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BENEFITS OF VARIABLE PRACTICE CONDITIONS FOR ATHLETES IN MIXED
MARTIAL ART

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the
Degree of Master of Science in Biology

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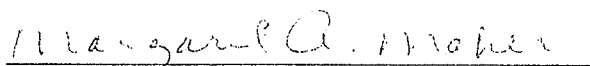
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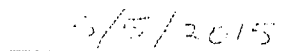
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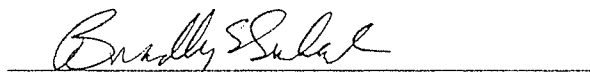
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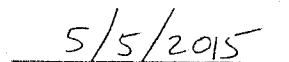
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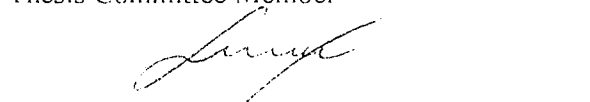
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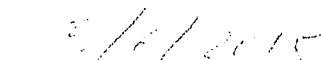
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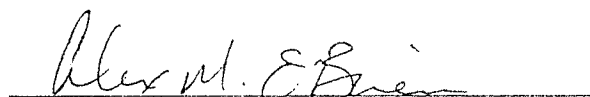
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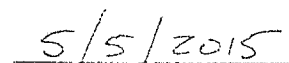
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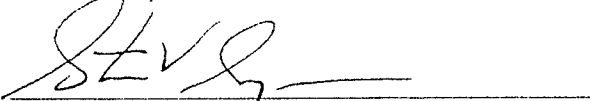


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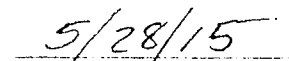


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ABSTRACT

Yang, X. Benefits of variable practice conditions for athletes in mixed martial art. MS in Biology, May 2015, 48pp. (M. Maher)

Mixed Martial Art (MMA) is a competitive sport requiring athletes to be versatile in striking and grappling techniques. With growing popularity, more athletes will be seeking to improve their overall performance. Trainers and coaches will be interested in which types of practice conditions are effective for enhancing the transfer of skills to novel situations. Participants (n=20; 6 males, 14 females) in this study engaged in a sequential key pressing task, which required them to learn four motor sequences in a blocked-practice or variable-practice schedule. Participants practiced three times in one week under the condition they were randomly assigned and completed a one day transfer test three days after the last practice session. The transfer of skills was tested using a randomized sequence to determine differences between groups in transfer of skills when the stimulus became unpredictable. At the end of acquisition, both groups demonstrated motor chunking of all four key-pressing sequences. However, the variable-practice group had significantly better transfer of skills during the test condition than the blocked-practice group. The present study provides support for the notion that a variable-practice condition not only improves sequence completion time but also influences how memory of motor actions is structured during practice.

ACKNOWLEDGEMENTS

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INTRODUCTION

Mixed martial art (MMA) is a competitive combat sport that is gaining worldwide popularity. Involving both striking and grappling techniques, MMA is a sport that requires high levels of motor skills, physical conditioning, and training strategies (Amtmann & Berry, 2003; Hirata & Franchini, 2011). Although MMA has been around since the 1900s, it has only recently been accepted in the United States, when it officially debuted on November 12, 1993 at the Ultimate Fighting Championship (UFC) in Denver, Colorado. As a result, there is limited research addressing optimal training methods for athletes competing in MMA (Buse, 2006; Bounty, Campbell, Galvan, Cooke & Antonio, 2011). Although previous work has examined training methods for optimizing the constructing and implementation of strength and conditioning programs, not much has been investigated about identifying the most effective practice conditions for enhancing acquisition, retention, and transfer of skills in MMA athletes. However, extensive studies in the field of motor skills learning, have examined the influence of organization and practice conditions on the acquisition, retention, and transfer of motor skills in other sports and experimental settings.

Upon acquisition of new skills, these are retained (retention) so that they can be used in new situations that may be encountered in the future (transfer) (Schmidt, 1975). The importance of retention is that it allows skills learned to later be used again under similar conditions as practiced, while transfer allows learned motor skills to be applied

under different conditions, thereby allowing adaptation to new situations (Vera et al., 2008). Especially in humans, where higher cognitive processing can occur, the ability to transfer skills to any condition is what permits good performance of complex motor activities. Schmidt's (1975) schema theory proposes that programmed actions are governed by generalizable motor programs (GMP) consisting of a set of pre-structured commands for a number of movements and specific motor parameters (such as speed and force) that can be varied before initiating execution of a motor program. Therefore, the ability to adapt to different situations depends on how a person determines which parameters are suitable for modifying the pre-existing stored motor program. In addition, Lai and Shea (1999) identified that different practice conditions can influence GMP and parameter processes, in which GMP learning has been shown to be superior with a blocked schedule, and variable practice fosters the development of parameter specification. They proposed that acquisition factors (i.e., feedback or practice manipulations) that promote trial-to-trial response stability enhance GMP development. Whereas, acquisition factors promoting trial-to-trial parameter variability facilitates the accuracy of specific parameters of movement under transfer conditions.

A similar motor learning phenomenon known as contextual interference, in which there is interference among multiple tasks being learned across practice trials, is often associated with Schmidt's (1975) variability of practice hypothesis. Practice conditions under high contextual interference (e.g., when multiple tasks are practiced in a random order) typically yield poorer performance during acquisition, but later improvements in performance during retention and transfer, compared to practice conditions experienced with low contextual interference (e.g., when multiple tasks are practiced in a blocked

order) (Shea & Morgan, 1979; Magill & Hall, 1990; Giuffrida, Shea & Fairbrother, 2002). A common interpretation for the learning effects of contextual interference is that information processing activities are enhanced and this reduces the time required for initiating a motor response, as shown through retention and transfer tests (Vera et al., 2008).

Many of our normal motor and skills-transferring behaviors are dependent on coordinating the execution of multiple movements arranged in a correct sequence (for review, see Tanji, 2001). Increasing the difficulty of a task would require more time to formulate a motor program, as there are more elements within a sequence with which to work. As the number of elements within a movement sequence increases, initiation and execution times increase in response (Verwey & Eikelboom, 2003). Demonstrated by Shea and colleagues (e.g., Park & Shea, 2005; Wilde & Shea, 2006; Shea, Park, & Braden, 2006), participants of a dynamic (14 elements) arm movement sequence experiment displayed, early in practice, an organization of chunking elements together in an attempt to learn and manage the many elements in the sequence. Verwey & Eikelboom (2003) also demonstrated that with increased practice, development of motor chunks, each representing a short segment of an entire sequence, can occur. Motor chunking is a process in which elements of a sequence begin to form strong connections, creating shorter segments that can be initiated and remembered easily. To enhance the learning of complex motor sequences, motor chunks are formed into organized and functionally intact subsequences, in order to reduce the number of elements requiring sensorimotor inputs. This, in turn, ensures a more efficient execution of the motor

program, which can be detected by the pattern of element duration (time duration between individual elements) (Kovacs & Mühlbauer, 2009).

In MMA practice provides a platform for acquiring new skills under a controlled situation, while in a real situation, the uncertainty and unpredictability of an uncooperative opponent becomes an anticipation cost of producing correct motor behavior. A clear advantage to predictable sequence movements is that the cost of uncertainty is far less; therefore the requirement of sensorimotor feedback updates is considerably reduced when initiating execution of movements. On the other hand, when introduced to an unpredictable deviation in movement sequences, the chances of errors (e.g., throwing a punch or a kick, counterattack, or grappling) greatly increases. Results of increased errors can lead to greater element durations and slowing of the connections between elements, inducing sequence latency (time required to start a movement or movement sequence) (Verwey & Eikelboom, 2003). In MMA, athletes experience a tremendous amount of uncertainty in their movements due to the unpredictable sequence of movements performed by their opponents. Improving the transfer of skills, response, and accuracy to produce the desirable behavioral response to unpredictable movements is key to a successful career in MMA.

Among the competitive combat sports participants, MMA athletes require an impressive blend of multiple combative styles to excel in their profession. Designing an effective practice schedule of training conditions will help them reach their goals of improving overall performance and success in the industry. Because MMA requires a blend of combative styles, there are different training methods used among coaches and athletes. Two common training methods used are a repetitive rehearsal schedule

(blocked training) and an alternating rehearsal schedule (variable training). A repetitive rehearsal schedule is often used for athletes training to incorporate a single combat style (e.g., Brazilian jujitsu, wrestling, Muay Thai kickboxing, etc.) to improve weak areas or for athletes who choose to specialize in a certain combat area (ground work, grappling or striking). Whereas, an alternating rehearsal schedule is often used for training athletes to incorporate multiple combat styles and to be versatile in all areas. In addition, an alternating rehearsal schedule is often used as a method for sparring (live simulation of a competition) to prepare athletes to work with less predictable situations and to learn to adapt to those situations. Wright et al. (2004) investigated different practice conditions on long-term motor programming and their results support the idea that a random practice schedule enhances the retention and transfer of motor behavior compared to a blocked schedule. They found that an extensive blocked practice condition resulted in only temporary movement sequence consolidation compared to a random practice condition. Furthermore, the random practice condition appeared to affect the structure of the memory developed during practice, leading to greater improvements in the completion of intra-trial movement planning processes.

In the present study, the primary focus was to determine whether a blocked-practice condition or variable-practice condition is more effective for the transfer of motor responses to a novel motor sequence. In addition, the presence of motor chunking and the accuracy of motor responses were also investigated. Motor chunking occurs when elements of a sequence are linked into relatively intact subsequences, which reduces the number of elements requiring sensorimotor information and was assessed through comparing element durations between key presses (time elapsed between stimulus onset

and depressing of the first key, keys 1-2, 2-3, and 3-4). Accuracy refers to the correct execution of a motor task, and was assessed by analyzing the numbers of key press errors. Examining differences in training with a blocked-practice schedule, which yields higher performance at the end of acquisition, versus a variable-practice schedule, which yields poorer performance early on but improved retention and transfer, will be of interest for trainers, coaches, and athletes in MMA.

MATERIALS AND METHODS

Participants

Twenty college students (6 male and 14 female, ages of 19-23 years) were recruited as volunteers through the use of printed and posted fliers and announcements in Exercise and Sports Science classes at University of Wisconsin – La Crosse. Participants had no prior experience with the experimental task, but were informed of the specific purposes of the study. Informed consent was obtained prior to participation in the study. This study was reviewed and approved by the Institutional Review Board (IRB) for the Protection of Human Subjects at the University of Wisconsin – La Crosse.

Procedures

Participants in the study were randomly assigned to a practice condition (blocked-practice group, n=10; variable-practice group, n=10). Upon entering the practice room, participants were assigned to a computer with their respective practice condition program installed. Once seated, participants were informed of instructions before starting, and were informed that if a break was needed, that it should last longer than 60 seconds. A delay of 60 or more seconds on the key pressing task was thus considered an outlier for data analysis purposes. Three practice stations were located laterally along one wall of a university experimental psychology laboratory, with approximately four feet between stations. Thus, up to three subjects could practice or test simultaneously. During practice and testing, the laboratory door was closed and no talking, music, or other distractions were allowed. Stations included a table with a computer to display visual cues and

attached SuperLab (Cedrus Corporation, San Pedro, CA) key-press apparatus and a straight-backed chair. The primary investigator was present at all training and testing sessions. Subjects practiced at the same time, in the afternoon or evening of each practice day (Monday, Wednesday, and Friday of one week) and on their transfer test day (the Monday of the following week).

Experimental Design

The experiment was carried out in two phases, an acquisition phase and a transfer phase. During the acquisition phase, participants were randomly assigned to a practice condition (blocked or variable) in which they were to respond to four visual stimuli. Each visual stimulus was associated with a four, color-coded, key-pressing sequence. For each visually presented stimulus, participants were to respond by pressing the correct sequence of all four keys in order to advance to the next stimulus (Figure 1). If an incorrect key was pressed, faulting an error, participants could not advance until the correct key response was selected. Each subject in the blocked-practice condition responded to a repetitive order of visual cues (such as left fist, left foot, right fist, right foot – as shown in Figure 2), which required pressing the correct order of colored keys for each cue (with 16 key presses total). Each subject in the variable-practice condition responded to an alternating order of visual cues (see Figure 3), which also required pressing the correct order of colored keys for each cue. Each day of the acquisition phase (three days in one week) required each participant to practice a total of 800 trials (200 trials per stimulus) over approximately 60 minutes. Once acquisition was completed, subjects completed a transfer test three days after the last practice session. This was designed to approximate what MMA athletes would experience during recovery time

between practices and matches. The transfer test required subjects to accurately respond using all four key-pressing sequences, but with novel visual cue sequences. All subjects were informed that the transfer test would involve these novel visual cue sequences.

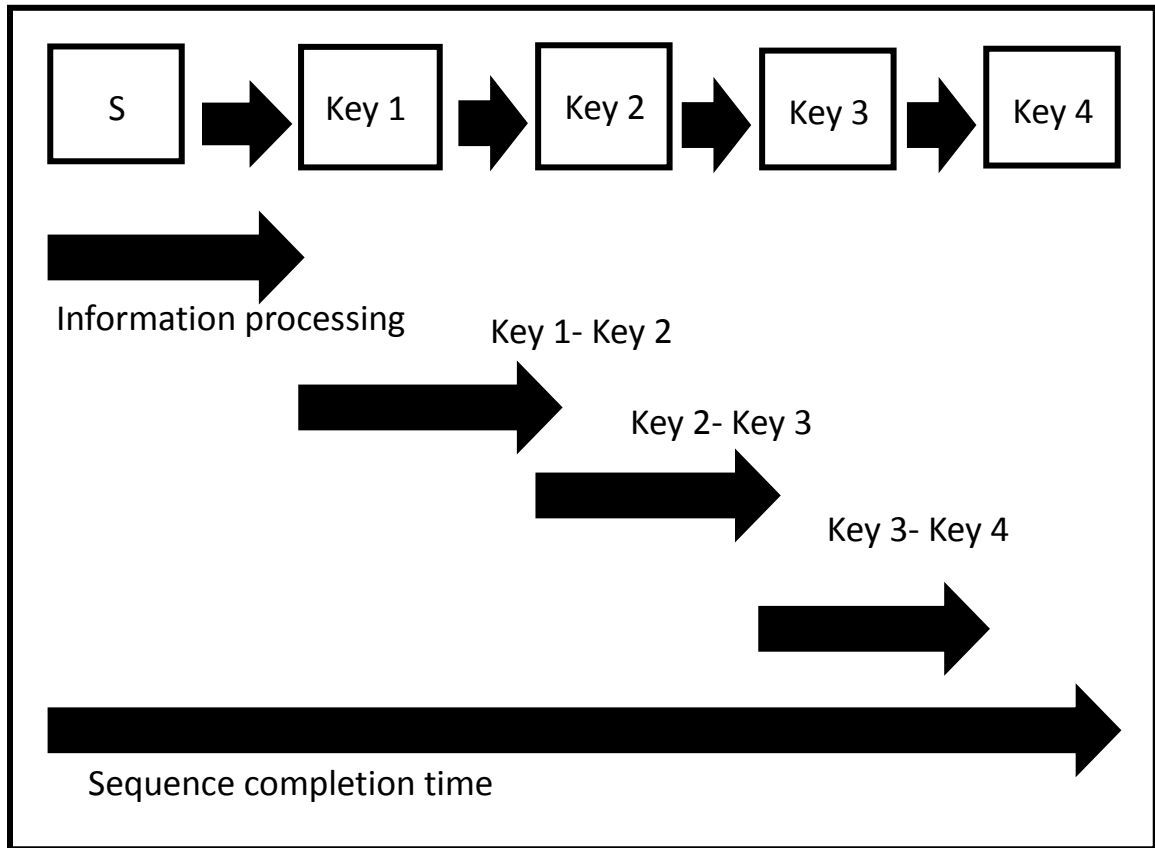


Figure 1. Illustration of a trial run: When a stimulus (S) is presented in the center of the computer display, four color keys (red, blue, green, and yellow) associated with it are also presented below the “S”. The order of key press must be correct in order to advance to the next key. In this figure, time response (msec) from “S” to key 1 is defined as the information processing stage and keys 1-2, keys 2-3, keys 3-4 are defined as the element duration between individual key presses. The time following the presence of “S” to the final depression of key 4 is defined as the sequence completion time.

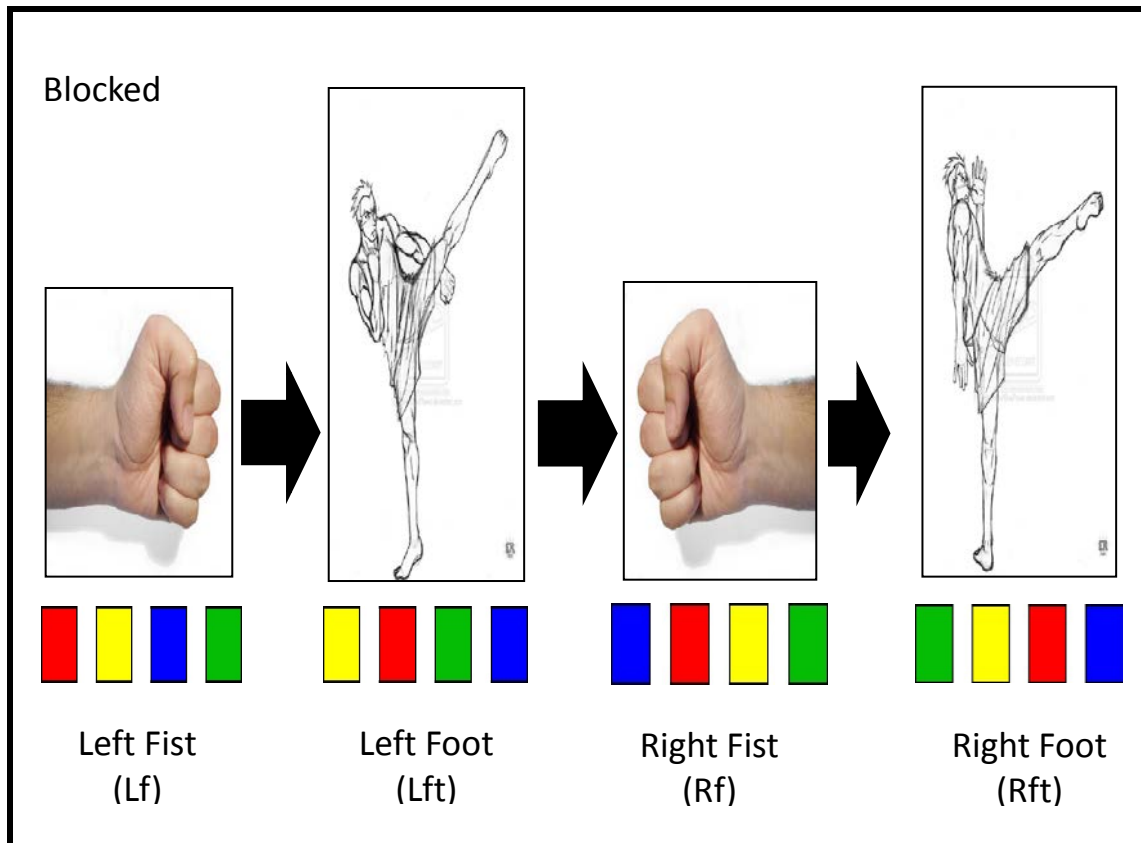


Figure 2. Illustration of learned motor sequence in the blocked-practice group. Each stimulus (Left fist (Lf), Left foot (Lft), Right fist (Rf), Right foot (Rft)) has a four-color key sequence that it corresponds to, which must be pressed in a correct order before advancing to the next target stimulus.

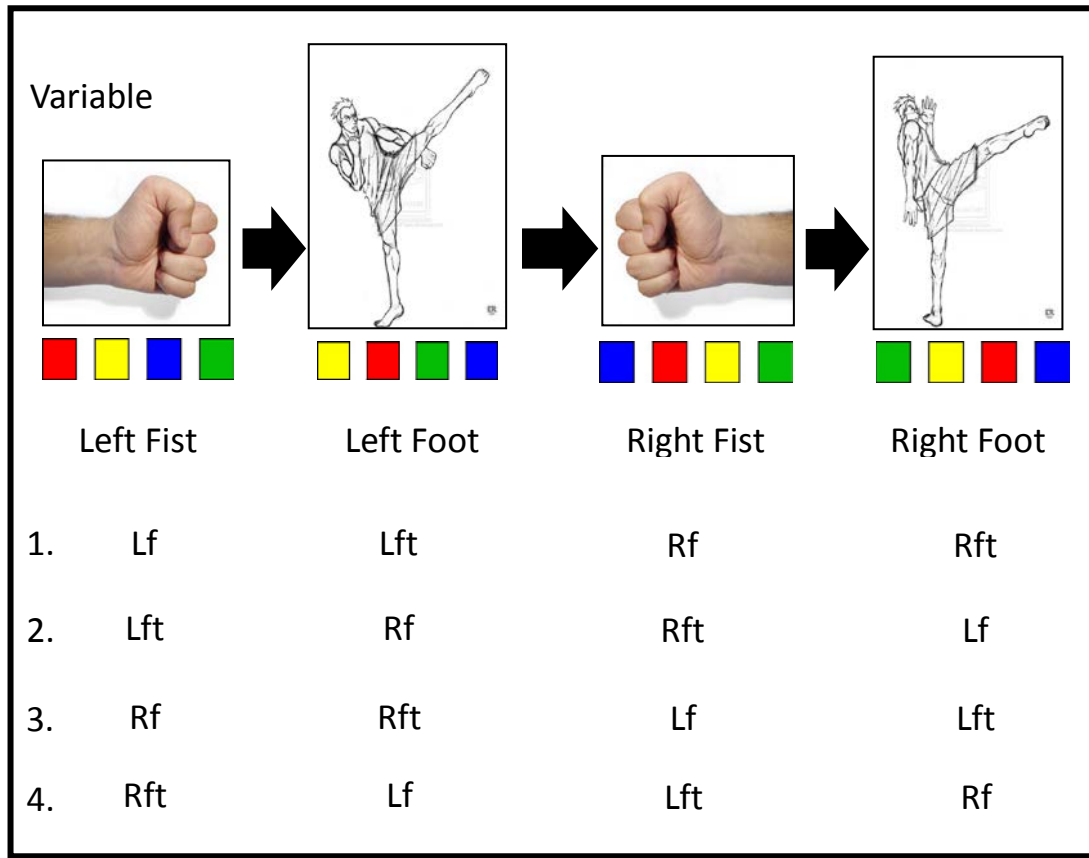


Figure 3. Illustration of learned motor sequence in the variable-practice group. Each sequence starts with alternation of the adjacent stimulus as the next starting point.

Statistical Analysis

Statistical analyses were performed using SPSS (IBM Corporation, Armonk, NY) with General Linear Model – Repeated Measures for: 1) acquisition with within-subjects factors of day (three levels = 1, 2, 3) and key (four levels = 1, 2, 3, 4) and between-subjects factor of practice condition (two levels = block and variable) and 2) test with within-subjects factor of key (four levels = 1, 2, 3, 4) and between-subjects factor of practice condition (two levels = blocked and variable). In addition, a pooled t-test was used for analyzing the mean numbers of errors for the transfer test condition. Dependent variables analyzed included total sequence completion time (time from stimulus to

fourth/final key press), element duration (time between stimulus onset and key 1, and between keys 1-2, 2-3, and 3-4), and numbers of key press errors per session.

RESULTS

Acquisition

There was no significant three-way day by key by practice interaction effect on mean key press time ($F_{(1.538,27.683)} = 0.785, p = 0.435$). A Greenhouse-Geisser adjustment was used since the Sphericity assumption was not met. With a Greenhouse-Geisser adjustment, there was a significant interaction effect of day and key on mean key press time ($F_{(1.538,27.683)} = 8.114, p = 0.003$). Across groups, subject performance improved with days of practice (Figure 4), with the mean initiation time (time from stimulus to the first key press) declining with each successive day of practice. The mean initiation time is much longer than the other mean element durations (times 1-2, 2-3, and 3-4) because visual cues must be interpreted and a decision to execute the sequence associated with each cue must be made. This involves more information processing and learning than does the performance of each additional step in the sequence completion. Thus with practice, decreases in mean initiation time are more profound than decreases in element durations. In addition, the mean initiation time difference between days 1 and 2 is larger than between days 2 and 3. Likewise, overall sequence completion time (total execution time from stimulus onset to fourth/final key press) decreased across practice days, but more profoundly between practice days 1 and 2 as opposed to days 2 and 3. Furthermore, there was a key by practice condition interaction ($F_{(1.321,23.785)} = 10.340, p = 0.002$) with

the mean initiation time (time to first key press) slower in the variable-practice group versus the blocked-practice group (Figure 5).

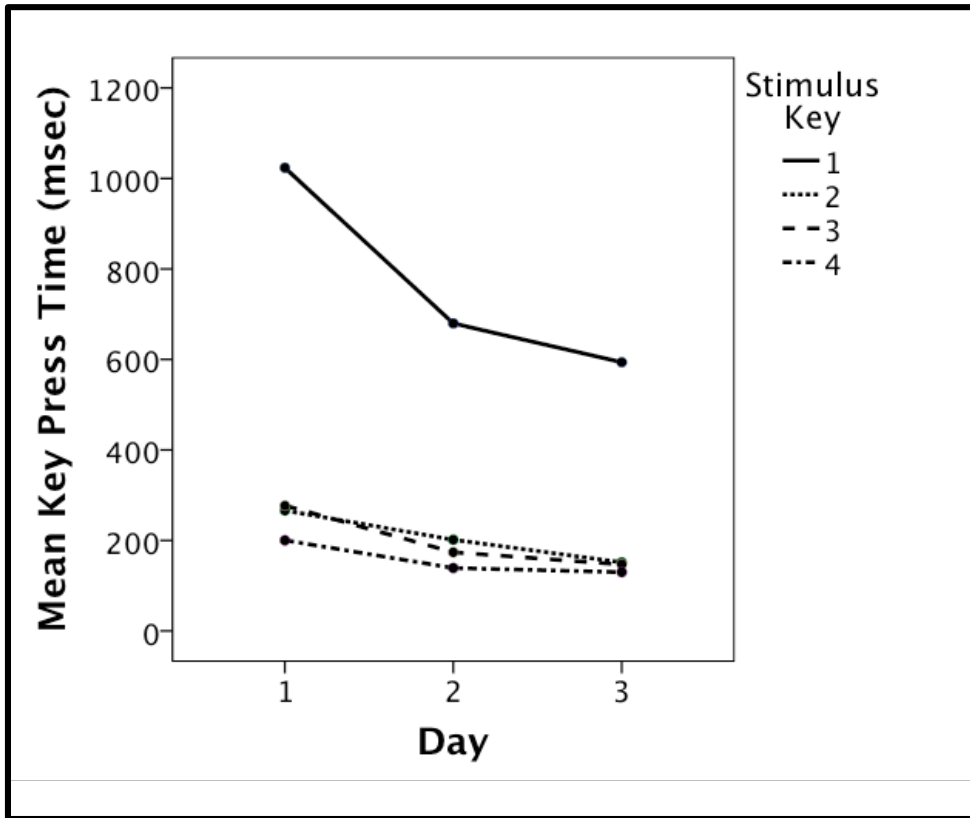


Figure 4. Interaction plot of mean key press times across days of practice of all subjects in both practice conditions. The solid line 1 = the initiation time (time from stimulus to 1st key press) and the dashed lines 2, 3, and 4 = element duration times (times between key presses 1-2, 2-3, and 3-4, respectively).

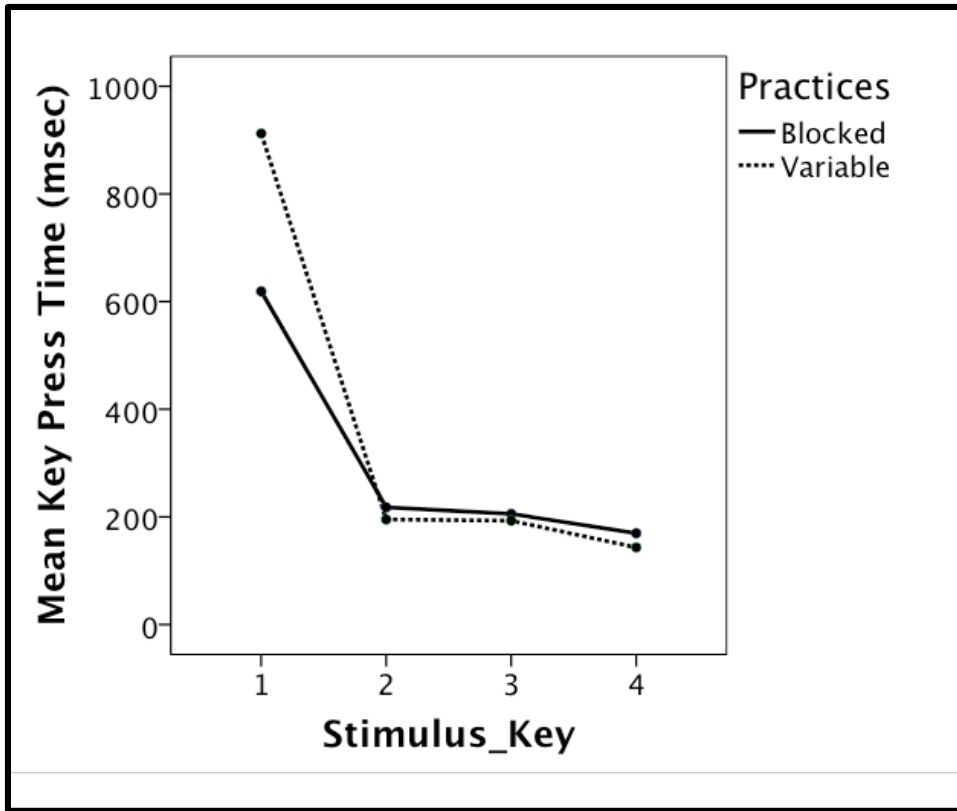


Figure 5. Interaction plot of mean key press time between practice conditions during days of practice. The solid line = blocked-practice group and the dashed line = variable-practice group.

Transfer Test

With a Greenhouse-Geisser adjustment, the blocked-practice group took significantly ($F_{(1,18)} = 4.557, p = 0.047$) longer to complete all four key press sequences in the correct order (504 msec average across keys) than the variable-practice group (362 msec average across keys) in the transfer test. Although there was no interaction between key by practice, with mean key press times relatively similar for both practice conditions ($F_{(1.731,31.162)} = 158.685, p = 0.132$), there was an interaction between keys; where the difference in initiation time (time between stimulus and 1st key press) is significantly longer than any of the other key press element durations ($F_{(1.731,31.162)} = 158.685, p =$

0.000). In addition, key press element duration 1-2 was longer than element duration 3-4, while neither of these was significantly different than element duration 2-3 (Figure 6).

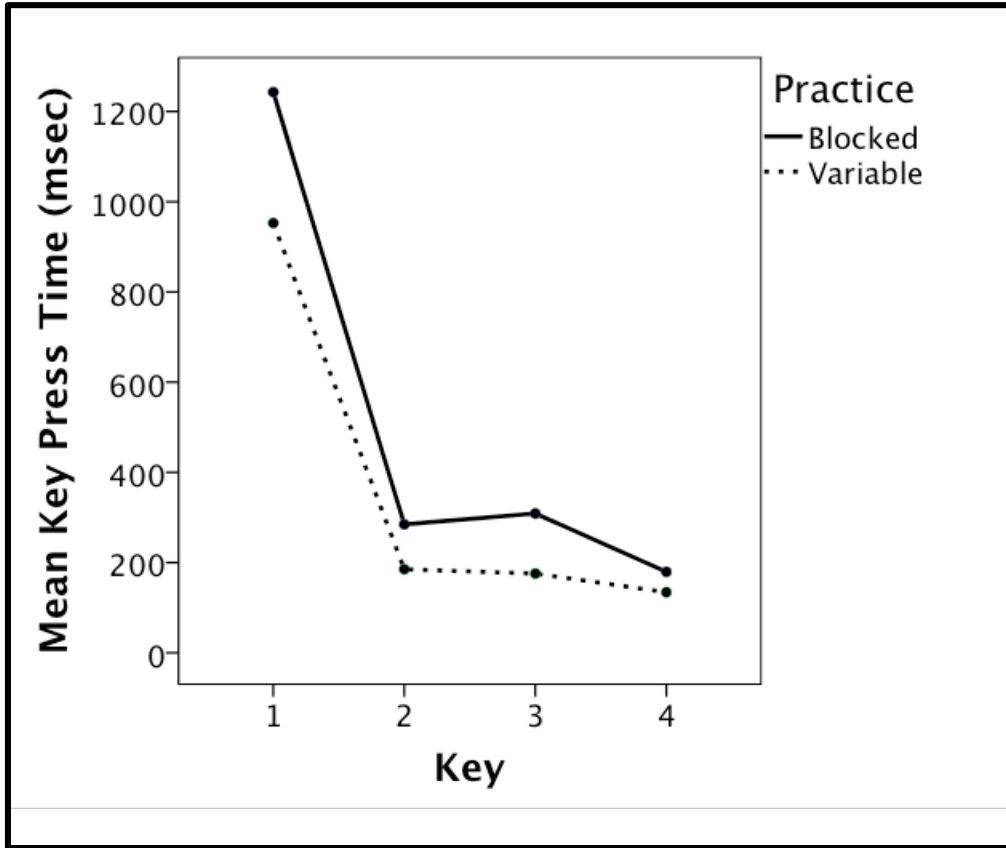


Figure 6. Mean key press time between practice conditions during transfer test condition.

Mean Number of Key Press Errors

Acquisition

No Greenhouse-Geisser adjustment was needed since the Sphericity condition was satisfied ($P = 0.833$) for the mean number of key press errors during acquisition. There was no interaction effect of day by condition ($F_{(2,36)} = 1.327, p = 0.278$) on mean number of key press errors. Both blocked-practice and variable-practice groups produced similar mean numbers of errors for all three days of practice. In addition, practice condition had no significant effect on the mean errors produced ($F_{(1,18)} = 0.316, p =$

0.581). Lastly, there was no main effect of day ($F_{(2,36)} = 2.452, p = 0.100$) on mean numbers of key press errors. Furthermore, it should be mentioned that within the variable-practice group, one subject had an unusually large number of key press errors during day 2 of practice, shifting the mean for day 2 higher. However, even with this outlier, there still was no interaction effect of day by practice condition ($F_{(2,36)} = 1.327, p = 0.278$), as there was greater variability within the variable-practice group (Figure 7).

Transfer Test

There was no significant difference in mean number of key press errors ($t_{(17)} = 0.475, p = 0.641$) between blocked-practice and variable-practice groups. Both groups produced similar mean numbers of errors during the transfer test.

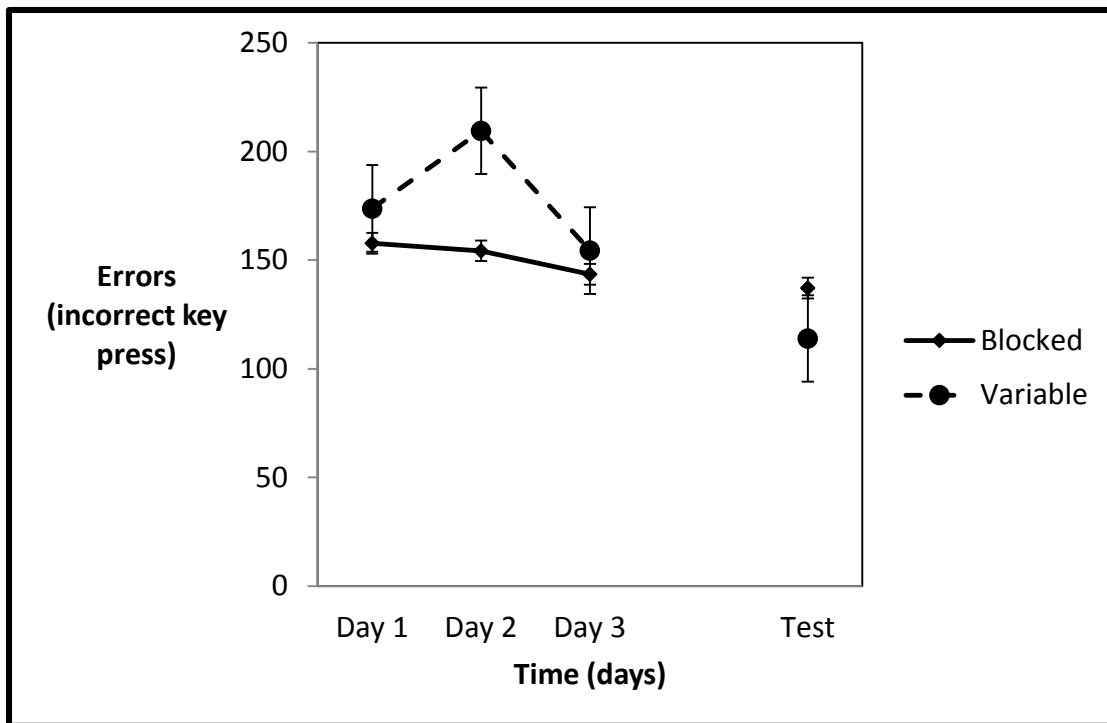


Figure 7. Mean numbers of key press errors (# of incorrect key press) across days of practice and test condition (# of incorrect key press) from both practice groups.

DISCUSSION

The present aim was to determine whether a blocked-practice condition or a variable-practice condition is more effective for enhancing the transfer of learned sensory-motor sequences to novel sensory-motor sequences. The manner in which we represent and arrange different motor movements in the central nervous system contributes to the retention and transfer of skills learned, and ability to adapt to different situations experienced in the future. Our results showed that overall performance was better for subjects of the variable-practice group compared to subjects in the blocked-practice group during the transfer test. In agreement with previous work, the blocked-practice group displayed better performance at the end of acquisition, while the variable-practice group demonstrated better performance on the transfer test (see Figure 8). Although sequence completion time provided an answer as to which practice condition was more effective for enhancing transfer of skill, the question still remains as to how or why this occurred. Determining how or why the variable-practice group was better at transfer of skills during test conditions is important for practical application to MMA training, but also to other sensory-motor sequence learning and testing applications. For instance, the variable practice group did better in testing, performing essentially as well as they performed on day 3 of practice. If their better performance occurred because they were accustomed to greater contextual interference, perhaps exposure to greater contextual interference in other learning environments may be beneficial. Or, might it be

that the blocked group were slower in testing because they had to disconnect (essentially unlearn) the stimulus-response associations previously learned and consciously hesitated more (lengthening initiation time) or committed more errors (lengthening total key press time)? Hesitation may be acceptable (without high cost) in some activities and not others. Likewise, error may be acceptable (without high cost) in some activities and not others.

To further investigate how or why the variable-practice group's transfer performance was superior, the durations between individual key presses (initiation time, keys 1-2, 2-3, and 3-4) were examined as they might indicate how the movement was structured or chunked. In addition, the mean numbers of key press errors were also compared.

Upon observation of element durations for blocked-practice and variable-practice groups, both appeared to have undergone development of motor chunking to facilitate the execution of the sequences. Although the initiation time to first key press was longer, subsequent keys were depressed much faster following the execution of key press 1. This finding corroborates previous work by Shea and colleagues (e.g., Park & Shea, 2005; Wilde & Shea, 2006; Shea, Park, & Braden, 2006), where subjects developed motor chunks to manage learning of 14-element sequence arm movement. To facilitate the learning of the four color-coded combination sequence, both of our groups demonstrated organization of motor chunking during the acquisition phase (see Figure 9). Even though both groups portrayed signs of similar development of motor chunks, the blocked-practice group was still far better at initiating the movement sequence compared to the variable-practice group. However, during the transfer test, the variable-practice group

initiated the movement sequence faster (Figure 8). Despite being slower at initiating the sequence during acquisition (compared to the blocked-practice condition), the variable-practice group executed the rest of the movement sequence at a similar pace to the blocked-practice group. This indicates that motor chunking may not play much of a role in determining how well subjects can transfer this particular skill. The lower performance in the variable-practice group during acquisition might be explained by an increased number of errors, but no significant difference between groups has been found (see Figure 7). If element duration, motor chunking, or numbers of errors could not explain the differences between blocked-practice and variable-practice conditions, this means that the answer may lie within the initiation time, the duration required to process the stimulus and initiate execution of the movement sequences.

Throughout practice the blocked-practice group might have developed a more rigid and more specific memory trace for a specific sequence as they experienced far less contextual interference. Whereas, the variable-practice group, who experienced higher contextual interference from the alternation of stimuli, may have developed a sequence structure that was not as robust, and therefore they were slower in initiating the sequence movement (first key press). For every stimulus presented to them, all four possible combinations had to be retrieved and ready for selection to ensure a correct response. This, in turn, increased their flexibility to adapt to novel sequences. As shown with the transfer test (Figure 8), where sequences were randomized and predictability of upcoming stimulus decreased by 75%, the variable-practice group was better able to adjust compared to the blocked-practice group.

In the variable-practice group, participants learned that there were four possible visual cue sequences resulting in four different correct motor response sequences. Whereas, in the blocked-practice group there was only one visual cue associated with one correct sequence of motor response. Thus the cognitive associations between stimulus and response patterns were strongly reinforced with 600 repetitive trials (200 trials with one 4 stimulus/4 key response sequence per day for 3 days) of practice for the blocked-practice group versus 150 repetitive trials (50 trials with four 4 stimulus/4 key response sequences per day for 3 days). This made the blocked-practice group much faster in initiation time (first key press) compared to the variable-practice group during practice. But then during transfer, the variable-practice group, who were used to responding to variable visual cues, had fewer cognitive associations to overcome. The blocked-practice group in the transfer test was tasked with learning the task like new, but with interference from previously reinforced associations. For a review of foundational theory related to associative learning, see Rescorla & Wagner (1972).

The reconstruction hypothesis (Lee & Magill, 1983, 1985) provides another possible explanation for why the variable-practice group displayed better performance during transfer compared to the blocked-practice group. The reconstruction hypothesis states that performing intervening tasks under a random-practice schedule causes the learner to forget the action plan in previous rehearsal of a task; therefore they must reconstruct the plan of action before each succeeding performance of the task. This process of reconstructing action plans yields a more detailed and permanent representation of the task in memory, which benefits both retention and transfer of skill.

Finally, the present findings help to provide insight for how professional trainers and coaches of MMA athletes may construct their training schedules to enhance their athletes' learning of new skills in practice and transferring those skills to competitive matches. As both blocked-practice and variable-practice conditions provide different benefits, with blocked condition supporting the development of GMP and variable conditions fostering the development of specific motor parameters, alternating between the two conditions during training may significantly improve the overall performance of a MMA athlete in transferring skills to novel situations during a competition.

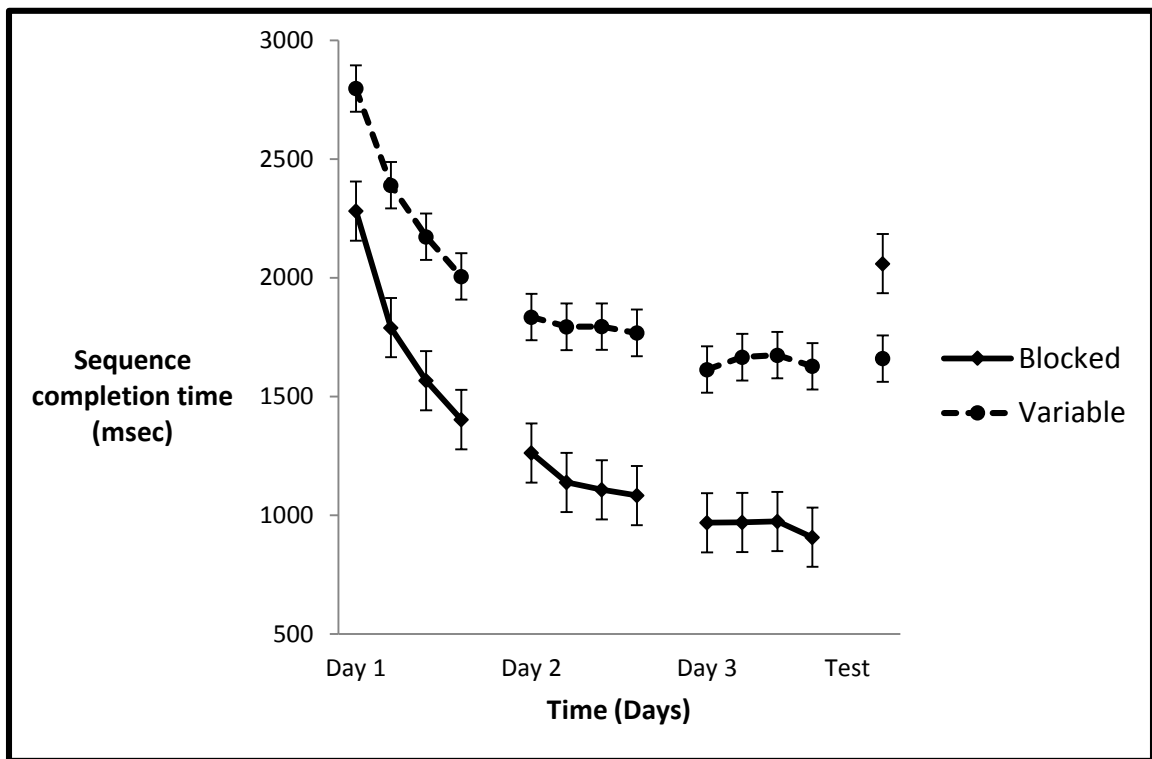


Figure 8. Mean sequence completion times for both practice groups and test. Each practice day was collapsed into sets of 50 data points (1-50, 51-100, 101-150, 151-200) for each stimulus (Left fist, Left foot, Right fist, Right foot) while the test condition is an average of all 50 trials for each stimulus.

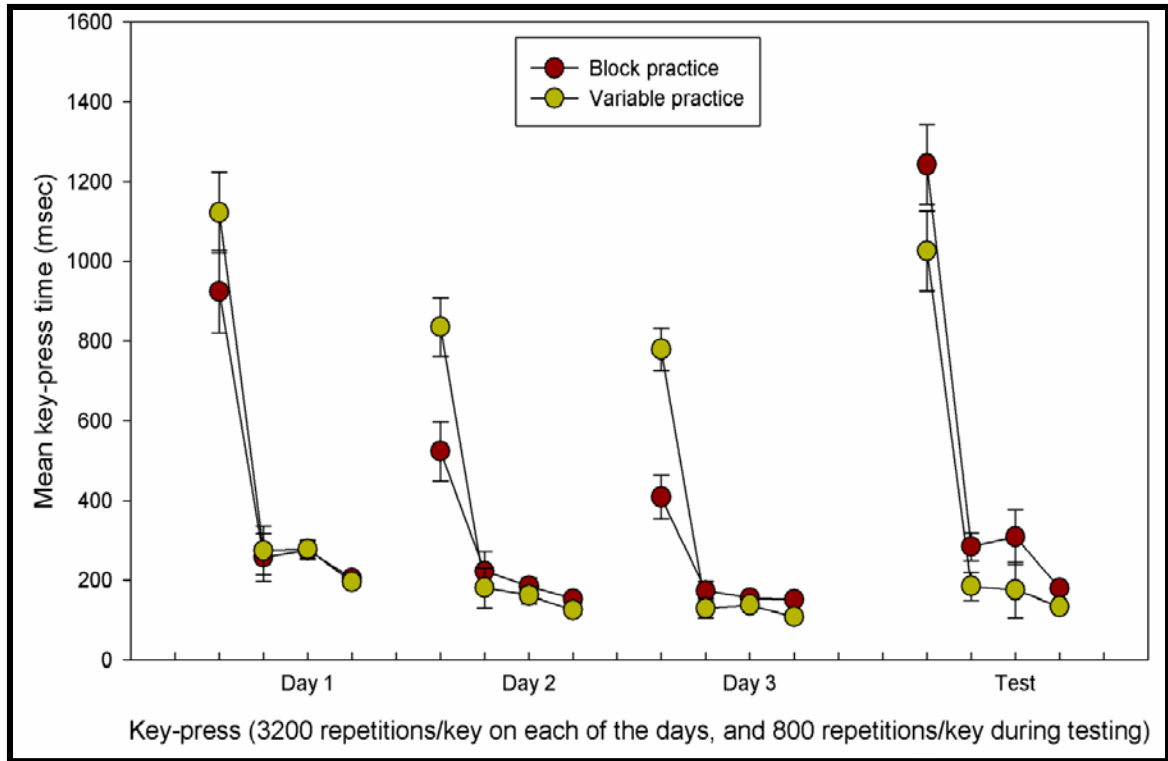


Figure 9. Mean key-press duration of all four keys (3200 repetitions/key on each of the days, and 800 repetitions/key during testing) for the practice and test conditions. Error bars are also included in the figure for comparing relative errors produced for each key.

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APPENDIX A
INFORMED CONSENT

APPENDIX A

INFORMED CONSENT

Protocol Title: Motor Adaptability to Randomized Sequential Motor Patterns

Principal Investigator: Xiong Yang, 1725 State Street, La Crosse, WI 54601

Emergency contact: Xiong Yang (608) 385-5339, yang.xio2@uwlax.edu

- ***Purpose and Procedure***

- The purpose of this study is to determine if learning multiple motor patterns (key presses) is more sufficient in adapting to unpredictable patterns compared to learning a single motor pattern. My participation will involve seven days of practice sessions learning sequential motor patterns, followed by a one day test trial.
- The total time requirement each of the eight days for practice and the test trial is 60 min/day with 2-3 minute breaks.
- Testing will take place in the Psychology Department room 328 in Graff Main Hall, UW-L.
- During all tests, I will be seated with a visual display screen in front of me and my ability to press button keys that corresponds to a pattern displayed on the screen will be analyzed.

- ***Potential Risks***

- The risk of serious or life-threatening complications with participation in this study, for healthy individuals, like me, is near zero.

- ***Rights & Confidentiality***

- My participation is voluntary. I can withdraw or refuse to answer any question without penalty, at any time and for any reason.
- The results of this study may be published in scientific literature or presented at professional meetings using grouped data only.
- All information will be kept confidential through the use of number codes. My data will not be linked with personally identifiable information.

- ***Possible Benefits***

- Through my participation in this study, I may contribute to the development of a therapeutic treatment for individuals with neurodegenerative disease that can affect motor control. I may also contribute to the body of knowledge and recommendations for training associated with sports that require sequential patterns of movement.
- Questions regarding study procedures may be directed to Xiong Yang (608-385-5339), the principal investigator, or the study advisors Dr. Peg Maher, Department of Biology, UW-L (608-785-6967), Dr. Attila Kovacs, Department of Exercise and Sport Science, UW-L (608-785-8786), Dr. Bradley Seebach, Department of Biology, UW-L (608-785-6966) or Dr. Alex O'Brien, Department of Psychology, UW-L (608-785-6886). Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects, (608-785-8124 or irb@uwlax.edu).

Participant_____

Date_____

Researcher_____

Date_____

APPENDIX B

ADVERTISEMENT FLYER

APPENDIX B
ADVERTISEMENT FLYER

Volunteers Wanted

Who:

Any participants welcome



What:

Research study involving motor adaptability to
randomized sequential patterns

Contact:

Xiong Yang, (608)-385-5339, yang.xio2@uwlax.edu

APPENDIX C

TABLES

APPENDIX C

TABLES

Table 1. Mean sequence completion time (msec) collapsed in 50-trial increments during acquisition for blocked-practice (Blk) and variable-practice (V) conditions.

		<u>Day1</u>				<u>Day2</u>				<u>Day3</u>		
	1-50	50-100	101-150	151-200	1-50	50-100	101-150	151-200	1-50	50-100	101-150	151-200
Blk	2282	1791	168	1403	1263	1139	1108	1084	969	970	974	908
V	2797	2390	2173	2006	1835	1794	1795	1768	1614	1666	1674	1628

Table 2. Mean key press time duration (msec) during acquisition for blocked-practice and variable-practice conditions.

<u>Blocked</u>					<u>Variable</u>			
Days	Key 1	Key 2	Key 3	Key 4	Key 1	Key 2	Key 3	Key 4
1	924	258	276	205	1123	274	278	195
2	524	222	185	153	835	181	163	126
3	409	173	156	15	779	131	138	109

Table 3. Mean key press time duration (msec) during transfer test condition for blocked-practice and variable-practice conditions

Conditions	Key 1	Key 2	Key 3	Key 4
Blocked	1243	285	309	180
Variable	1026	185	176	134

Table 4. Mean numbers of key press errors (incorrect key press) during acquisition and transfer test condition for blocked-practice and variable-practice conditions

Conditions	Day 1	Day 2	Day 3	Test
Blocked	158	154	144	137
Variable	174	210	154	114

APPENDIX D
LITERATURE REVIEW

APPENDIX D

LITERATURE REVIEW

Studies have provided insights of how acquisition, retention, and transfer of motor skill learning are affected by the type of practice schedule introduced. Upon acquisition of new skills, these are retained (retention) so that they can be used in new situations that may be encountered in the future (transfer) (Schmidt, 1975). The importance of retention is that it allows skills learned to later be used again under similar conditions as practiced, while transfer allows learned motor skills to be applied under different conditions, thereby allowing adaptation to new situations (Vera et al., 2008). Especially in humans, where higher cognitive processing can occur, the ability to transfer skills to any condition is what permits good performance of complex motor activities.

In determining the most effective conditions to enhance acquisition, retention, and transfer of motor skills, different practice conditions have been extensively studied in the research of motor skills learning. One method of learning is a repetitive or blocked practice, which involves practicing only the skill learned and keeping practice conditions as similar as possible during retention (Proteau, 1992). A second learning method is to practice a number of different skills or variations of a skill to enhance learning, by increasing the difficulty of the practice and is called variable practice (Schmidt & Lee, 1999; Sherwood & Lee, 2003). There are many factors that can affect both the rate of transfer and the accuracy of transferring the correct behavior (the number of tasks being practiced, the variations involved, and the order in which tasks are presented) (Vera et al., 2008).

Many of our normal motor and skills-transferring behaviors are dependent on coordinating the execution of multiple movements arranged in a correct sequence. This

process involves a network of organized connections among various areas of the central nervous system (CNS) (e.g. cerebellum, basal ganglia, supplementary motor area (SMA), and pre-SMA) and arranging how movements are represented and processed in an appropriate temporal order to perform a sequence of movements (for review, see Tanji, 2001). Representation of movement sequences involves both spatial and motor processing, which are developed in parallel. Hikosaka et al. (1999) proposed a model suggesting that movement sequence learning involves both a fast-developing, effector-independent component represented in a visual-spatial coordinate system (e.g., spatial locations of end effectors and/or sequential target positions) and a slower-developing, effector-dependent motor component that is represented in a motor coordinate system (e.g., sequences of activation patterns of the agonist/antagonist muscles and/or achieved joint angles), which allows for a more automatic execution of the sequences (Hikosaka et al., 1999; 2002). However, the successful execution of desired behavior requires that both components (visual-spatial coding and motor coding) must interact to produce the correct response. For purposeful task goals, the arrangement of multiple single movements must be coordinated in various spatial and temporal configurations to ensure correct execution of movement (Rosenbaum, 1991).

Contrary to the Hikosaka et al. (1999) model, Kovacs, Mühlbauer, and Shea (2009) showed rather interesting results, providing strong evidence that even after 12 days of practice of a complex 14-element motor sequence, the visual-spatial coordinate remained dominant. Supporting this notion are results from Panzer et al. (2009), confirming the visual-spatial coordinate played a dominant role in complex movement sequences of interlimb (between hands) practice. Their findings suggested that reliance

on a motor coordinate system may be based on other factors, such as movement difficulty, number of elements in a sequence, feedback availability, and stage of learning (Kovacs, Mühlbauer, & Shea, 2009). Continuing with the previous work, Panzer's et al. (2009) experiment with inter-manual transfer and practice of simple, rapid motor sequences further demonstrated that the complexity of task-specific goals is one attribute responsible for the shift in reliance from a visual-spatial coding to a motor coding. The authors proposed that longer movement sequence may require more extensive practice before reliance on motor coding is beneficial, compared to simple movement sequences which may benefit more from reliance on motor coding earlier in practice.

Furthermore, complex responses have shown to require more time to program as there are more elements within a sequence to work with. As the number of elements within a movement sequence increases, initiation and execution times increase in response. However, Verwey & Eikelboom (2003) demonstrated that practice induces the development of motor chunks, each chunk representing a short segment of the entire movement sequence. Similarly Park & Shea (2005) showed that subjects handling a complex 14-element movement sequence demonstrated chunking of elements early in practice in an attempt to learn and manage the many elements in the sequence. Motor chunking is developed slowly over time with practice as new sequences are initially executed as individual elements, requiring inputs from other sensorimotor sources. However, with practice, individual elements of the sequence form connections (chunk together) into organized, functionally intact subsequences, reducing the number of elements requiring sensorimotor inputs. This organization of chunking elements into subsequence structures allow for a more rapid and precise execution of the sequence, and

can be detected by the pattern of element duration (time duration between individual elements) (Kovacs, Mühlbauer, & Shea, 2009).

The development of motor chunking allows for easier arrangements of motor sequences into organized motor programs, a set of commands of structural movement that are ready for initiation at any time (e.g. reaching, which requires a set of commands for innervating agonist/antagonist muscles of the forearm to execute reaching behavior). This allows for much faster initiation and execution of the desirable motor response. However, there are some response specifications that can vary by how a response is executed with a given motor program (e.g. the difference in speed, difference in force, etc.). This does not mean that every variation of a motor program is coded differently, but rather there is a single generalized motor program (GMP) consisting of a set of commands for a number of movements with specific parameters (speed, order of muscles involved, and force) that can be varied before initiating execution of a motor program. Therefore, the ability to adapt to different situations depends on how a person determines which parameters are suitable for modifying the pre-existing stored motor program (Schmidt, 1975).

Although humans can acquire the ability to adapt to motor changes through extensive practice, the uncertainty and unpredictability of changes becomes an anticipation cost of producing correct motor behavior. A clear advantage to predictable sequence movements is that the cost of uncertainty is greatly reduced; therefore the CNS does not have to wait for sensorimotor information before it initiates execution of movement. When introduced to an unpredictable deviation in movement sequences, the chances of errors greatly increases. Results of increased errors can lead to greater

element durations, and slowing of the connections between elements inducing sequence latency (time required to start a movement or movement sequence) (Verwey & Eikelboom, 2003). In MMA, fighters experience a tremendous amount of uncertainty in their movements due the unpredictable sequence of movements performed by their opponents. Improving the transfer of skills, response, and accuracy to produce the desirable behavioral response to unpredictable movements is the key to a successful career in MMA.

APPENDIX E

REFERENCES

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