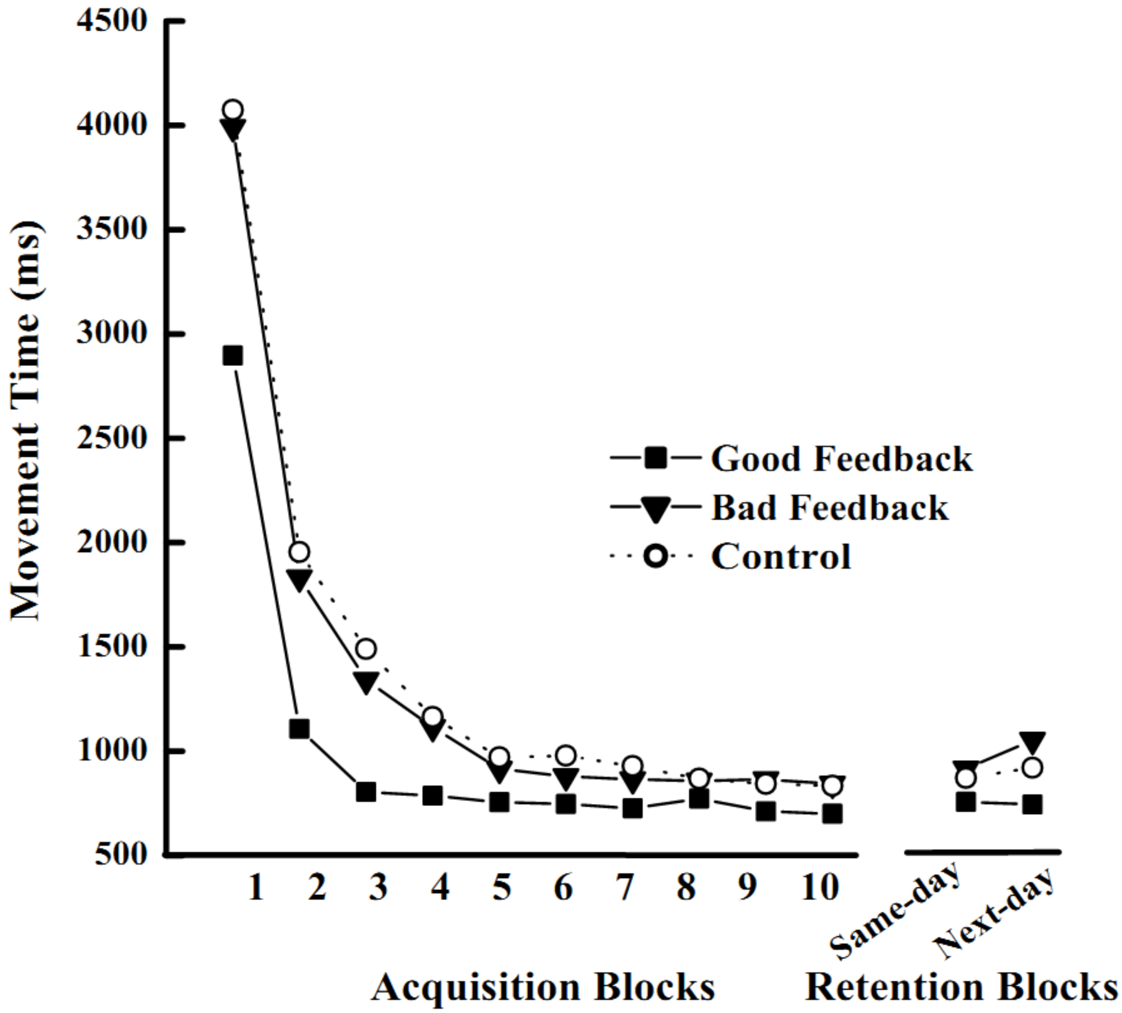


Figure 16. Overall summary graph of Movement Time (ms) for the Good Feedback, Bad Feedback, and Control groups across all acquisition and retention blocks, with each block consisting of 16 total trials in Experiment 2.

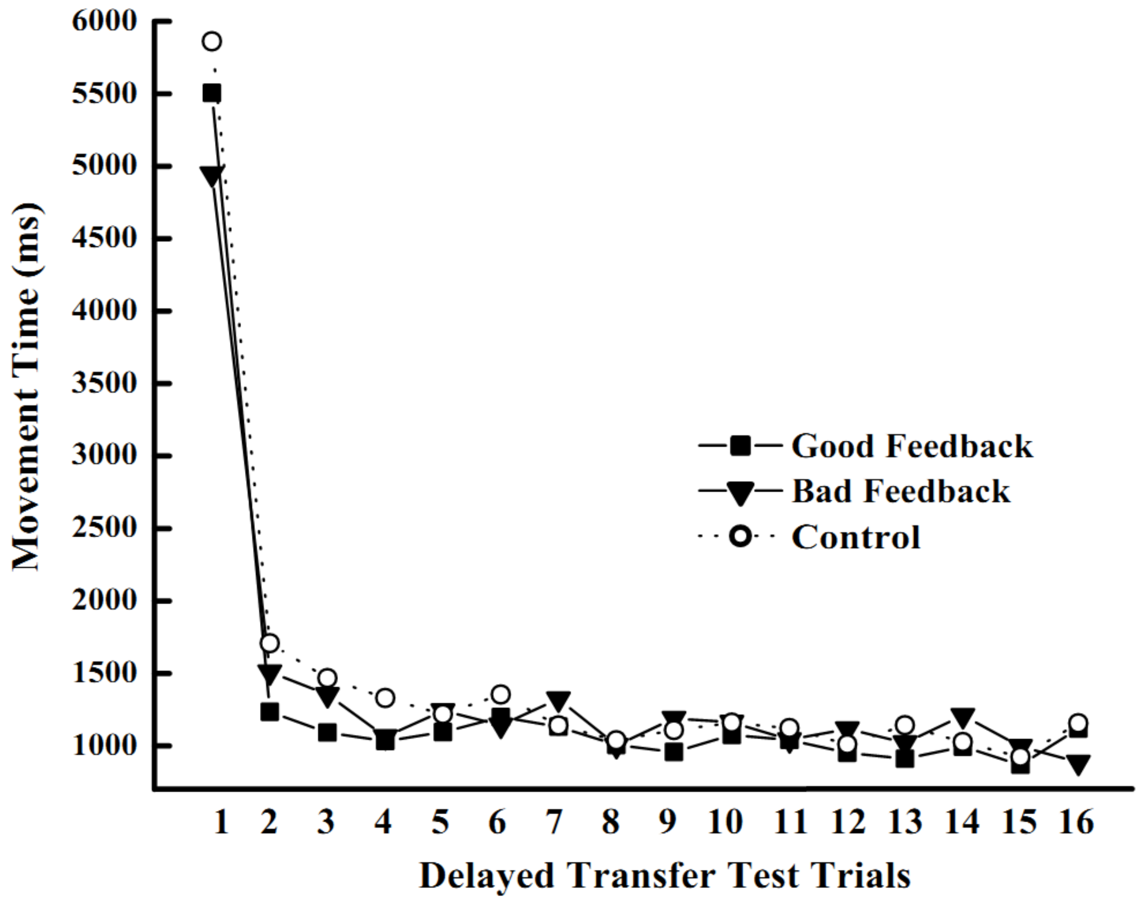


Figure 17. Movement Time (ms) for the Good Feedback, Bad Feedback, and Control groups across each transfer trial (delayed transfer test) in Experiment 2. No significant differences were found.

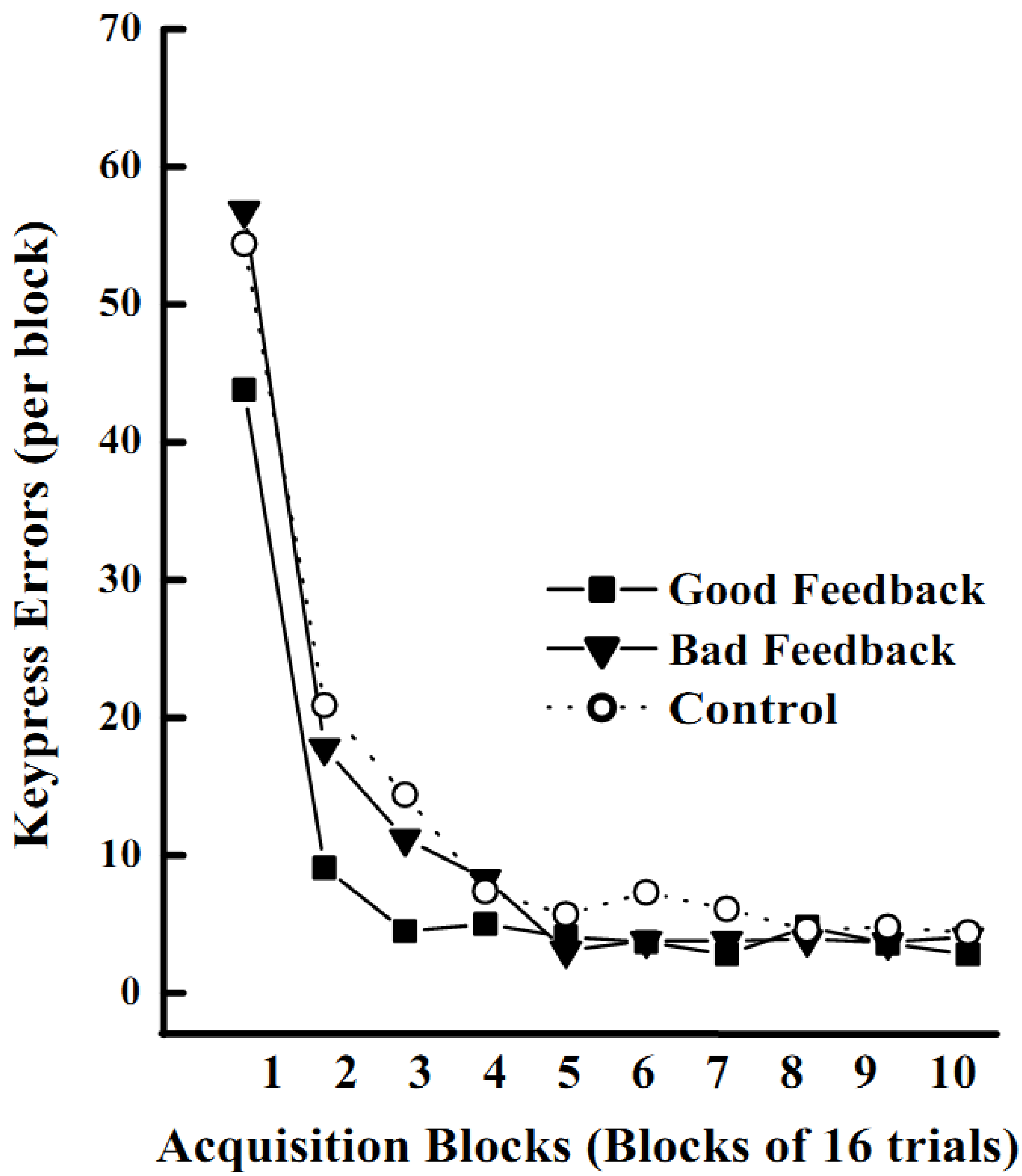


Figure 18. Keypress Errors for the Good Feedback, Bad Feedback, and Control groups across all 10 acquisition blocks (16 trials per block) in Experiment 2. Significant differences were found across block (blocks 1, 3 and 5).

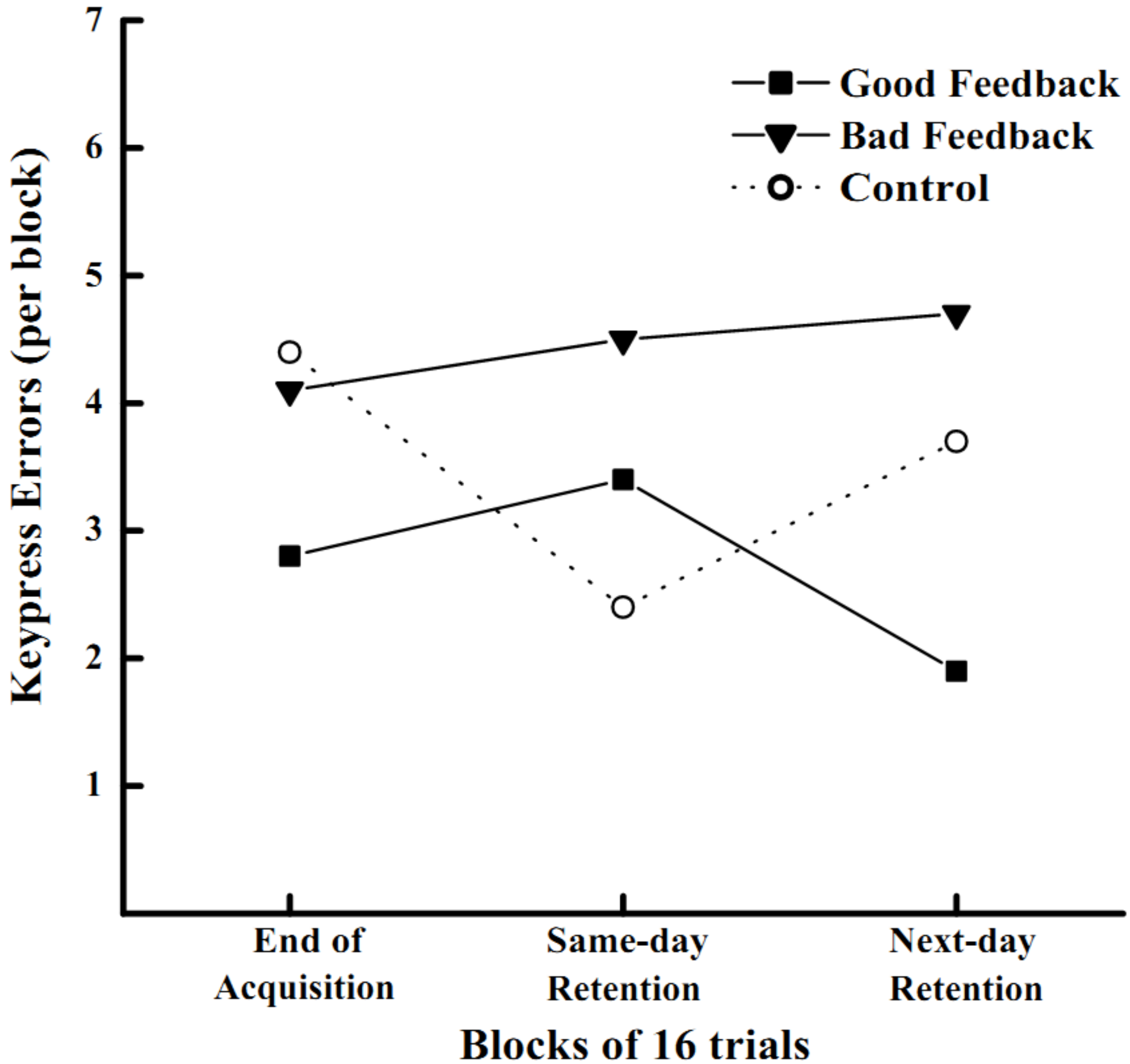


Figure 19. Keypress Errors for the Good Feedback, Bad Feedback, and Control groups across all test blocks (last block of acquisition, immediate (same-day) retention, delayed (next-day) retention) in Experiment 2. No significant differences were found.

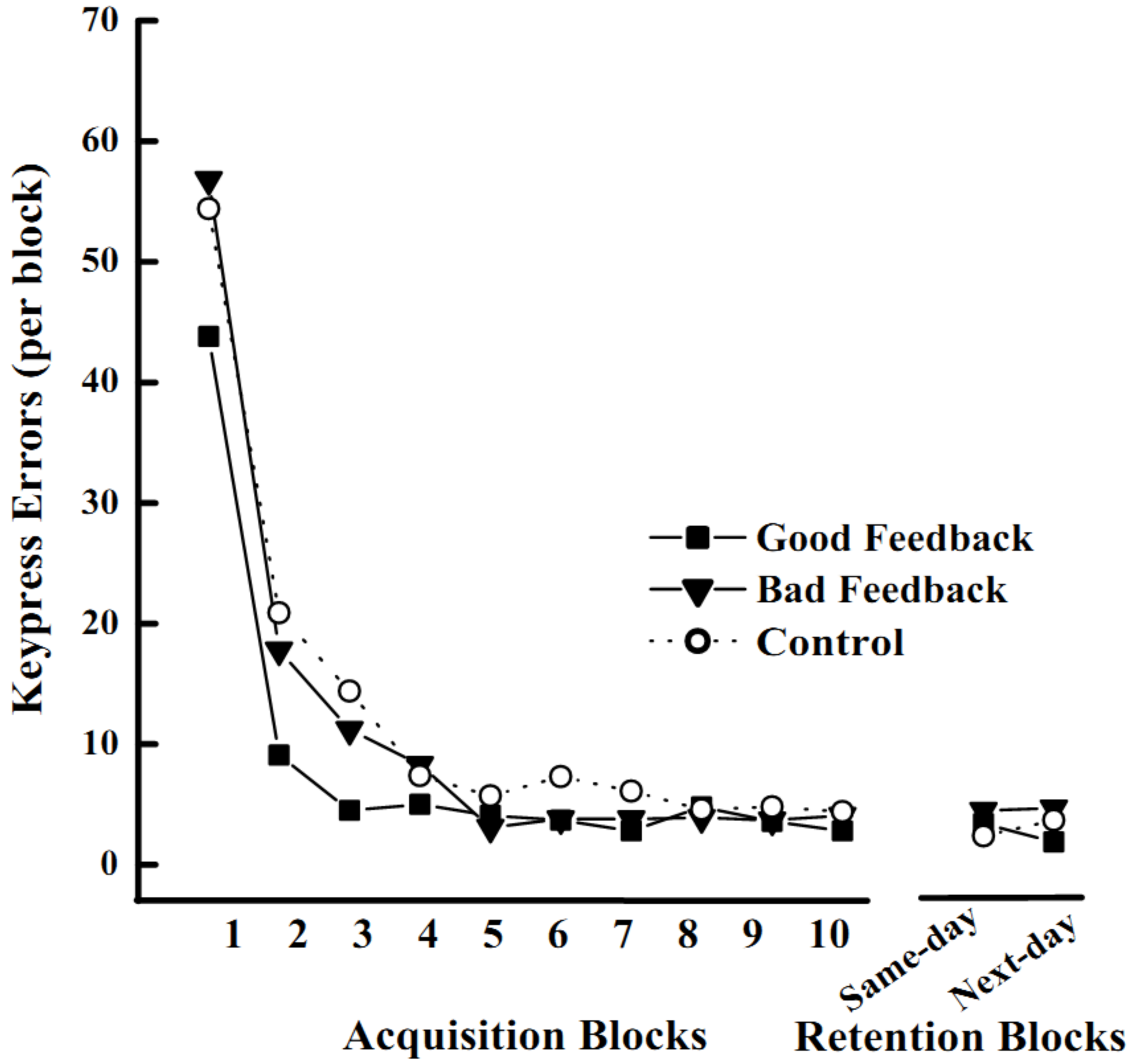


Figure 20. Overall summary graph of Keypress Errors for the Good Feedback, Bad Feedback, and Control groups across all acquisition and retention blocks, with each block consisting of 16 total trials in Experiment 2.

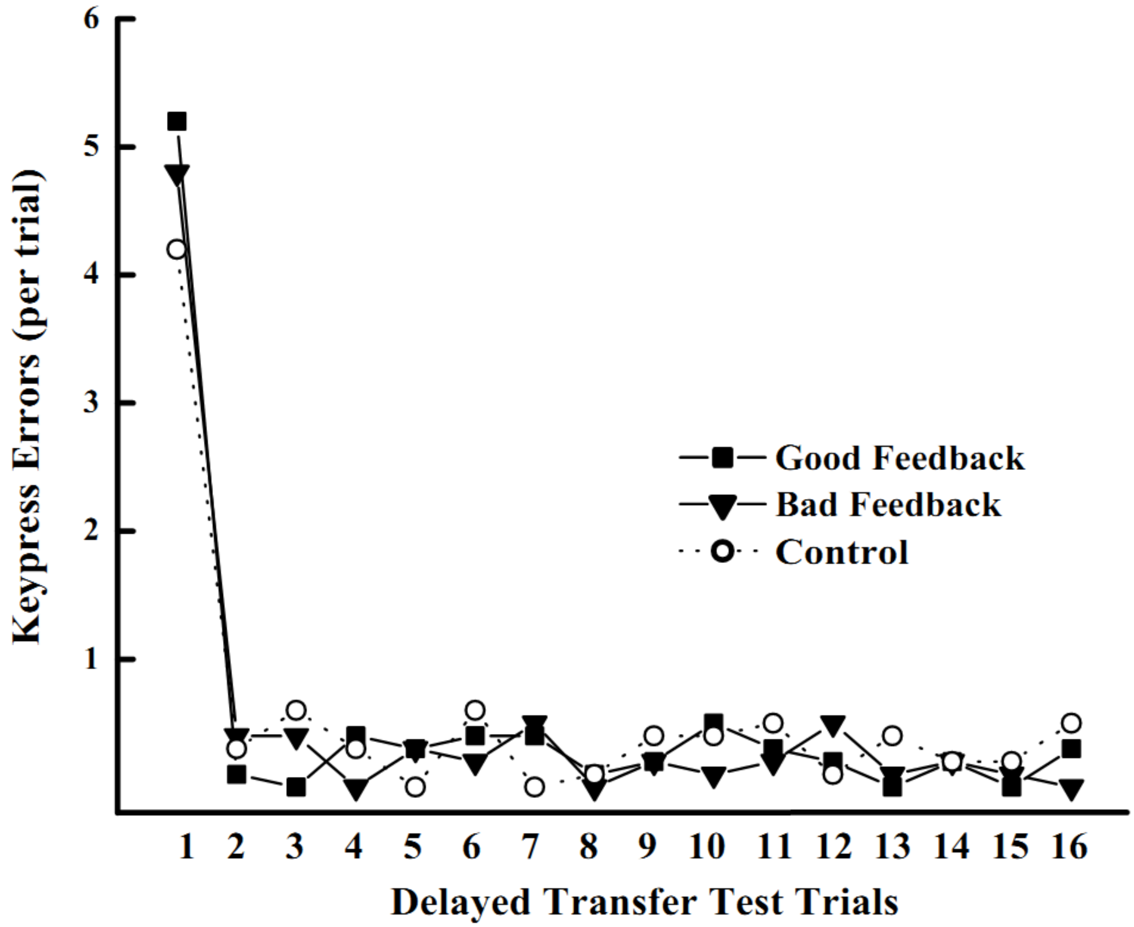


Figure 21. Keypress Errors for the Good Feedback, Bad Feedback, and Control groups across each transfer trial (delayed transfer test) in Experiment 2. No significant differences were found.

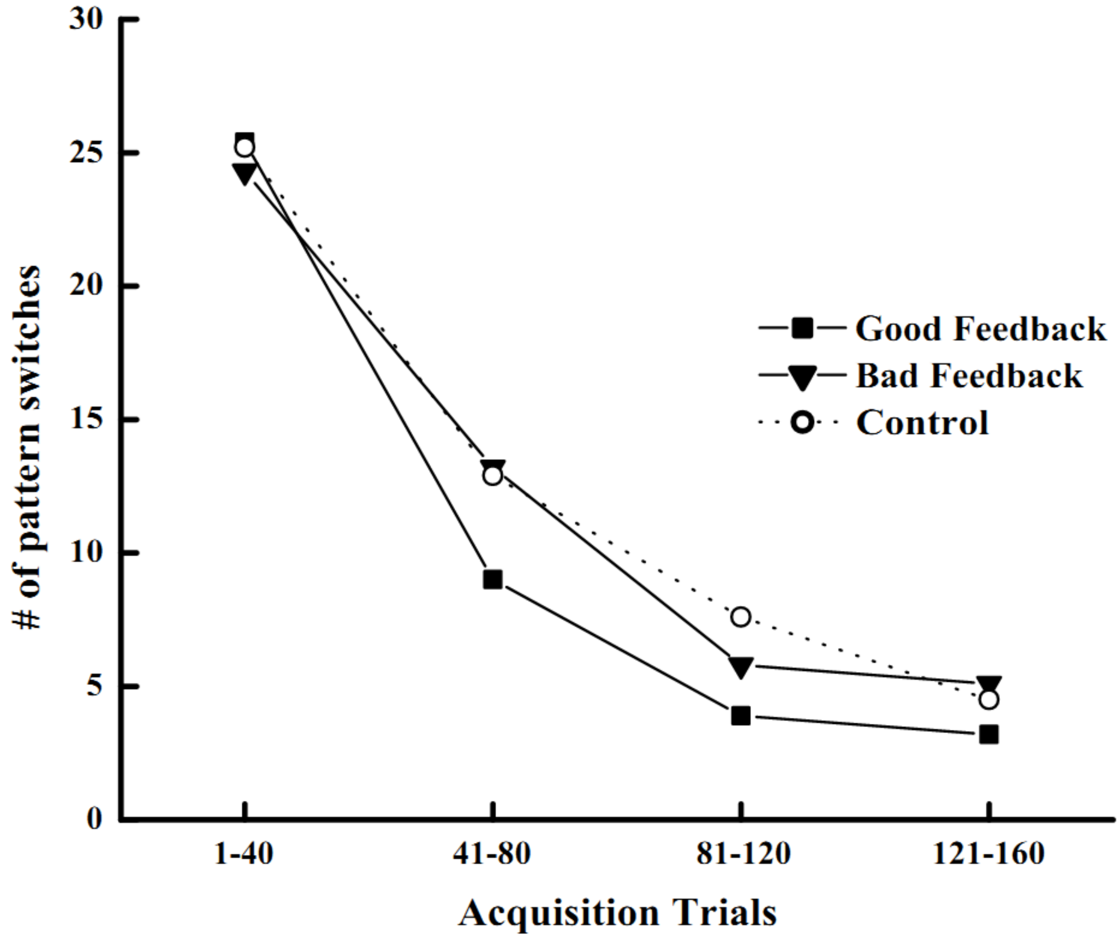


Figure 22. Mean Task (pattern) Switches for the Good Feedback, Bad Feedback, and Control groups during acquisition in Experiment 2, with each of the four blocks consisting of 40 total trials. Significant differences between group (Good compared to Bad and Control) were found for the Acquisition Trial Blocks. Significant differences were found across block (Trials 1-40, 41-80, 81-120, and 121-160).

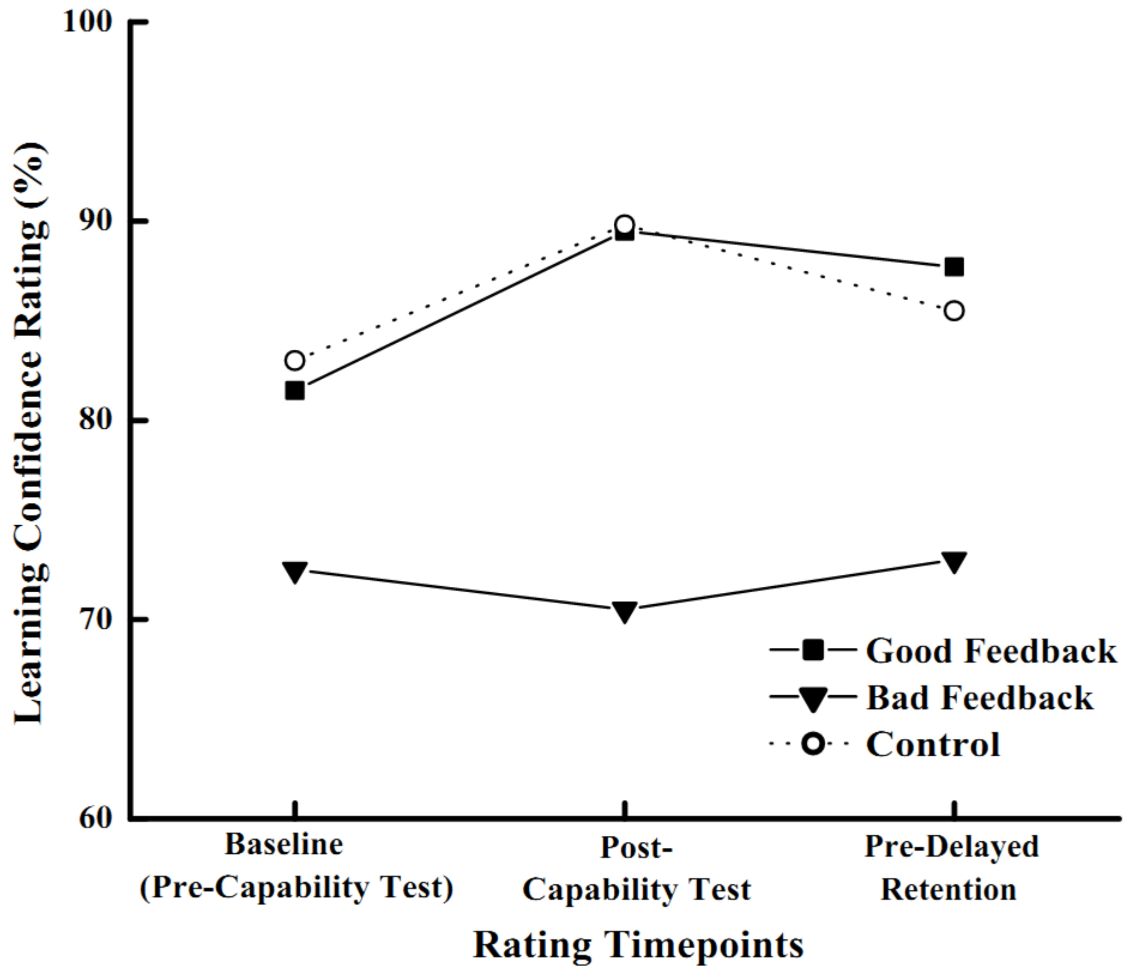


Figure 23. Mean Learning Confidence Ratings for the Good Feedback, Bad Feedback, and Control groups across testing block in Experiment 2. Self-reported ratings were taken prior to the capability/pre-acquisition test (baseline measure), after the capability/pre-acquisition test, and prior to delayed (next-day) retention. A significant main effect for group was found (Bad compared to Good and Control).

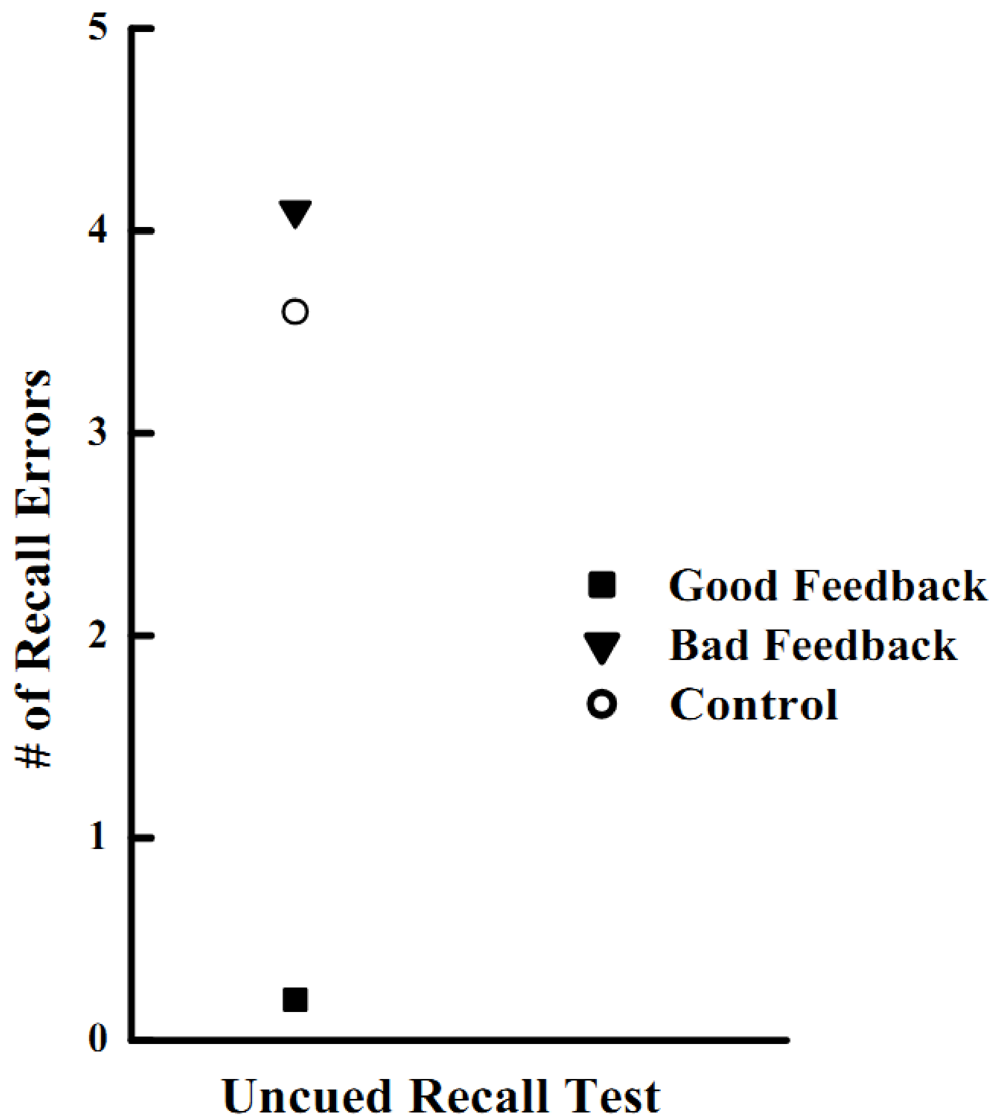


Figure 24. Mean Recall Errors for the Good Feedback, Bad Feedback, and Control groups during the uncued recall test in Experiment 2. A significant main effect for group was found (Good compared to Bad and Control).

Table 1. Movement Time (ms) **means** (top table) and **standard deviations** (bottom table) in acquisition, immediate retention test, delayed retention test as a function of group and block in Experiment 1

		Acquisition Blocks (blocks of 16 trials)										Retention Blocks	
Group	n	1	2	3	4	5	6	7	8	9	10	Immediate	Delayed
WinSwitch ADAPTIVE	10	3994.0	2291.7	1528.6	1152.1	1016.5	950.0	912.7	836.3	830.0	725.0	946.2	1004.6
WinRepeat ADAPTIVE	10	2647.9	1486.4	1517.3	1132.7	885.1	829.9	743.5	771.8	774.5	719.8	759.0	726.6
WinSwitch YOKED	10	4361.1	2086.9	1331.6	1017.6	909.8	807.7	825.1	760.0	743.5	763.1	822.7	759.8
WinRepeat YOKED	11	2460.1	1439.4	1383.3	1047.0	798.4	837.4	747.2	765.8	688.0	741.5	713.0	691.5

		Acquisition Blocks (blocks of 16 trials)										Retention Blocks	
Group	n	1	2	3	4	5	6	7	8	9	10	Immediate	Delayed
WinSwitch ADAPTIVE	10	673.3	704.6	599.2	317.0	301.8	292.8	262.2	219.7	181.8	119.3	394.9	521.9
WinRepeat ADAPTIVE	10	450.3	514.7	644.6	428.2	166.3	165.3	132.1	100.5	103.8	119.8	106.7	125.1
WinSwitch YOKED	10	858.2	679.8	355.4	224.4	104.6	101.2	73.5	85.9	96.8	79.9	122.9	58.6
WinRepeat YOKED	11	649.3	383.8	508.4	461.3	168.0	223.8	136.6	73.2	89.7	125.2	110.1	113.1

Table 2. Keypress Errors (# of errors) **sum** (top table) and **standard deviations** (bottom table) in acquisition, immediate retention test, delayed retention test as a function of group and block in Experiment 1

		Acquisition Blocks (blocks of 16 trials)										Retention Blocks	
Group	n	1	2	3	4	5	6	7	8	9	10	Immediate	Delayed
WinSwitch ADAPTIVE	10	74.1	28.0	14.6	8.1	5.2	6.8	6.3	5.0	4.7	3.2	6.3	7.3
WinRepeat ADAPTIVE	10	24.4	10.2	14.0	7.0	3.1	3.6	1.4	2.9	3.5	1.5	1.6	1.4
WinSwitch YOKED	10	50.5	20.5	9.0	5.5	5.0	2.4	3.4	3.3	2.2	3.5	3.6	2.6
WinRepeat YOKED	11	25.4	12.8	12.5	6.6	4.2	5.0	3.5	4.7	2.3	5.0	0.9	1.2

		Acquisition Blocks (blocks of 16 trials)										Retention Blocks	
Group	n	1	2	3	4	5	6	7	8	9	10	Immediate	Delayed
WinSwitch ADAPTIVE	10	28.7	14.9	10.2	6.4	4.2	5.6	4.8	4.6	4.0	3.3	7.8	10.1
WinRepeat ADAPTIVE	10	6.9	8.6	13.0	6.8	2.2	3.5	1.3	3.2	2.0	1.2	1.4	1.6
WinSwitch YOKED	10	11.5	9.6	6.5	5.3	5.9	3.2	4.1	4.2	4.1	4.6	4.3	3.7
WinRepeat YOKED	11	8.1	7.5	10.6	6.5	3.2	4.1	3.1	3.0	2.3	4.8	1.6	1.2

Table 3. Task Switch (# of switches) **means** (top table) and **standard deviations** (bottom table) in acquisition as a function of group and block in Experiment 1

		Acquisition Blocks (blocks of 40 trials)			
Group	n	1	2	3	4
WinSwitch	10	23.1	13.9	9.1	5.7
WinRepeat	10	14.4	27.5	28.6	35.9

		Acquisition Blocks (blocks of 40 trials)			
Group	n	1	2	3	4
WinSwitch	10	4.1	4.8	4.3	1.7
WinRepeat	10	4.4	4.8	3.8	2.1

Table 4. Task Difficulty Rating (%) **means** (top table) and **standard deviations** (bottom table) for acquisition patterns (taken post-acquisition) for each group in Experiment 1

*a higher rating indicates greater perceived task difficulty for the acquisition patterns

		Task Difficulty (Post-Acquisition)
Group	n	Task Difficulty Rating
WinSwitch ADAPTIVE	10	46.3
WinRepeat ADAPTIVE	10	38.6
WinSwitch YOKED	10	40.3
WinRepeat YOKED	11	37.0

		Task Difficulty (Post-Acquisition)
Group	n	Task Difficulty Rating
WinSwitch ADAPTIVE	10	18.8
WinRepeat ADAPTIVE	10	23.7
WinSwitch YOKED	10	19.4
WinRepeat YOKED	11	14.0

Table 5. Perceived Learning Confidence Rating (%) **means** (top table) and **standard deviations** (bottom table) taken pre-acquisition, post-acquisition, post-immediate retention and pre-delayed retention for each group in Experiment 1

*a higher rating indicates greater perceived learning confidence (greater self-efficacy belief)

		Learning Confidence Rating Timepoints			
Group	n	Baseline	Post-Acquisition	Post-Immediate	Pre-Delayed
WinSwitch ADAPTIVE	10	70.0	84.8	85.5	75.8
WinRepeat ADAPTIVE	10	70.5	89.0	95.5	88.5
WinSwitch YOKED	10	70.0	88.5	89.9	84.5
WinRepeat YOKED	11	74.5	90.5	96.1	87.3

		Learning Confidence Rating Timepoints			
Group	n	Baseline	Post-Acquisition	Post-Immediate	Pre-Delayed
WinSwitch ADAPTIVE	10	9.4	13.8	14.6	26.6
WinRepeat ADAPTIVE	10	16.2	12.0	8.1	10.7
WinSwitch YOKED	10	12.5	11.5	10.4	11.0
WinRepeat YOKED	11	13.7	9.7	6.1	11.7

Table 6. Recall Errors (# of errors) **means** (top table) and **standard deviations** (bottom table) on *cued* recall test for each group in Experiment 1

Group	n	Recall Errors (Cued Test)
		Errors
WinSwitch ADAPTIVE	10	0.38
WinRepeat ADAPTIVE	10	0.03
WinSwitch YOKED	10	0.00
WinRepeat YOKED	11	0.02

Group	n	Recall Errors (Cued Test)
		Errors
WinSwitch ADAPTIVE	10	0.89
WinRepeat ADAPTIVE	10	0.08
WinSwitch YOKED	10	0.00
WinRepeat YOKED	11	0.08

Table 7. Movement Time (ms) **means** (top table) and **standard deviations** (bottom table) in acquisition, immediate retention test, delayed retention test as a function of group and block in Experiment 2

		Acquisition Blocks (blocks of 16 trials)										Retention Blocks	
Group	n	1	2	3	4	5	6	7	8	9	10	Immediate	Delayed
Good Feedback	10	2896.8	1106.6	804.3	786.0	755.6	746.1	726.3	772.4	711.0	699.9	757.3	743.9
Bad Feedback	10	3990.7	1831.3	1340.4	1114.9	914.3	879.3	864.4	857.9	865.1	843.0	916.1	1053.4
Control	10	4073.9	1954.7	1490.1	1164.1	970.2	978.7	928.7	868.3	843.3	833.8	871.6	920.7

		Acquisition Blocks (blocks of 16 trials)										Retention Blocks	
Group	n	1	2	3	4	5	6	7	8	9	10	Immediate	Delayed
Good Feedback	10	462.1	326.0	110.4	110.1	107.0	125.6	71.0	142.2	61.2	88.7	115.1	99.3
Bad Feedback	10	1243.0	885.4	611.0	447.6	312.4	200.3	229.2	208.5	239.0	274.8	218.6	370.9
Control	10	1300.5	1027.2	684.5	479.2	281.5	355.1	219.5	184.7	188.0	160.6	203.5	277.0

Table 8. Keypress Errors (# of errors) **sum** (top table) and **standard deviations** (bottom table) in acquisition, immediate retention test, delayed retention test as a function of group and block in Experiment 2

		Acquisition Blocks (blocks of 16 trials)										Retention Blocks	
Group	n	1	2	3	4	5	6	7	8	9	10	Immediate	Delayed
Good Feedback	10	43.8	9.1	4.5	5.0	4.1	3.7	2.8	4.8	3.6	2.8	3.4	1.9
Bad Feedback	10	56.8	17.8	11.2	8.3	3.1	3.8	3.8	3.9	3.7	4.1	4.5	4.7
Control	10	54.4	20.9	14.4	7.4	5.7	7.3	6.1	4.6	4.8	4.4	2.4	3.7

		Acquisition Blocks (blocks of 16 trials)										Retention Blocks	
Group	n	1	2	3	4	5	6	7	8	9	10	Immediate	Delayed
Good Feedback	10	11.4	9.4	4.5	5.2	3.1	5.2	2.2	4.4	2.5	3.0	3.8	1.6
Bad Feedback	10	22.5	13.3	8.8	8.4	3.3	2.1	4.2	2.7	3.0	3.4	4.3	5.6
Control	10	18.4	17.9	9.9	7.5	4.0	8.3	5.2	4.1	4.7	4.1	2.1	2.9

Table 9. Task Switch (# of switches) **means** (top table) and **standard deviations** (bottom table) in acquisition as a function of group and block in Experiment 2

		Acquisition Blocks (blocks of 40 trials)			
Group	n	1	2	3	4
Good Feedback	10	25.4	9.0	3.9	3.2
Bad Feedback	10	24.3	13.2	5.8	5.1
Control	10	25.2	12.9	7.6	4.5

		Acquisition Blocks (blocks of 40 trials)			
Group	n	1	2	3	4
Good Feedback	10	3.8	2.9	2.6	2.9
Bad Feedback	10	3.9	2.9	2.4	3.1
Control	10	4.1	4.2	2.5	1.6

Table 10. Movement Time (ms) **means** (top table) and **standard deviations** (bottom table) in capability/pre-acquisition test as a function of group and trial in Experiment 2

		Capability/Pre-Acquisition Test Trials (16 trials)															
Group	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Good Feedback	10	6299.0	1704.7	1231.2	1271.0	1072.7	1104.0	1060.8	964.0	1100.8	1117.5	1133.5	982.4	951.1	899.8	851.8	984.8
Bad Feedback	10	7293.4	2217.6	1977.5	1722.3	1545.7	1362.4	1447.9	1738.4	1452.9	1271.9	1355.8	1289.5	1219.2	1179.2	1270.4	1189.6
Control	10	9593.3	2652.7	1959.2	1935.8	1666.4	1722.3	1535.9	1440.0	1430.4	1315.1	1390.3	1175.7	1169.5	1103.1	1147.2	1073.4

		Capability/Pre-Acquisition Test Trials (16 trials)															
Group	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Good Feedback	10	1160.3	437.6	225.7	305.6	189.8	175.8	306.7	175.8	349.1	592.0	543.6	223.5	238.4	156.5	189.4	286.2
Bad Feedback	10	2888.1	638.5	918.2	582.1	790.0	320.1	434.7	907.5	537.3	348.2	455.0	322.7	239.8	274.0	435.3	211.0
Control	10	4978.6	1118.8	675.6	839.3	696.7	715.5	538.6	536.6	637.4	584.9	814.5	372.6	412.6	387.2	464.6	396.1

Table 11. Keypress Errors (# of errors) **sum** (top table) and **standard deviations** (bottom table) in capability/pre-acquisition test as a function of group and trial in Experiment 2

		Capability/Pre-Acquisition Test Trials (16 trials)															
Group	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Good Feedback	10	5.0	0.2	0.2	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.4	0.1	0.1	0.1	0.0	0.4
Bad Feedback	10	5.5	0.6	0.5	0.2	0.5	0.1	0.3	0.7	0.2	0.1	0.2	0.1	0.0	0.0	0.1	0.2
Control	10	6.1	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0

		Capability/Pre-Acquisition Test Trials (16 trials)															
Group	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Good Feedback	10	1.4	0.4	0.4	0.0	0.0	0.0	0.3	0.0	0.4	0.3	0.8	0.3	0.3	0.3	0.0	1.0
Bad Feedback	10	2.1	1.1	1.0	0.4	1.6	0.3	0.5	1.6	0.4	0.3	0.4	0.3	0.0	0.0	0.3	0.6
Control	10	2.4	0.5	0.3	0.3	0.3	0.3	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0

Table 12. Movement Time (ms) **means** (top table) and **standard deviations** (bottom table) in delayed transfer test as a function of group and trial in Experiment 2

		Delayed Transfer Test Trials (16 trials)															
Group	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Good Feedback	10	5505.5	1234.4	1092.0	1032.9	1095.1	1197.7	1131.9	1006.2	957.0	1074.8	1040.0	951.1	911.2	993.6	867.9	1118.4
Bad Feedback	10	4947.7	1510.3	1353.4	1062.5	1241.4	1143.0	1323.1	1003.1	1188.8	1162.3	1041.5	1117.6	1020.9	1209.5	995.1	887.2
Control	10	5862.2	1707.1	1466.3	1328.8	1217.4	1353.6	1139.2	1036.8	1107.8	1159.0	1122.1	1009.7	1141.6	1025.6	923.2	1154.1

		Delayed Transfer Test Trials (16 trials)															
Group	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Good Feedback	10	1389.5	488.5	335.7	416.1	426.3	482.1	501.0	384.9	329.4	322.5	255.0	307.4	210.8	330.1	206.9	422.5
Bad Feedback	10	2222.5	548.1	558.3	223.9	509.2	386.3	555.9	209.4	485.2	706.2	309.3	381.5	252.5	452.4	301.2	190.5
Control	10	3159.7	1527.4	841.5	554.8	361.6	337.8	372.8	334.8	411.9	394.8	565.2	341.5	428.0	321.0	261.7	601.2

Table 13. Keypress Errors (# of errors) **sum** (top table) and **standard deviations** (bottom table) in delayed transfer test as a function of group and trial in Experiment 2

		Delayed Transfer Test Trials (16 trials)															
Group	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Good Feedback	10	5.2	0.1	0.0	0.4	0.3	0.4	0.4	0.1	0.2	0.5	0.3	0.2	0.0	0.2	0.0	0.3
Bad Feedback	10	4.8	0.4	0.4	0.0	0.3	0.2	0.5	0.0	0.2	0.1	0.2	0.5	0.1	0.2	0.1	0.0
Control	10	4.2	0.3	0.6	0.3	0.0	0.6	0.0	0.1	0.4	0.4	0.5	0.1	0.4	0.2	0.2	0.5

		Delayed Transfer Test Trials (16 trials)															
Group	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Good Feedback	10	1.8	0.3	0.0	1.0	0.5	0.7	0.7	0.3	0.6	0.8	0.7	0.4	0.0	0.4	0.0	0.5
Bad Feedback	10	3.5	0.5	0.5	0.0	0.7	0.4	1.1	0.0	0.6	0.3	0.4	0.8	0.3	0.4	0.3	0.0
Control	10	1.7	0.7	0.8	0.5	0.0	0.8	0.0	0.3	0.7	1.0	0.8	0.3	0.8	0.4	0.4	0.7

Table 14. Perceived Learning Confidence Rating (%) **means** (top table) and **standard deviations** (bottom table) taken pre-capability test (prior to any feedback manipulations), post-capability test, and pre-delayed retention for each group in Experiment 2

*a higher rating indicates greater perceived learning confidence (greater self-efficacy belief)

		Learning Confidence Rating Timepoints		
Group	n	Pre-Capability	Post-Capability	Pre-Delayed
Good Feedback	10	81.5	89.5	87.7
Bad Feedback	10	72.5	70.5	73.0
Control	10	83.0	89.8	85.5

		Learning Confidence Rating Timepoints		
Group	n	Pre-Capability	Post-Capability	Pre-Delayed
Good Feedback	10	11.1	10.1	7.3
Bad Feedback	10	11.8	16.7	16.2
Control	10	14.9	9.2	8.6

Table 15. Recall Errors (# of errors) **means** (top table) and **standard deviations** (bottom table) on *uncued* recall test for each group in Experiment 2

		Recall Errors (Uncued Test)
Group	n	Errors
Good Feedback	10	0.2
Bad Feedback	10	4.1
Control	10	3.6

		Recall Errors (Uncued Test)
Group	n	Errors
Good Feedback	10	0.6
Bad Feedback	10	3.6
Control	10	3.7

APPENDIX A - **EXPERIMENT 1** Letter of Information and Consent Form

McMaster University
Inspiring Innovation and Discovery

Department of Kinesiology
1280 Main St. West
Hamilton, ON
L8S 4K1

Dr. Timothy D. Lee
Motor Behavior Lab
scapps@mcmaster.ca

Letter of Information and Consent

Title of Study: The effects of practice schedule on learning different motor sequences in healthy young adults

Investigators:

Timothy D. Lee Ph.D
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 23579
scapps@mcmaster.ca

Laurie Wishart Ph.D
School of Rehabilitation Sciences, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 2268
wishartl@mcmaster.ca

Kinga Eliasz MSc candidate
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 27384
eliaszkl@mcmaster.ca

Research Sponsor: Natural Sciences and Engineering Research Council (NSERC)

Statement of Invitation

You are invited to participate in a research project, which is a collaborative effort between researchers in the Department of Kinesiology and Rehabilitation Sciences at McMaster University. The investigators listed above are conducting this research project. Your involvement and feedback are greatly appreciated and will further our understanding of the factors that affect learning under different practice conditions.

Purpose of the Study

The purpose of this study is to examine the effect of practice conditions on learning four different motor sequences in young adults. Results from this study will help us to understand the influence of goal setting, motivation and practice conditions on young adults learning motor tasks. This study will also help us to examine the difference between how well young adults perceive that they have learned a motor task and how well they actually learned the task.

Procedures involved in the Research

Participation will require approximately 1 hour and 15 minutes of your time over two sessions. If you agree to participate in this study, you will be asked to complete the following:

1. Complete a brief demographic questionnaire.
2. Provide informed consent prior to the experimental session.

3. Perform the following tasks for data acquisition:

You will be asked to come to the Motor Behavior Laboratory at McMaster University for 2 sessions approximately 24 hours apart. During the first session (approximately 1 hour), you will complete brief questionnaires and 2 computer tasks. The computer tasks will provide clear instructions on what your task will be. During the first computer task, you will complete 160 brief trials (approximately 35 minutes). During the second computer task, you will complete 16 brief trials (approximately 5 minutes). You will be asked to return to the lab approximately the same time the following day for session 2 (approximately 15 minutes). During this session you will complete brief questionnaires, a Trail Making test and 1 computer task where you will complete 16 brief trials (approximately 5 minutes). If at any time during the experiment you get tired or feel discomfort you can discontinue your participation.

Potential Benefits and Risks

You will be paid $15 for participation in the study. You will also have the chance to be paid an additional $15. This $15 will be paid to the person who will best remember the patterns that they practiced in session 1 during the session 2 retention test. The data obtained will further our understanding of how people use information to learn motor tasks. It is unlikely that you will experience any serious injury or discomfort during the study. There are no serious risks involved in this research. However, if you do experience any concerns, you may contact Dr. Lee at the above number or email.

Voluntary Participation

Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time and may do so without any penalty or loss of benefits to which you are entitled.

Confidentiality

All information you provide is considered confidential; your name will not be included or, in any other way, associated with the data collected in the study. Furthermore, because our interest is in the average responses of the entire group of participants, you will not be identified individually in any way in written reports of this research. **No personal identification will be used in publications of any form pertaining to this study.** Data collected during this study will be stored in a locked filing cabinet in a locked storage room on campus. Electronic data will be encrypted, stored on an external storage device and locked in the cabinet mentioned above. Access to this data will be restricted to the investigators listed above and their student research assistants.

Contact Information and Ethics Clearance

If you have questions or require more information about the study itself, please contact Dr. Tim Lee, Department of Kinesiology, McMaster University, Hamilton, ON, L8S 4K1
(905-525-9140, ext. 23579; scapps@mcmaster.ca).

This study has been reviewed and approved by the McMaster Research Ethics Board. If you have concerns or questions about your rights as a participant or about the way the study is conducted, you may contact:

McMaster Research Ethics Board Secretariat
Telephone: (905) 525-9140 ext. 23142
c/o Office of Research Services
E-mail: ethicsoffice@mcmaster.ca

Thank you for your assistance in this project. Please keep a copy of this form for your records.

Department of Kinesiology
1280 Main St. West
Hamilton, ON
L8S 4K1

Dr. Timothy D. Lee
Motor Behavior Lab
scapps@mcmaster.ca

Informed Consent Form

Title of Study: The effects of practice schedule on learning different motor sequences in healthy young adults

Investigators:

Timothy D. Lee Ph.D
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 23579
scapps@mcmaster.ca

Laurie Wishart Ph.D
School of Rehabilitation Sciences, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 2268
wishartl@mcmaster.ca

Kinga Eliasz MSc candidate
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 27384
eliaszkl@mcmaster.ca

CONSENT

I, **____,** agree to voluntarily participate in the study described above.

I have received and read a detailed description of the experimental protocol. I have had the opportunity to ask questions about my involvement in this study and to receive any additional details I wanted to know about the study. I am completely satisfied with the explanation given to me regarding the nature of this research project, including the potential benefits, risks and discomforts related to my participation in this study.

I understand that I have the right to withdraw my consent and discontinue my participation from this study at any time without penalty or prejudices.

____
Name of Participant (please print)

______________________________________ ____________________
Signature of Participant **Date**

In my opinion, the person who has signed above is agreeing to participate in this study voluntarily and understands the nature of the study and the consequences associated with participation.

______________________________________ ____________________
Signature of Researcher or Witness **Date**

APPENDIX B - **EXPERIMENT 1** Questionnaire Package

B-1: Demographic Questionnaire

B-2: Baseline Perceived Learning Confidence Scale

B-3: Day 1 Pattern Questionnaire

B-4: Sudoku

B-5: Perceived Learning Confidence Scale

B-6: Cued Recall Test

B-7: Trail Making Test

B-1: Demographic Questionnaire

Participant ID: __________ Today's Date: __________________

Date of Birth: ______________ Hand: L/R
(day/month/year)

1) Do you wear corrective lenses? Y/N

2) If yes, are you wearing them today? Y/N

3) How many hours per week do you spend using a computer? (please circle what describes your best computer usage)

never less than 5 hrs 5-15 hrs 16-30 hrs more than 30 hrs

4) How many hours per week do you spend playing video games? (please circle what describes your best video game usage)

never less than 5 hrs 5-15 hrs 16-30 hrs more than 30 hrs

5) Do you have any conditions that may prevent you from performing computer tasks? Y/N

If yes, please describe
____

B-2: Baseline Perceived Learning Confidence Scale

Using the following scale, please rate on a scale of 0%-100% how confident you are that you can learn the 4 patterns and reproduce them at a later time:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

B-3: Day 1 Pattern Questionnaire

Using the following scale, please rate on a scale of 0%-100% how confident you are that you have successfully learned the **RED PATTERN**:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

Please rate how difficult on a scale of 0%-100% you thought the **RED PATTERN** was:

0......10......20......30......40......50......60......70......80......90......100

I did not find it difficult at all	I found it moderately difficult	I found it completely difficult

---

Using the following scale, please rate on a scale of 0%-100% how confident you are that you have successfully learned the **BLUE PATTERN**:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

Please rate how difficult on a scale of 0%-100% you thought the **BLUE PATTERN** was:

0......10......20......30......40......50......60......70......80......90......100

I did not find it difficult at all	I found it moderately difficult	I found it completely difficult

---

Using the following scale, please rate on a scale of 0%-100% how confident you are that you have successfully learned the **GREEN PATTERN**:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

Please rate how difficult on a scale of 0%-100% you thought the **GREEN PATTERN** was:

0......10......20......30......40......50......60......70......80......90......100

I did not find it difficult at all	I found it moderately difficult	I found it completely difficult

Using the following scale, please rate on a scale of 0%-100% how confident you are that you have successfully learned the **ORANGE PATTERN**:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

Please rate how difficult on a scale of 0%-100% you thought the **ORANGE PATTERN** was:

0......10......20......30......40......50......60......70......80......90......100

I did not find it difficult at all	I found it moderately difficult	I found it completely difficult

B-4: Sudoku

What are the rules?

There is only one rule: Every row, column and box of 3x3 cells must contain the numbers 1 through 9 exactly once.

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

B-5: Perceived Learning Confidence Scale

Using the following scale, please rate on a scale of 0%-100% how confident you are that you have successfully learned the **RED PATTERN**:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

Using the following scale, please rate on a scale of 0%-100% how confident you are that you have successfully learned the **BLUE PATTERN**:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

Using the following scale, please rate on a scale of 0%-100% how confident you are that you have successfully learned the **GREEN PATTERN**:

0......10......20......30......40......50......60......70......80......90......100

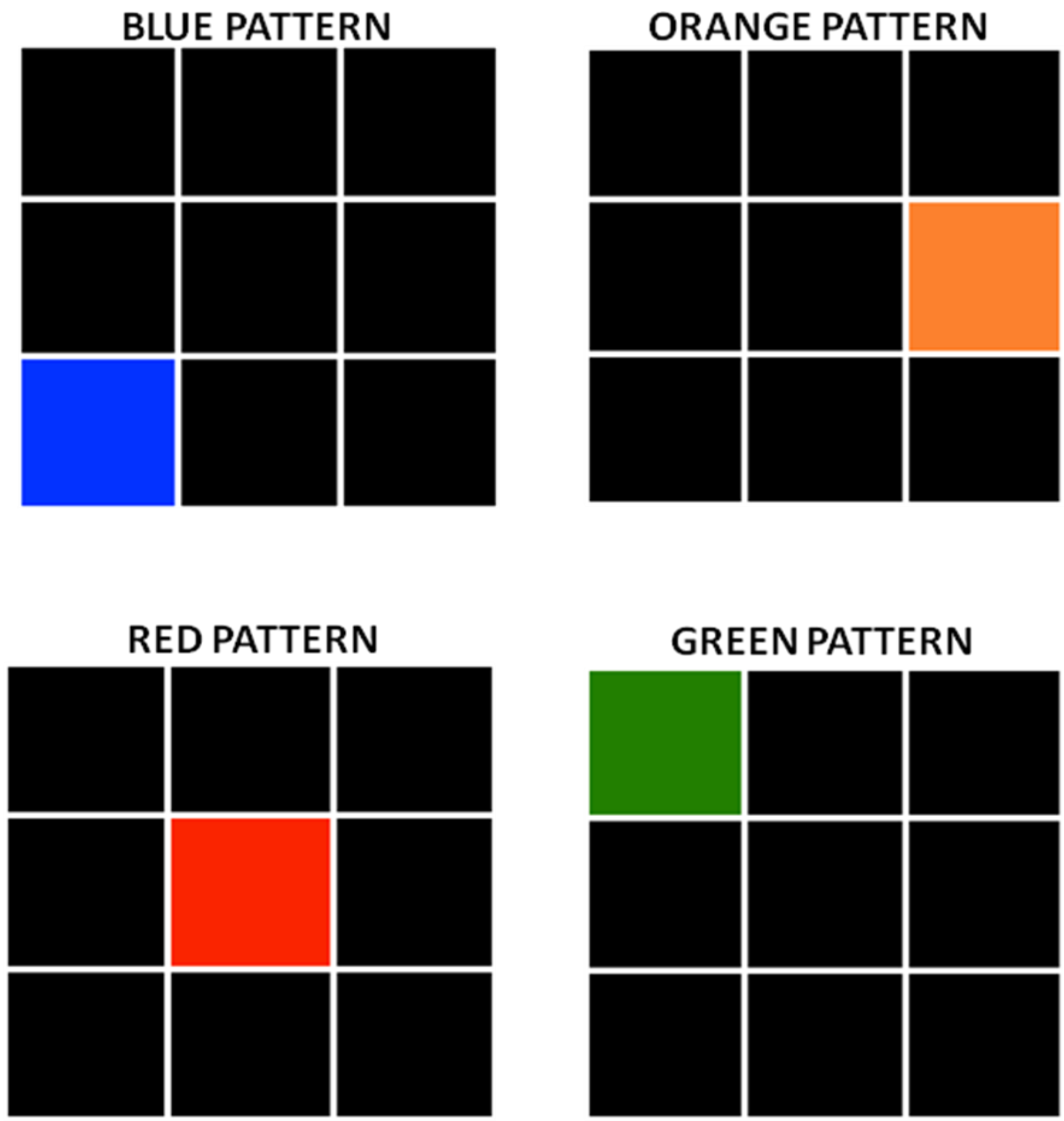
I do not feel confident at all	I feel moderately confident	I feel completely confident

Using the following scale, please rate on a scale of 0%-100% how confident you are that you have successfully learned the **ORANGE PATTERN**:

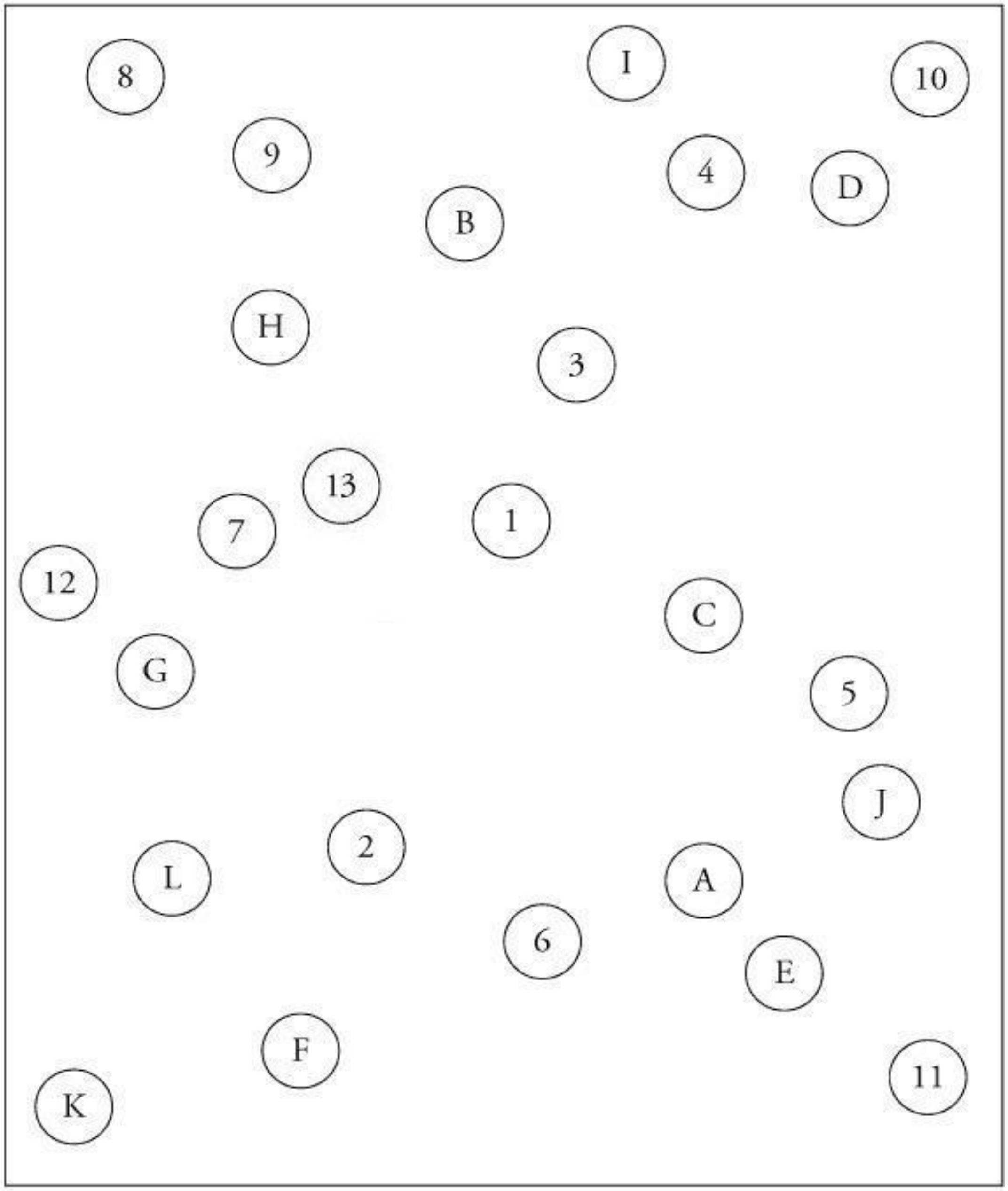
0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

B-6: Cued Recall Test



B-7: Trail Making Test



Time (seconds): ______________________

APPENDIX C - **EXPERIMENT 2** Initial Letter of Information and Consent Form

McMaster University
Inspiring Innovation and Discovery

Department of Kinesiology
1280 Main St. West
Hamilton, ON
L8S 4K1

Dr. Timothy D. Lee
Motor Behavior Lab
scapps@mcmaster.ca

Letter of Information and Consent

Title of Study: The effects of practice schedule on sequence learning in young adults

Investigators: Timothy D. Lee Ph.D
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 23579
scapps@mcmaster.ca

Kinga Eliasz MSc candidate
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 21436
eliaszkl@mcmaster.ca

Research Sponsor: Natural Sciences and Engineering Research Council (NSERC)

Statement of Invitation

You are invited to participate in a research project, which is a collaborative effort between researchers in the Department of Kinesiology and Rehabilitation Sciences at McMaster University. The investigators listed above are conducting this research project. Your involvement and feedback are greatly appreciated and will further our understanding of the factors that affect learning under different practice conditions.

Purpose of the Study

The purpose of this study is to examine the effect of practice schedules on learning different motor sequences in young adults. Results from this study will help us to understand the influence of goal setting, motivation and practice conditions on young adults learning motor tasks.

Procedures involved in the Research

Participation will require approximately 1 hour of your time over two sessions. If you agree to participate in this study, you will be asked to complete the following:

1. Complete a brief demographic questionnaire.

2. Provide informed consent prior to the experimental session.

3. Perform the following tasks for data acquisition:

You will be asked to come to the Motor Behavior Laboratory (department of Kinesiology) at McMaster University for 2 consecutive sessions approximately 24 hours apart. The duration of the entire study is approximately 1 hour. During the first session (approximately 45 minutes), you will complete brief questionnaires and 3 computer tasks. The computer tasks will provide clear instructions on what your task will be. During the first computer task, you will complete 16 briefs trials (approximately 5 minutes) then you will complete 160 brief trials (approximately 35 minutes). After a 10 minute break, you will complete the last computer task consisting of 16 brief trials (approximately 5 minutes). You will also be asked to fill out some brief questionnaires throughout this session. Then you will be asked to return to the lab approximately the same time the following day for session 2 (approximately 15 minutes). During this session you will complete brief questionnaires, a Trail Making test and 1 computer task where you will complete 16 brief trials (approximately 5 minutes). If at any time during the experiment you get tired or feel discomfort you can discontinue your participation.

Potential Benefits and Risks

You will be paid $15 for participation in the study ($10 for session 1, $5 for session 2). You will also have the chance to be paid an additional $15. This $15 will be paid to the person who will best remember the patterns that they practiced in session 1 during the session 2 retention test. The data obtained will further our understanding of the effect of different practice schedules on motor learning. It is unlikely that you will experience any serious injury or discomfort during the study. There are no serious risks involved in this research. However, if you do experience any concerns, you may contact Dr. Lee at the above number or email.

Voluntary Participation

Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time and may do so without any penalty or loss of benefits to which you are entitled. If you choose not to complete session 2 of the study, there will be no session 1 monetary consequence/penalty, however, you will not be eligible to receive an additional $15 for best performance.

Confidentiality

All information you provide is considered confidential; your name will not be included or, in any other way, associated with the data collected in the study. Furthermore, because our interest is in the average responses of the entire group of participants, you will not be identified individually in any way in written reports of this research. No personal identification will be used in publications of any form pertaining to this study. Data collected during this study will be stored in a locked filing cabinet in a locked storage room on campus. Electronic data will be encrypted, stored on an external storage device and locked in the cabinet mentioned above. Access to this data will be restricted to the investigators listed above and their student research assistants.

Contact Information and Ethics Clearance

If you have questions or require more information about the study itself, please contact Dr. Tim Lee, Department of Kinesiology, McMaster University, Hamilton, ON, L8S 4K1
(905-525-9140, ext. 23579; scapps@mcmaster.ca).

This study has been reviewed and approved by the McMaster Research Ethics Board. If you have concerns or questions about your rights as a participant or about the way the study is conducted, you may contact:

McMaster Research Ethics Board Secretariat
Telephone: (905) 525-9140 ext. 23142
c/o Office of Research Services
E-mail: ethicsoffice@mcmaster.ca

Thank you for your assistance in this project. Please keep a copy of this form for your records.

Department of Kinesiology
1280 Main St. West
Hamilton, ON
L8S 4K1

Dr. Timothy D. Lee
Motor Behavior Lab
scapps@mcmaster.ca

Informed Consent Form

Title of Study: The effects of practice schedule on sequence learning in young adults

Investigators:

Timothy D. Lee Ph.D
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 23579
scapps@mcmaster.ca

Kinga Eliasz MSc candidate
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 21436
eliaszkl@mcmaster.ca

CONSENT

I, ___________________________________, agree to voluntarily participate in the study described above.

I have received and read a detailed description of the experimental protocol. I have had the opportunity to ask questions about my involvement in this study and to receive any additional details I wanted to know about the study. I am completely satisfied with the explanation given to me regarding the nature of this research project, including the potential benefits, risks and discomforts related to my participation in this study.

I understand that I have the right to withdraw my consent and discontinue my participation from this study at any time without penalty or prejudices.

____
Name of Participant (please print)

______________________________________   ____________________
Signature of Participant   Date

In my opinion, the person who has signed above is agreeing to participate in this study voluntarily and understands the nature of the study and the consequences associated with participation.

______________________________________   ____________________
Signature of Researcher or Witness   Date

APPENDIX D - **EXPERIMENT 2** Post Debriefing Letter and Re-Consent Form

McMaster University
Inspiring Innovation and Discovery

Department of Kinesiology
1280 Main St. West
Hamilton, ON
L8S 4K1

Dr. Timothy D. Lee
Motor Behavior Lab
scapps@mcmaster.ca

DEBRIEFING LETTER

Title of Study: The effects of practice schedule on sequence learning in young adults

Investigators:

Timothy D. Lee Ph.D
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, L8S 4K1
(905) 525-9140 ext. 23579
scapps@mcmaster.ca

Kinga L. Eliasz MSc candidate
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, L8S 4K1
(905) 525-9140 ext. 21436
eliaszkl@mcmaster.ca

Research Sponsor: Natural Sciences and Engineering Research Council (NSERC)

We greatly appreciate your participation in our study, and thank you for spending the time helping us with our research. When you began the study, you were told that the purpose of this study was to examine the effects of practice schedule on sequence learning in young adults. However, the study was more complicated than we explained at the beginning. Since everyone has different past experiences, motivation may be greatly affected by a one's past history. This becomes problematic when conducting research that involves motivation. In order to see group effects in motivation research, motivation has to be altered, by either positive or negative feedback, so that everyone has a similar level of motivation. The most successful way to isolate motivation and ensure that the behavior evoked by the feedback would be independent of the participants' actual ability or past history is through the use of fabricated deception. Recently, studies in motor learning research have revealed that motivation has a direct impact on motor learning, however, it is unclear how much, what type and where this motivation needs to be present to facilitate learning. Learning is usually defined as a relatively permanent change in an individual's capability to perform a skill and is typically examined through retention tests (Schmidt & Lee, 2011). So in this study, we were investigating whether having a positive or negative sense of motivation before and/or during practice would facilitate the learning of a motor task (computer keypress sequence task) in healthy young adults.

In this study, you were presented with fabricated deceptive feedback during two separate tasks. After you completed the first task (pre-practice task), regardless of your actual performance, you were provided with fabricated information about your capability to successfully learn the upcoming tasks. This was done to try to alter your perceived level of motivation before you began practicing the patterns so that you would have a similar level of motivation, as other participants in your group, to do the experiment tasks. The second time you were provided with fabricated feedback was during the practice task/session (when you were learning the four different patterns). You were provided with your actual performance results, however, a few times during practice you were also shown a visual bar graph of the average performance results of a group of hypothetical test participants (fabricated social comparison). This was done to try to alter your level of motivation during practice by another strong motivational tactic - social comparison. We tried to influence your perceived level of motivation in order to investigate whether this would have an effect on how you learned the motor tasks (computer keypress patterns). We want to emphasize to you that the information you received regarding your performance results (i.e., your 'capability' to learn upcoming tasks) was fabricated by the researchers and we in fact have no such test to predict someone's capability or future success on such sequence tasks (computer keypressing tasks). We also want to emphasize that the information you received during the practice session when you were socially compared to other participants was fabricated/made up by the researchers and we in fact have not even analyzed any participant data at this present time and do not even have this information to give to you. Throughout the study, we also assessed your perceived learning judgments by asking you to self-report your confidence, motivation and how difficult you perceived the task to be at various time points.

We could not give participants complete information about the study before their involvement because it may have influenced participants' behavior during the study in a way that would make investigations of the research question invalid. The reason that we used fabricated deception in this study was because we needed participants' behavior and attitudes to be unaffected by the study objectives. We apologize for omitting details and for providing you with fictional information about the purpose of and tasks in our study. We hope that you understand the need for deception now that the purpose of the study has been more fully explained to you. We would also like to assure you that most Psychology and Motor Learning research does not involve the use of deception.

If any of the questions, concerns, comments or exercises in this study caused you to feel uncomfortable, please feel free to contact my faculty supervisor, Dr. Timothy D. Lee, anytime at (905) 525-9140 ext. 23579 or email at scapps@mcmaster.ca. Also please feel free to contact McMaster Research Ethics Board Secretariat at (905) 525-9140 ext. 23142 or email at ethicsoffice@mcmaster.ca, if you have any concerns or comments resulting from your participation.

The information you provided will be kept confidential by not associating your name with the responses. The data will be stored with all identifying or potentially identifying information removed. Electronic data will be stored on a password protected computer in the Motor Behavior Laboratory. Printed data will be kept in a locked room in the Motor Behavior Laboratory for 7 years then destroyed by confidential shredding. No one other than the researchers will have access to the data.

Since the study involves some aspects that you were not told about before starting, it is very important that you not discuss your experiences with any other students who potentially could be in this study until after the end of the term. If people come into the study knowing about our specific predictions, as you can imagine, it could influence their results, and the data we collect would be not be useable. Also, since you will be given a copy of this feedback letter to take home with you, please do not make this available to other students. Moreover, because some elements of the study are different from what was originally explained, we have another consent form for you to read and sign if you are willing to allow us to use the information that you have provided. This form is a record that the purpose of the study has been explained to you, and that you are willing to allow your information to be included in the study. We really appreciate your participation and hope that this has been an interesting experience.

During the debriefing session, I, ____, received a detailed verbal and written description and explanation of the real purpose of this study. I am completely satisfied with the explanation given to me regarding the true nature of this research project.

Name of Participant (please print):

____

Signature of Participant ____

Date____________________________

McMaster University
Inspiring Innovation and Discovery

Department of Kinesiology
1280 Main St. West
Hamilton, ON
L8S 4K1

Dr. Timothy D. Lee
Motor Behavior Lab
scapps@mcmaster.ca

Post Debrief Informed Consent Form

Title of Study: The effects of practice schedule on sequence learning in young adults

Investigators:

Timothy D. Lee Ph.D
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 23579
scapps@mcmaster.ca

Kinga Eliasz MSc candidate
Department of Kinesiology, McMaster University
1280 Main Street West, Hamilton, Ontario, L8S 4K1
(905) 525-9140 ext. 21436
eliaszkl@mcmaster.ca

POST DEBRIEF CONSENT

During the debriefing session, I have received a detailed verbal and written description and explanation of the real purpose of this study. I was informed that having full information about the actual purpose of the study might have invalidated the results. Thus, to ensure that this did not happen, some details misrepresented the real purpose of the study. I have had the opportunity to ask questions about my involvement in this study and to receive any additional details I wanted to know about the study. I am completely satisfied with the explanation given to me regarding the true nature of this research project, including the potential benefits, risks and discomforts related to my participation in this study.

I have been asked to give permission for the researchers to use my data (or information I provided) in their study, and agree to this request. I understand that I have the right to withdraw my consent by notifying the Principle Investigator of this decision to discontinue my participation from this study without penalty or prejudices.

____
Name of Participant (please print)

____________________________________ ____________________
Signature of Participant Date

In my opinion, the person who has signed above is agreeing to participate in this study voluntarily and understands the nature of the study and the consequences associated with participation.

____________________________________ ____________________
Signature of Researcher or Witness Date

I would like to receive a summary (1-2 page) of the study's results Yes □ No □

If yes, then please send them to this email address: ________________________________
or this mailing address: ____

APPENDIX E - **EXPERIMENT 2** Questionnaire Package

E-1: Demographic Questionnaire

E-2: Perceived Learning Confidence Scale PRE One Pattern (pre-capability Day 1 test)

E-3: Perceived Learning Confidence Scale POST One Pattern (post-capability Day 1 test)

E-4: Sudoku

E-5: Perceived Learning Confidence Scale PRE Four Patterns (pre-delayed Day 2 retention test)

E-6: Uncued Recall Test

E-7: Trail Making Test

E-1: Demographic Questionnaire

Participant ID: __________   Today's Date: __________________

Date of Birth: ______________   **Dominant Hand**: Left / Right
(day/month/year)

1) Do you wear corrective lenses? Y / N

2) If yes, are you wearing them today? Y / N

3) If you do wear corrective lenses, do you need to wear them when doing a computer task? Y / N

4) Are you color-blind? Y / N

5) How many hours per week do you spend using a computer? (please circle what describes your best computer usage)

never   less than 5 hrs   5-15 hrs   16-30 hrs   more than 30 hrs

6) How many hours per week do you spend playing video games? (please circle what describes your best video game usage)

never   less than 5 hrs   5-15 hrs   16-30 hrs   more than 30 hrs

7) Do you have any conditions that may prevent you from performing computer tasks? Y / N

If yes, please describe

____

E-2: Perceived Learning Confidence Scale PRE One Pattern

Using the following scale, please rate, as of right now, on a scale of 0%-100%, how confident you are that you can successfully learn the upcoming pattern **and** that you can successfully reproduce and perform it as fast and accurate as possible at a later time:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

E-3: Perceived Learning Confidence Scale POST One Pattern

Using the following scale, please rate, as of right now, on a scale of 0%-100%, how confident you are that you successfully learned this pattern **and** that you can successfully reproduce and perform it as fast and accurate as possible at a later time:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

E-4: Sudoku

What are the rules?

There is only one rule: Every row, column and box of 3x3 cells must contain the numbers 1 through 9 exactly once.

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

E-5: Perceived Learning Confidence Scale PRE Four Patterns

Using the following scale, please rate, as of right now, on a scale of 0%-100%, how confident you are that you can successfully learn the upcoming 4 patterns **and** that you can successfully reproduce and perform them as fast and accurate as possible at a later time:

0......10......20......30......40......50......60......70......80......90......100

I do not feel confident at all	I feel moderately confident	I feel completely confident

E-6: Uncued Recall Test

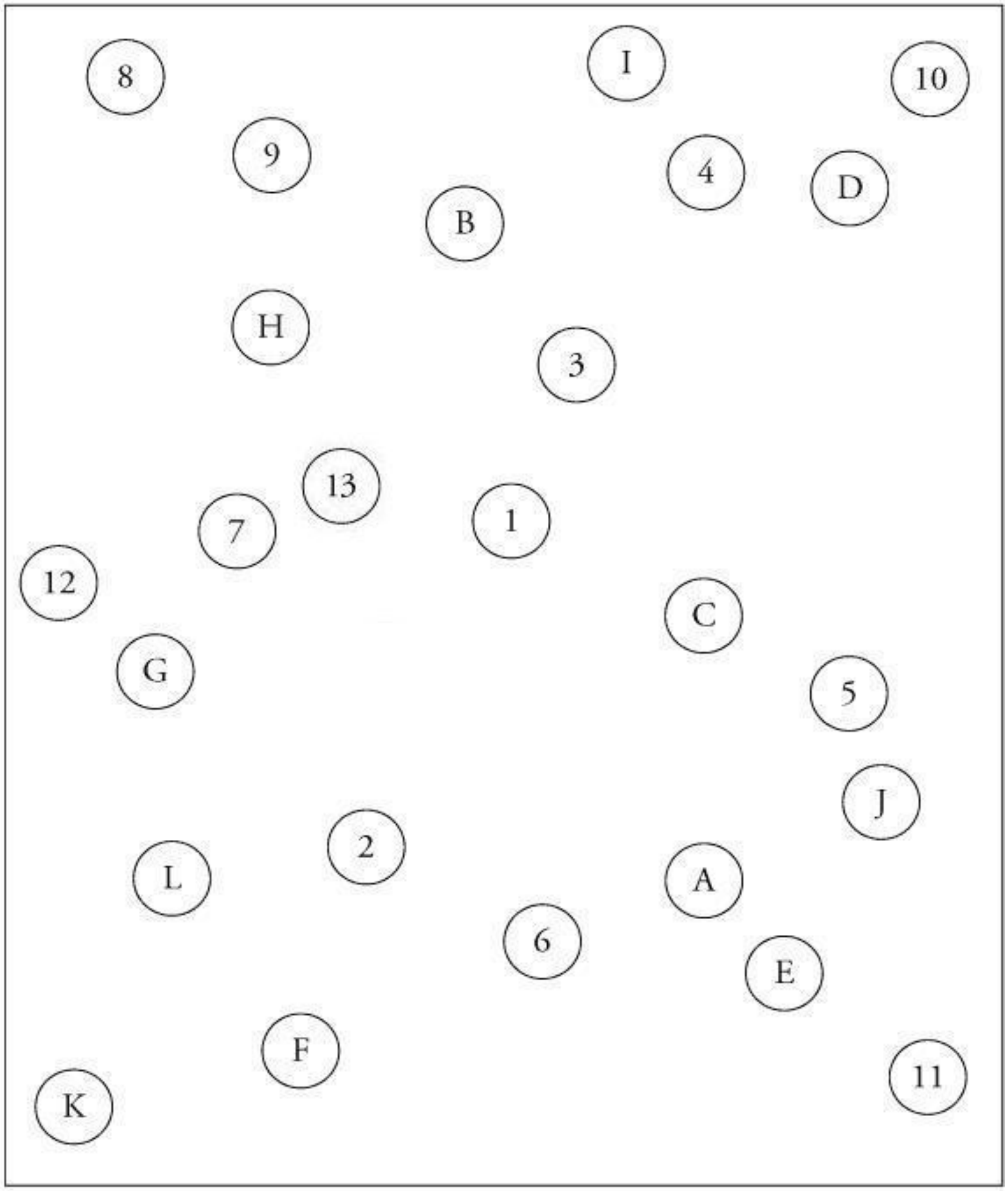
BLUE PATTERN

ORANGE PATTERN

RED PATTERN

GREEN PATTERN

E-7: Trail Making Test



Time (seconds): ______________________

APPENDIX F - Ethics Clearance

McMaster University
Inspiring Innovation and Discovery

McMaster University Research Ethics Board (MREB)

c/o Office of Research Services, MREB Secretariat, GH-305, e-mail: ethicsoffice@mcmaster.ca

CERTIFICATE OF ETHICS CLEARANCE TO INVOLVE HUMAN PARTICIPANTS IN RESEARCH

Application Status: New ☑ **Addendum** ☐ **Project Number:** 2011 126

TITLE OF RESEARCH PROJECT:

Motivation and motor learning in young adults

Faculty Investigator (s)/ Supervisor(s)	Dept./Address	Phone	E-Mail
T. Lee	Kinesiology	23579	scapps@mcmaster.ca
Student Investigator(s)	**Dept./Address**	**Phone**	**E-Mail**
K. Eliasz	Kinesiology	21436	kinga.eliasz@gmail.com

The application in support of the above research project has been reviewed by the MREB to ensure compliance with the Tri-Council Policy Statement and the McMaster University Policies and Guidelines for Research Involving Human Participants. The following ethics certification is provided by the MREB:

☐ The application protocol is approved as presented without questions or requests for modification.

☐ The application protocol is approved as revised without questions or requests for modification.

☐ The application protocol is approved subject to clarification and/or modification as appended or identified below:

COMMENTS AND CONDITIONS: Ongoing approval is contingent on completing the annual completed/status report. A "Change Request" or amendment must be made and approved before any alterations are made to the research.

Reporting Frequency:	Annual: Jul-21-2012	Other:

Date: Jul-21-2011 **Chair, Dr. D. Maurer/ Vice-Chairs, Dr. Tina Moffat & Dr. Bruce Milliken:**

Dr. G. Parise July 22/11