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Abstract

An experiment was designed to investigate whether an easy-to-difficult or a difficult-to-easy practice order is best for motor learning. The motor skill used was a fine-motor, bimanual, lever-positioning task with movement complexity as the difficulty variable, which had yet to be studied. One group learned the skill in an easy-to-difficult order with the combination of the two lever movements increasing in difficulty, and one group learned the skill in a difficult-to-easy order with the combination of the two movements decreasing in difficulty. Questions were asked after each condition to gauge participants' levels of self-efficacy, confidence, and frustration. Both groups returned after 24 hours to complete a transfer and retention test. The results support Maxwell, Masters, Kerr, and Weedon's (2001) findings that an easy-to-difficult order leads to greater retention and transfer due to implicit learning of the task. Both groups experienced similar levels of confidence, so confidence does not appear to be a factor determining superiority of task progressions versus degressions. These findings suggest that, when learning a new fine-motor, bimanual, complex task, practice should be introduced in an easy-to-difficult order to optimize retention and transfer.

Introduction

An ongoing question of considerable importance to motor learning specialists is: "What is the best way to learn a new motor skill?" Motor skills are necessary to carry out everyday activities, from learning a new sport, to driving, to writing, to a surgeon mastering a new operational procedure. Because motor skills require precise movements of the body to achieve goals, mastery of motor skills is only achieved through motor learning, which requires practice.

Therefore, the importance of developing the most efficient practice regimen is crucial to optimize motor learning.

The learning of bimanual tasks is especially important, since they are extremely common in everyday activities. A common example of a bimanual task is piano playing. While expert pianists demonstrate great skill in making simultaneous movements of the left and right hand—even when the movements for both hands vary greatly—novice piano players may find acquiring this new skill challenging. Therefore, if one can find a way to make learning these bimanual motor skills more efficient, the widespread applications will be beneficial for many.

The acquisition phase is the period of practice in which a new motor skill is acquired. There are many ways to organize practice. A question that has not been well studied is whether an easy-to-difficult practice order (also known as a progression) or a difficult-to-easy practice order (or degression) is better for motor learning. Progressions are practice orders in which the subject moves from an easier task to a more complex task, and degressions are the reverse order. The best practice order will lead to better motor learning, which is measured indirectly through a retention and transfer test. Retention tests are typically completed 24 hours to weeks after the acquisition phase and are used to assess how well the motor skill was retained by the subject (i.e. permanent changes in performance). A transfer test tests adaptability, or how well the subject is able to apply his/her skill to a new situation.

In the 1950s, a large number of studies on tracking or steering tasks were conducted to determine the training benefits of different practice progressions. However, the studies offered mixed results. Many of them showed that the easy-to-difficult practice order was superior (Ammons, Ammon, & Morgan, 1956; Kaestner & Grant, 1956; Levine, 1953; Lincoln & Smith, 1951; Lordahl & Archer, 1958). Conversely, many of the studies showed that the difficult-to-easy practice order was superior (Andreas, Green, & Spragg, 1954; Baker, Wylie, & Gagné, 1950; Gerall & Green, 1958; Gibbs, 1951; Jones & Bilodeau, 1952; Szafran & Welford, 1950). Still, the majority of studies were inconclusive (Barch, 1953; Barch & Lewis, 1954; Briggs & Waters, 1958; Browne, 1954; Gibbs, 1954; Green, 1955; Green, R. F., Goodenouge, D. R., Andreas, B. G., Gerall, A. A., & Spragg, S. D. S.; Holland & Henson, 1956; Maltzman, Smith, & Brooks, 1955; Morin, 1951; Muckler & Matheny, 1954). Most of the studies had speed, target size, or course complexity as the difficulty variable.

These results showed, at first glance, that neither practice order was superior. However, there were many limitations of these studies (Holding, 1962). For instance, the absolute difficulty of the tasks was difficult to determine because universal standards for determining difficulty levels did not exist. So although a study may have a task progression increasing in difficulty, the absolute difficulty of the task may be much lower than in another study. Therefore, if the answer to our research question is conditional and there are optimal points of task difficulty, it will be challenging to deduce overall conclusions because difficulty level has not been quantified. The best we can do without universal standards is to design an experiment that has a very wide spectrum of difficulty levels, so that it’s likely that any optimal difficulty level will be encompassed within the experiment.

Holding (1962) recognized this problem and designed an experiment with a wide spectrum of difficulty levels. He utilized a pursuit tracking task of a horizontal spot with a joystick-like device. His results indicated that a difficult-to-easy practice order was superior. Still—similar to the majority of the studies before it—his study did not look at coordination/bimanual tasks.

More recently, Sanli (2013) conducted a series of three studies in which participants propelled a disc along a smooth tabletop to targets a certain distance away. For all studies, they returned the following day for a retention test and two versions of a transfer test (one of which was a dual-task test). Sanli (2013) found that the easy-to-difficult group performed with more error than the difficult-to-easy group during acquisition. Additionally, the easy-to-difficult group performed with greater error on the transfer tests (there was no significant difference on retention).

Sanli's (2013) task was a fine-motor task (similar to the present study), but it was unimanual. Other experiments have utilized gross-motor, bimanual tasks. Maxwell, Masters, Kerr, and Weedon (2001) studied the learning of golf putting, in which half of participants putted distances closer that progressively became farther away (easy-to-difficult) and half of participants putted farther distances that became closer (difficult-to-easy). They found that the easy-to-difficult group performed better during acquisition, and this translated into better performance on retention and transfer tests. The results for another gross-motor, bimanual task were demonstrated in Masters, Poolton, and Maxwell's (2008) rugby ball throwing task, in which difficulty was determined by distance of the target. Those in the progression group demonstrated better performance on transfer tests than the degression group.

Based on the conclusions drawn from these more recent studies, the answer to which practice order is better for motor learning has not been answered due to disputing evidence. It could be that simply changing distance does not provide enough of a challenge resulting in little change in task difficulty. Using a bimanual task with different distance goals for each hand may generate more task difficulty than the previous studies using only a distance manipulation.

Introducing this new difficulty variable may translate into a better understanding of complex motor skills, unlike simpler, distance-related tasks.

An aspect of past research that can be improved upon is the determination of true task progressions. One unique feature of the current study was a clear task progression from easy-to-difficult and vice versa, which was accomplished using a bimanual task. The current literature has shown that for bimanual movements, when there is discrepancy between the limb targets, there will be interference (assimilation effect) between the two limbs. This means that the movement of one hand will be affected by the task requirement of the other hand.

This interference effect was shown by Marteniuk, MacKenzie, and Baba (1984) in a task that required the precise, lateral movement of a stylus to a target. They found that subjects who had target goals of 10 cm movements paired with 30 cm movements experienced overshooting of the 10 cm movement and undershooting of the 30 cm movement. Similarly, Sherwood (1994) identified this interference effect in a lever-positioning study. It was discovered that overshooting in the left hand (with a target movement of 30°) and undershooting of the right hand (with a target movement of 60°) occurred when these movements were paired. Sherwood (1994) further described that the amount of interference is directly related to the difference between the spatial goals of the two hands.

The physiological explanation for the interference effect is due to "neural crosstalk" at several levels in the nervous system (for example, subcortical or spinal levels; Marteniuk et al., 1984). The descending pathway from the brain to the limbs for movement is composed of both ipsilateral and contralateral pathways. In bimanual tasks the left motor cortex will send a signal to the right hand to move, but as the signal descends, it mixes with signals from the right motor cortex telling the left hand to move, and this produces the interference effect.

Specifically, neural crosstalk affects spatial accuracy by interfering with the musculature's setting of end points. The central nervous system decides the impulse (force and duration of a muscle contraction) needed to reach a target distance. Because the movement is preprogrammed, any interference thereafter will result in deviations from the programmed movement and a failure to obtain the target distance. Of particular relevance to the current study is the fact that as peak amplitude of a movement increases, the impulse variability also increases in a linear fashion. Therefore, increases in amplitude should cause proportional increases in spatial error (Schmidt & Lee, 2011).

As a result of interference, the movements of both limbs become more similar, and error is seen. Once again, the greater the difference between end points of the limbs, the greater the assimilation effect. In the current study, a bimanual lever-positioning task is used, in which subjects attempt to move a lever a specific distance in each hand. An easy-to-difficult task progression of 15°-15°, 15°-25°, 15°-35°, 15°-55°, and 15°-65° is logical given the physiology explained previously. Each of these five conditions is coded as follows: the first number represents the target distance for the non-dominant hand, and the second number represents the target distance for the dominant hand. For example, the 15°-35° condition requires a 15° movement of the non-dominant hand and a 35° movement of the dominant hand, which are performed simultaneously. Similar to the findings of Maxwell et al. (2001) and Masters et al. (2008), my hypothesis is that the easy-to-difficult group will display better retention and transfer, which is in line with the learning paradigm that practice should gradually increase in difficulty to maximize learning.

Finally, another unique aspect of this study is the incorporation of psychological parameters. A limitation of the studies mentioned earlier is that they did not examine the role of psychological aspects on training progression. This may be a crucial key to explaining why a certain practice order is superior. Self-efficacy is the strength of one's belief that he/she will succeed in a given situation. Bandura (1977) hypothesized that the more successful a person is for a given task, the greater his/her sense of self-efficacy and competence. As a result of this enhanced self-efficacy and competence, the subject will have greater motivation and persistence, which will ultimately lead to better performance. The opposite scenario is also true: when a subject experiences a lack of success, he/she will have a lower sense of self-efficacy and competence, and worse performance will result.

The practice order of motor skills potentially has a major impact on subjects' feelings of self-efficacy and confidence. Herbert, Landin, and Solmon (2000) conducted research in which subjects learned tennis in either an easy-to-difficult progression or by practicing the criterion task. They found that students who were in the progression group had better practice quality (indicated by a higher success rate and more trials completed) and higher levels of confidence and self-efficacy.

Simpler tasks may provide a greater sense of self-efficacy, which in turn may lead to better performance (Stevens, Anderson, O'Dwyer, & Williams, 2012). Starting easy and progressing in difficulty may lead to better performance of the task due to an elevated level of self-efficacy compared to the difficult-to-easy group. Additionally, the difficult tasks may cause frustration compared to the easier tasks. In the current study, participants will be periodically questioned to gauge their sense of confidence, self-efficacy, and frustration in order to investigate the effects of underlying psychological variables. In line with Herbert et al.'s (2000) findings, my hypothesis is that an easy-to-difficult progression will result in greater confidence, which will translate into improved performance on retention and transfer tests.

Method

Participants

The participants included 24 undergraduates (age range 19-26, male n= 5, female n= 19) from the University of Colorado who were enrolled in an Integrative Physiology Statistics course. Participants received extra credit for their participation. Inclusion criteria included subjects between the ages of 18 and 40 who did not have any previous experience with the task. Subjects' handedness was determined using the Edinburgh Handedness Inventory (Oldfield, 1971). Based on this assessment, 23 subjects were right-handed and one subject was left-handed. Subjects provided participation consent through reading and signing a consent form, which had been approved by CU-Boulder's Institutional Review Board.

Apparatus

The lever apparatus was identical to the apparatus detailed in Sherwood (1994). The lever apparatus consisted of a Plexiglas platform with two slots to allow two lightweight, aluminum hand levers to move in the sagittal plane (Figure 1). The platform was affixed to a standard table top. The levers were 16 cm long and 36.5 cm apart and allowed a maximal movement of 75° in the sagittal plane, with the most proximal position called 0° and the most distal position called 75°. The path of the levers was semicircular, so that a vertical distance of 3 cm was obtained through the full range of movement. The maximal horizontal distance obtained by the levers was 22.5 cm. The levers were connected to precision potentiometers (Beckman Industrial, #3381, 10K) which gave a computer trace showing lever placement from 0° to 75°, with a measurement error of 0.1°. Subjects were blocked from seeing their visual feedback during their movements by a cloth placed over subjects' hands and arms and a cardboard barrier covering the computer monitor.

Task

Participants were instructed to move both levers simultaneously from the proximal position to a target position and return to the proximal position with no hesitation at the reversal point. Thus, for these out and back movements, target movement was reflected in the reversal point, which was also the point of peak amplitude. To achieve a simultaneous movement, subjects were instructed to have the same start time for both the non-dominant and the dominant hand. Subjects had a goal movement time (MT) of 0.7 seconds; if they were over or under by 10% of this MT, they were instructed to quicken or slow MT.

Practice was blocked into the 5 conditions of difficulty with 20 trials for each condition. The goal reversal points were (from easy to difficult): 15°-15°, 15°-25°, 15°-35°, 15°-55°, and 15°-65°, with the non-dominant hand always aiming for a 15° movement.

Procedure

The 24 subjects were randomly assigned into one of two groups: an easy-to-difficult group (*n*= 12), with the difficulty of the lever-positioning task increasing across conditions, and a difficult-to-easy group (*n*= 12), with the difficulty decreasing across conditions. Each subject completed two days in the laboratory; the acquisition phase was completed on Day 1 and the transfer and retention tests were completed on Day 2.

On Day 1, subjects were given the definition of a motor skill and a brief description of the task, after which they were asked the first confidence-assessment question: "How would you rate your ability to perform motor skills on a scale of 1-10?" They were then given a maximum of one minute to become familiar with the lever apparatus, watching the feedback from the computer monitor to associate movement with degree angle.

After one minute of practice time, they began the acquisition phase in either the easy-to-difficult progression or the difficult-to-easy degression. After each trial, participants were given visual feedback by looking at their computer trace, where they could easily see the amplitude of their movement for both hands (Figure 2). After each condition, subjects were asked a series of four confidence-assessment questions to evaluate their sense of self-efficacy and confidence: "How would you rate your ability to perform motor skills on a scale of 1-10?," "On a scale of 1-10, how confident are you in your ability to complete an easier task?", "On a scale of 1-10, how confident are you in your ability to complete a more difficult task?", "On a scale of 1-10, how would you rate your frustration on the last set of practice?" These questions between conditions additionally served as brief rest periods to prevent muscle fatigue.

After all conditions were complete, subjects were told that they would complete a transfer and retention test on Day 2 and were given a brief definition of each test type. Afterwards, they answered the last confidence-assessment question: "On a scale of 1-10, how well do you feel you'll be able to remember these movements when you come in again for a retention test?"

On Day 2, subjects performed both a retention and transfer test to evaluate motor learning. The retention test consisted of 15 trials of 15°-35° movements. Subjects did not receive immediate performance feedback. Only after completing the retention test were they allowed to view their performance on the last five trials. Afterwards the transfer test was completed, which consisted of 15 trials of 15°-45° movements. Once again, participants did not receive feedback until completion of the trials, which added to the stress of the testing environment.

Data Analysis

From the computer trace for the subjects, peak amplitude of movement (measured in degrees) and movement time (measured in seconds and defined as the initiation of the movement from the 0° proximal position to the return of the lever to the proximal position) for each trial were determined (Figure 2). From these, average MT, standard deviations (SD), constant error (CE), and overall error (E) were calculated for each condition and test. Error occurred when there was undershooting or overshooting of the target reversal point. CE is the average overshooting or undershooting of the movement and E is the standard deviation of the responses relative to the target distance. Mixed 2 (group) x 5 (condition) x 2 (hand) ANOVAs with repeated measures on condition and hand were used to find statistical significance. For analysis of the questions asked during acquisition, individual Group (2) x Condition (5) ANOVAs were performed, with the exception of the final question, which was a between-subjects ANOVA by group (2). Any significant interactions were explored using post-hoc comparisons (least significant difference tests).

Results

Acquisition Phase

Movement Time

During the acquisition phase, there was no significant difference between the movement times of either group: the easy-to-difficult group's average movement time was 0.507 seconds and the difficult-to-easy group's average movement time 0.530 seconds. As the spatial target difference between both hands increased, so did the movement time (Figure 3). The Condition x Hand interaction was significant [$F(4, 88) = 45.6$, $p < .001$]. The post-hoc analysis showed differences at the following conditions: 15°-25°, 15°-35°, 15°-55°, and 15°-65° ($p < .05$).

Constant Error

Figure 4 shows the CE for the non-dominant hand for both groups. There was more overshooting in the difficult-to-easy group in the 15°-65° condition and there was more overshooting in the easy-to-difficult group in the 15°-15° and 15°-25° conditions. For the dominant hand (Figure 5), there was more undershooting of the 15°-65° condition in the difficult-to-easy group. These two figures show a three-way interaction of Condition x Group x Hand [$F(4, 88) = 14.9$, $p < .001$]. The post-hoc analysis showed that the practice groups were significantly different in the 15°-15°, 15°-25°, and 15°-65° conditions for the non-dominant hand ($p < .05$). For the dominant hand, there was a significant difference between groups in the 15°-65° condition ($p < .05$). Generally, the absolute value of constant error increased over the conditions, which confirms a true progression. Additionally, both Figure 4 and Figure 5 confirm an assimilation effect: as the interlimb target difference increased, the non-dominant hand increased overshooting and the dominant hand increased undershooting.

Overall Error

Figure 6 shows the non-dominant hand E for both groups. The difficult-to-easy group had greater variability of the 15°-65° condition, whereas the easy-to-difficult group had greater variability of the 15°-15° condition. Figure 7 shows the dominant hand E for both groups. The difficult-to-easy group had greater variability of the 15°-65° condition. There was a three-way interaction of Condition x Hand x Group [$F(4, 88) = 3.47$, $p < .05$]. The post-hoc analysis showed that for the non-dominant hand, there was a significant difference between groups for the 15°-15° and 15°-65° conditions ($p < .05$). This result suggests that when participants begin their first condition of practice, they are prone to greater error and variability. In the dominant hand, there was a significant difference in the 15°-65° condition ($p = .001$).

Questions

"Rate your ability to perform motor skills": The ratings for the pre-question in both groups were higher than the ratings following the five conditions, indicating an overall drop of confidence after beginning the task (Figure 8). Additionally, the difficult-to-easy group showed a higher initial sense of confidence than the easy-to-difficult group. The ANOVA revealed a significant effect of condition [$F(5, 110) = 6.98$, $p < .001$]. The post-hoc analysis did not show a difference between groups, but the pre-question rating was significantly higher than the rest of the conditions.

"How confident are you in your ability to complete an easier task?": Figure 9 shows that in general, confidence tended to increase for both groups after performing the first condition, though the easy-to-difficult group had a greater sense of confidence for the majority of practice conditions compared to the difficult-to-easy group. There was an interaction of Group x Condition [$F(4, 88) = 2.9$, $p < .05$]. Post-hoc analysis showed that there was significance at the 15°-65° condition between groups ($p < .05$).

"How confident are you in your ability to complete a more difficult task?": Figure 10 shows that as task difficulty increased, confidence decreased. The ANOVA confirmed this effect of condition [$F(4, 88) = 2.78$, $p < .05$]. The post-hoc tested showed that the first condition (15°-15°) was significantly different from the final condition (15°-65°).

"How would you rate your frustration on the last set of practice?": Figure 11 shows a trend that as task difficulty increased, frustration also increased. However, there was no significant effect of condition.

"How well do you feel you'll be able to remember these movements when you return for a retention test?": Figure 12 shows that the difficult-to-easy group rated higher on this last

confidence-assessment question. The ANOVA showed that there was a significant difference between groups [$F(1, 22)= 4.6$, $p < .05$].

Retention Testing

Movement Time

Figure 13 shows that both groups had similar movement times, though the easy-to-difficult group may have had slightly greater MT with the dominant hand. There was a Hand x Group interaction [$F(1,22)= 6.25$, $p < .05$], but the post-hoc test was not powerful enough to detect the difference.

Constant Error

The easy-to-difficult group tended to overshoot the movements, whereas the difficult-to-easy group tended to undershoot the movements (Figure 14). There was a significant interaction of Hand x Group [$F(1, 22)= 6.78$, $p < .05$]. The post-hoc test showed that for the non-dominant hand, the easy-to-difficult group had significantly greater error ($p < .05$). For the dominant hand, the difficult-to-easy group had significantly greater error ($p < .05$).

Overall Error

Figure 15 shows that the easy-to-difficult group had greater variability for the non-dominant hand, whereas the difficult-to-easy group had slightly greater variability for the dominant hand. Additionally, the dominant hand experienced much greater E than the non-dominant hand for both groups. An ANOVA revealed an effect of hand [$F(1, 22)= 27.7$, $p < .001$]. There was no significant difference between groups.

Transfer Testing

Movement Time

Figure 16 indicates that both groups had similar movement times, although the difficult-to-easy group was slightly slower for the non-dominant hand. Though there was a Hand x Group interaction [$F(1,22) = 4.45$, $p < .05$], the post-hoc test was not strong enough to detect the difference.

Constant Error

For both the non-dominant and the dominant hand, the difficult-to-easy group had greater error, though there was only a detectable difference for the dominant hand (Figure 17). An ANOVA showed a Hand x Group interaction [$F(1,22) = 5.53$, $p < .05$] and a post-hoc analysis revealed that the difficult-to-easy group performed significantly worse with the dominant hand than the easy-to-difficult group ($p < .05$).

Overall Error

Figure 18 shows that the difficult-to-easy group had greater overall error during the transfer test and that there was a great deal of difference between the E of the non-dominant and the dominant hand. There was a significant effect of hand [$F(1,22) = 23.88$, $p < .001$], but the initial ANOVA did not show an effect of group.

Discussion

Manipulation of task difficulty was shown to be effective, as indicated in the results of error during acquisition. As the interlimb difference in target distance increased, so did constant error and overall error. The only exception to this trend was only minor changes in error for the 15°-15°, 15°-25°, and 15°-35° conditions. This can be explained due to observations made by Sherwood (1994) that spatial assimilation effects are only observed in tasks in which the interlimb difference is greater than 20° in end location. Nevertheless, the physiology is undeniable that the greater the difference between limb targets, the greater the interference. Therefore, the interference effect for the 15°-25° and 15°-35° conditions was too minimal to be differentiated from the 15°-15° condition, though there was in fact an increase in interference.

There was no difference in movement times between the easy-to-difficult and the difficult-to-easy groups, which additionally served to control the difficulty level for both groups. Another indication of sound study design was the appearance of an assimilation effect as described by Marteniuk et al. (1984) and Sherwood (1994) during acquisition.

During acquisition, both groups showed positive transfer effects. For both the non-dominant and the dominant hand, the easy-to-difficult group had greater error for their first condition (15°-15°) compared to the reverse group. Similarly, the difficult-to-easy group had greater error for their first condition (15°-65°) compared to the opposite group. So initially, both groups began with greater error but improved performance across conditions, ultimately performing better on their final condition relative to the opposite group. These positive transfer effects indicate a positive effect of practice and increased learning, though transfer and retention tests are a better indicator of motor learning.

The results on which practice order is most efficient for motor learning are mixed, with advantages seen for both progressions and degressions. The retention test was especially mixed, with benefits seen for both groups depending on hand. However, the easy-to-difficult group demonstrated slightly better retention due to much less CE of the dominant hand (Figure 14). Both practice orders resulted in transfer of the motor task, but greater transfer was witnessed for the easy-to-difficult group, which performed with significantly less CE and a trend of less E.

These results support the hypothesis that an easy-to-difficult progression leads to improved retention and transfer, and both support and refute previous study results. Maxwell et al. (2001) saw better performance on both retention and transfer for the progressive group for a gross, bimanual task. Masters et al. (2008) found that the progressive group performed better on a transfer test compared to the degressive group for a gross, bimanual task. Finally, Sanli (2013) found results contrary to the current study: the progressive group performed worse on transfer but had no difference on retention for a fine-motor, unimanual task. Because my research question is unique in the sense that a fine-motor, bimanual task was studied with movement complexity as the difficulty variable, it is plausible for these particular tasks that an easy-to-difficult progression is better for retention and transfer.

It was also hypothesized that an easy-to-difficult progression would result in a greater sense of confidence and self-efficacy in participants, which would translate into better performance. The results from the questions asked throughout the study are mixed, with one group showing greater confidence in some questions and the other group showing greater confidence in other questions. The graphs for both groups had similar slopes (rates of change) across conditions for each question. Therefore, because it appears that both groups experienced about the same change in confidence, it seems that an easy-to-difficult progression does not mean a greater sense of confidence, which is contrary to my hypothesis.

Though there was no substantial difference between groups as far as confidence levels, the data showed a clear trend that as task difficulty increased, confidence in motor ability and confidence in performance decreased, while frustration increased. This provides an explanation for the difficult-to-easy group's greater confidence in their ability to perform on a retention test

(Figure 12). Because they finished with the easiest task, they ended with greater confidence compared to the easy-to-difficult group, which ended with the most difficult task.

The effects of task difficulty on confidence and frustration and subsequent performance poses an interesting question. An aspect of the current study that may be improved upon in future studies is the quantifying of true confidence levels. For instance, when asked the questions "How confident are you in your ability to complete an easier task?" and "How confident are you in your ability to complete a more difficult task?" the participants in each group switched so that the easy-to-difficult group rated higher in one question (easier), but the difficult-to-easy group rated higher in the other question (more difficult; Figure 9 and Figure 10). Because the two questions are very similar and were meant to assess confidence, one group should have rated higher for both questions. Therefore, if one can find a way to better assess subjects' confidence levels, it would be easier to determine whether confidence explains why one practice order is superior. One option is to use confidence inventories, but they are general and not designed for very specific motor tasks, like lever-positioning. Another option is to simplify the scale used. For instance, subjects may be asked to rate their confidence levels as "very low, low, average, high, or very high." Using this simple scale may lead to a better depiction of participants' confidence.

As mentioned previously, the fact that both groups had similar levels of confidence could not explain why the easy-to-difficult group showed greater retention and transfer. Instead, this phenomenon may be explained due to what researchers have termed implicit learning (Maxwell et al., 2001; Masters et al., 2008; Sanli, 2013). Implicit learning is incidental learning of a task, in which cognition is low enough that the learner is unaware of new knowledge. This is the opposite of explicit learning, which is a cognition-intensive process that involves greater utilization of working memory and attention. It is believed that when a task is learned implicitly, the learner is able to easily recollect information in stressful situations (Masters et al., 2008). If a task is learned explicitly, then the learner may revert to conscious thought and “choke” under stressful situations. According to Maxwell et al. (2001) and Masters et al. (2008) an easy-to-difficult progression results in implicit learning of a new motor skill, whereas a difficult-to-easy degression results in explicit learning of a new motor skill. When undergoing a retention and transfer test, the easy-to-difficult group should not have a problem with the task, whereas the difficult-to-easy group may “choke” under these stressful situations. The results from the current experiment support this explanation. A stressful testing environment for retention and transfer was created by not allowing subjects to see their feedback, so they were unaware of their performance and unable to correct errors, despite the apparent importance of these tests.

In conclusion, it appears that an easy-to-difficult progression results in greater retention and transfer of a motor skill and thus superior motor learning, though there are benefits for both practice orders on retention. Both practice orders resulted in similar levels of confidence, so confidence does not appear to be a factor for the greater performance of the easy-to-difficult group. Therefore, the most likely explanation for the results from the current study is that easy-to-difficult groups learn implicitly (resulting in greater retention and transfer under a stressful situation), whereas difficult-to-easy groups learn explicitly (resulting in less retention and transfer under a stressful situation).

References

Ammons, R. B., Ammons, C. H., & Morgan, R. L. (1956). Transfer of skill and decremental factors along the speed dimension in rotary pursuit. *Perception and Motor Skills, 6,* 43.

Andreas, B. G., Green, R. F., & Spragg, S. D. S. (1954). Transfer effects between performance on a following (modified SAM two-hand co-ordination test) and a compensatory tracking task (modified two-hand pursuit test). *Journal of Psychology, 37*, 173-83

Baker, K. E., Wylie, R. C., & Gagné, R. M. (1950). Transfer of training to a motor skill as a function of *variation* in rate response. *Journal of Experimental Psychology, 40,* 721-32

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84,* 191-215.

Barch, A. M. (1953). The effect of difficulty of task on proactive facilitation and interference. *Journal of Experimental Psychology, 48,* 37-42.

Barch, A. M. & Lewis, D. (1954).The effect of task difficulty and amount of practice on proactive transfer. *Journal of Experimental Psychology, 48,* 134-42.

Briggs, G. E. & Waters, L. E. (1958). Training and transfer as a function of component interaction. *Journal of Experimental Psychology, 56*, 492-500.

Browne, R. C. (1954). Figure and ground in a two-dimensional display. *Journal of Applied Psychology, 38*, 462-7.

Gerall, A. A. & Green, R. F. (1958). Effect of torque changes upon a two-handed co-ordination task. *Perception and Motor Skills, 8*, 287-90.

Gibbs, C. B. (1951). Transfer of training and skill assumptions in tracking. *Quarterly Journal of Experimental Psychology, 3*, 99-110.

Gibbs, C. B. (1954). The continuous regulation of skilled response by kinesthetic feedback. *British Journal of Psychology, 45*, 24-39.

Green, R. F. (1955). Transfer of skill on a following tracking task as a function of task difficulty. *Journal of Psychology, 39*, 355-70.

Green, R. F., Goodenouge, D. R., Andreas, B. G., Gerall, A. A., & Spragg, S. D. S. (1955). The effects of phases of rotation and control cranks on performance levels and transfer effects in compensatory and following tracking. *U.S. Specdevcen.* No. 241-6-22.

Herbert, E. P., Landin, D., & Solmon, M. A. (2000). The impact of task progressions on students' practice quality and task-related thoughts. *Journal of Teaching in Physical Education*, *19,* 338-354.

Holding, D. H. (1962). Transfer between easy and difficult tasks. *British Journal of Psychology*, *53*, 397-407.

Holland, J. G. & Henson, J. B. (1956). Transfer of training between quickened and unquickened tracking systems. Washington, *N.R.L. Representative*, No. 4703.

Jones, E. I. & Bilodeau, E. A. (1952). Differential transfer of training between motor tasks of different difficulty. *H.R.R.L. Bull*, No 52-35.

Kaestner, N. F. & Grant, D. A. (1956). Transfer of training in tracking as a function of the predictability of uni-dimensional target courses. *Journal of General Psychology*, *55*, 103-16.

Levine, M. (1953). Transfer of tracking performance as a function of a delay between the control and the display. *W.A.D.C. Technical Report*, No. 52-237.

Lincoln, R. S. & Smith, K. U. (1951). Transfer of training in tracking performance at different target speeds. *Journal of Applied Psychology*, *35*, 358-62.

Lordahl, D. S. & Archer, E. J. (1958). Transfer effects on a rotary pursuit task as a function of first task difficulty. *Journal of Experimental Psychology, 56*, 421-6.

Maltzman, I., Smith, W. M., & Brooks, L. O. (1955). Some effects of different training conditions and manifest anxiety upon target tracking. *Perception and Motor Skills, 4*, 185-91.

Marteniuk, R. G., MacKenzie, C. L., & Baba, D. M. (1984). Bimanual movement control: Information processing and interaction effects. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 3,* 335-365.

Masters, R. S. W., Poolton, J. M., & Maxwell, J. P. (2008). Stable implicit motor processes despite aerobic locomotor fatigue. *Consciousness and Cognition, 17 (1),* 335-338.

Maxwell, J.P., Masters, R.S.W., Kerr, E., & Weedon, E. (2001). The implicit benefit of learning without errors. *Quarterly Journal of Experimental Psychology*, *54A,* 1049-1068.

Morin, R. E. (1951). Transfer of training between motor tasks varying in precision of movement required to score. *American Psychologist, 6*, 390 (Abstract).

Muckler, F. A. & Matheny, W. G. (1954). Transfer of training in tracking as a function of control friction. *Journal of Applied Psychology*, *38,* 364-7.

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, *9*(1), 97-113.

Sanli, E. A. (2013). *The role of minimization and facilitation of learner involvement during acquisition in the learning of a motor task*. Unpublished doctoral dissertation, McMaster University, Hamilton, ON, Canada.

Schmidt, R. A. & Lee, T. D. (2011). *Motor Control and Learning: A Behavioral Emphasis (5th ed.)*. Champaign, IL: Human Kinetics Publishers.

Sherwood, D. E. (1994). Interlimb amplitude differences, spatial assimilations, and the temporal structure of rapid bimanual movements. *Human Movement Sciences, 13*, 841-860.

Stevens, D., Anderson, D. I., O'Dwyer, N. J., & Williams, A. M. (2012). Does self-efficacy mediate transfer effects in the learning of easy and difficult motor skills? *Conscious. Cogn. 21*, 1122–1128.

Szafran, J. & Welford, A. T. (1950). On the relation between transfer of difficulty of initial task. *Quarterly Journal of Experimental Psychology*, *2*, 88-94.

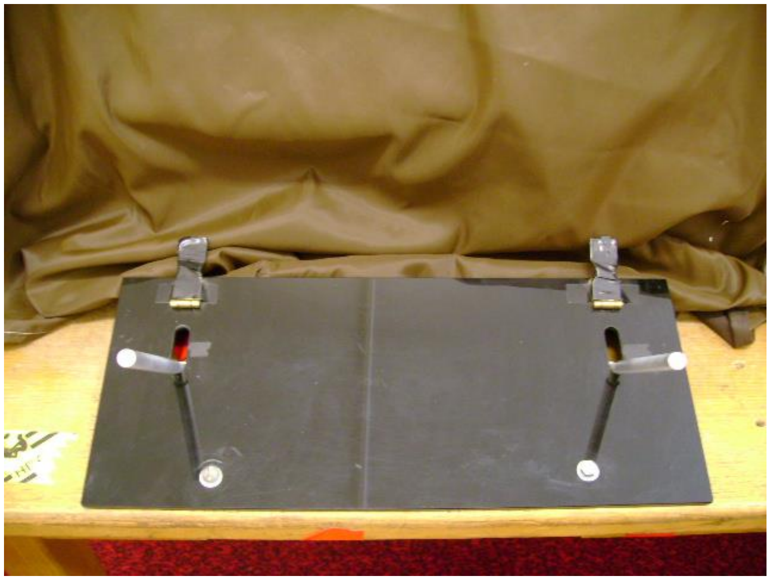

Figure 1. The lever apparatus.

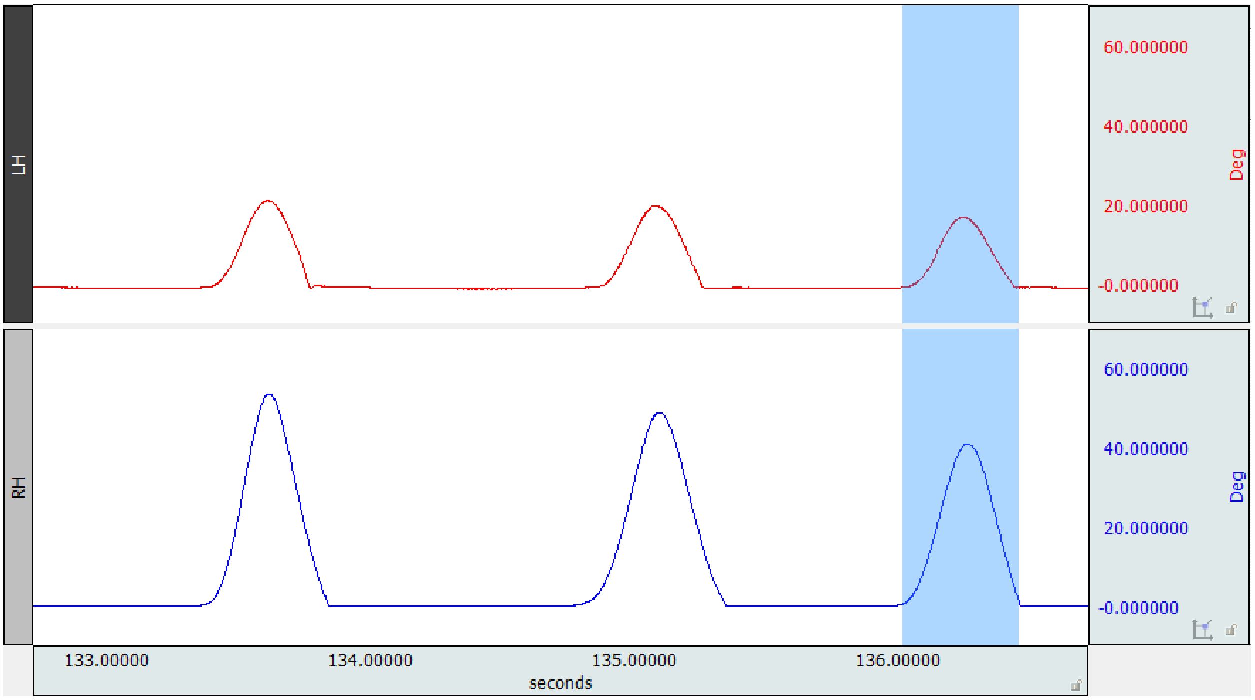

Figure 2. A computer trace of three trials. The top window displays the left hand and the bottom window displays the right hand. Seconds are given along the bottom of the screen, and the degrees are shown along the right of the screen. A single trial is highlighted in light blue. From these computer traces, movement time and peak amplitude were collected for each trial. From peak amplitude, constant error and overall error were calculated.

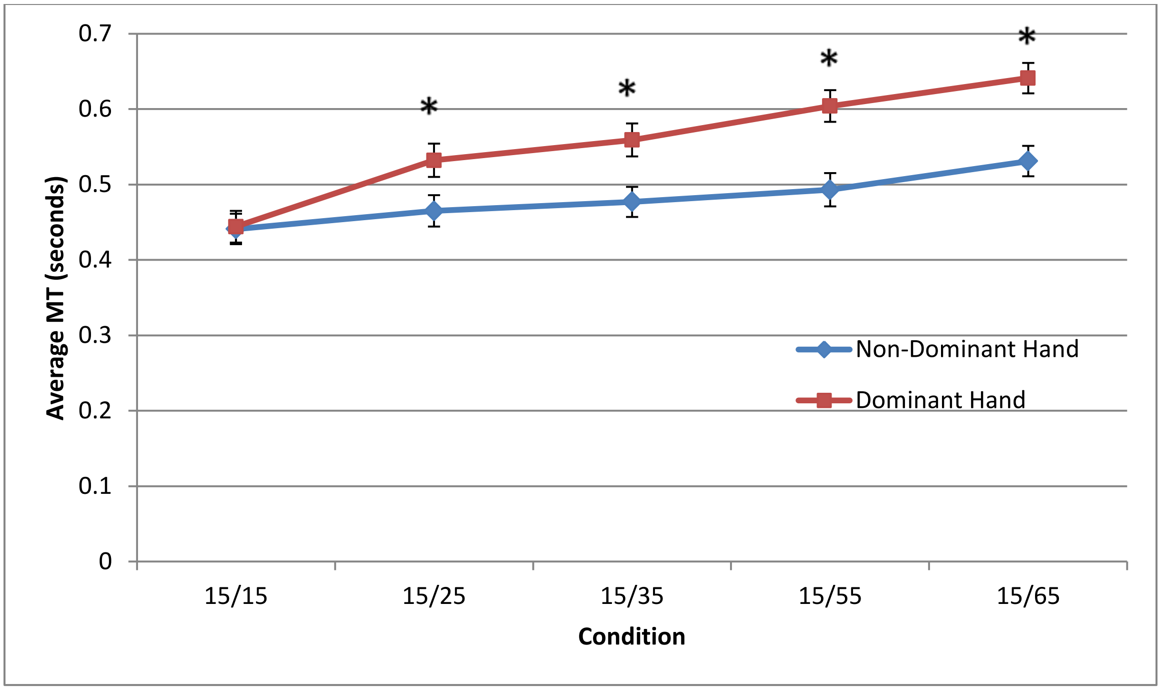

Figure 3. Acquisition phase average movement time (MT; ±*SE*) for both hands across the various conditions. As the spatial target difference between both hands increased, so did the movement time. The post-hoc analysis showed differences of hand MT at the following conditions (indicated with an *): 15°-25°, 15°-35°, 15°-55°, and 15°-65° ($p < .05$).

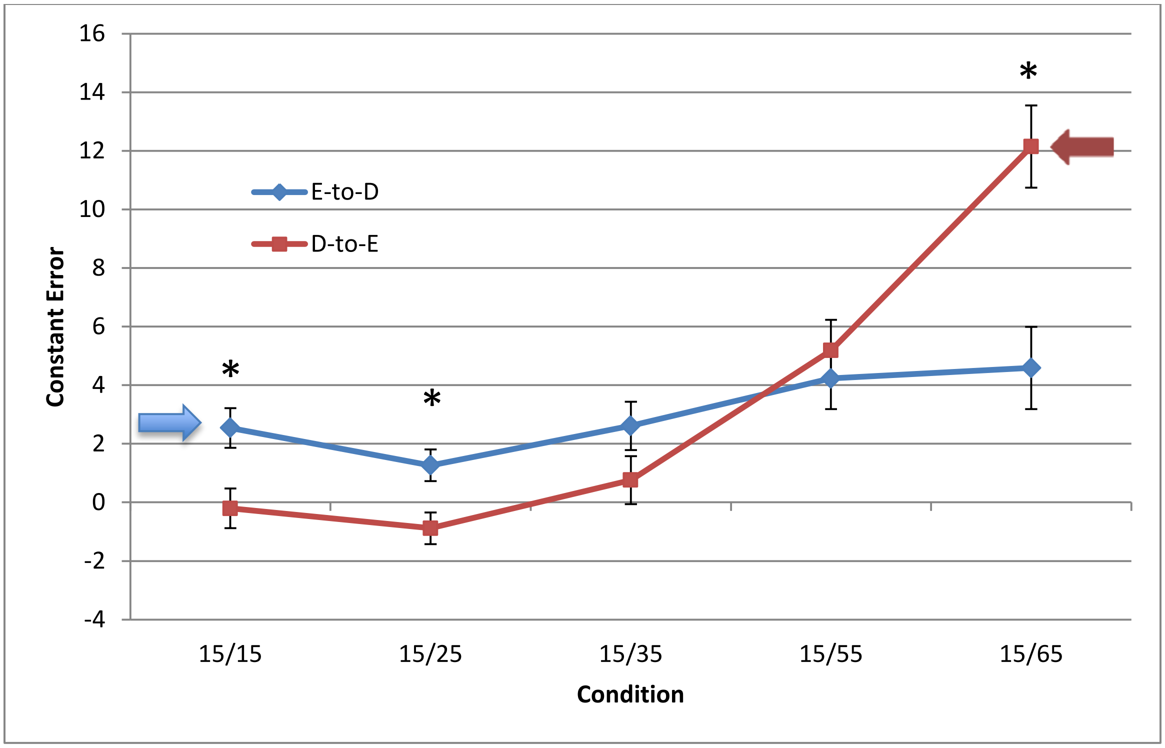

Figure 4. Acquisition phase, non-dominant hand constant error (±*SE*) for easy-to-difficult (E-to-D; $n = 12$) and difficult-to-easy (D-to-E; $n = 12$) groups in various conditions. There was a significant difference between groups at the 15°-15°, 15°-25°, and 15°-65° conditions ($p < .05$, indicated with an *). Arrows indicate the order of the conditions for each group.

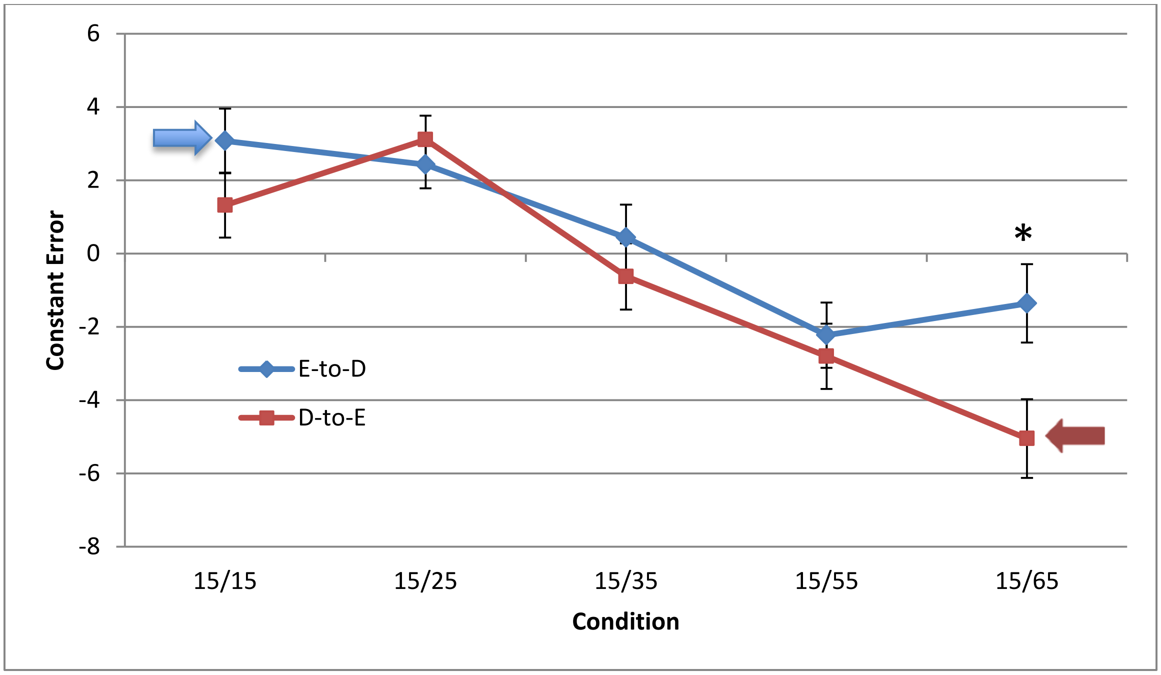

Figure 5. Acquisition phase, dominant hand constant error (±*SE*) for easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups in various conditions. There was a significant difference between groups at the 15°-65° condition (*p* <.05, indicated with an *). Arrows indicate the order of the conditions for each group.

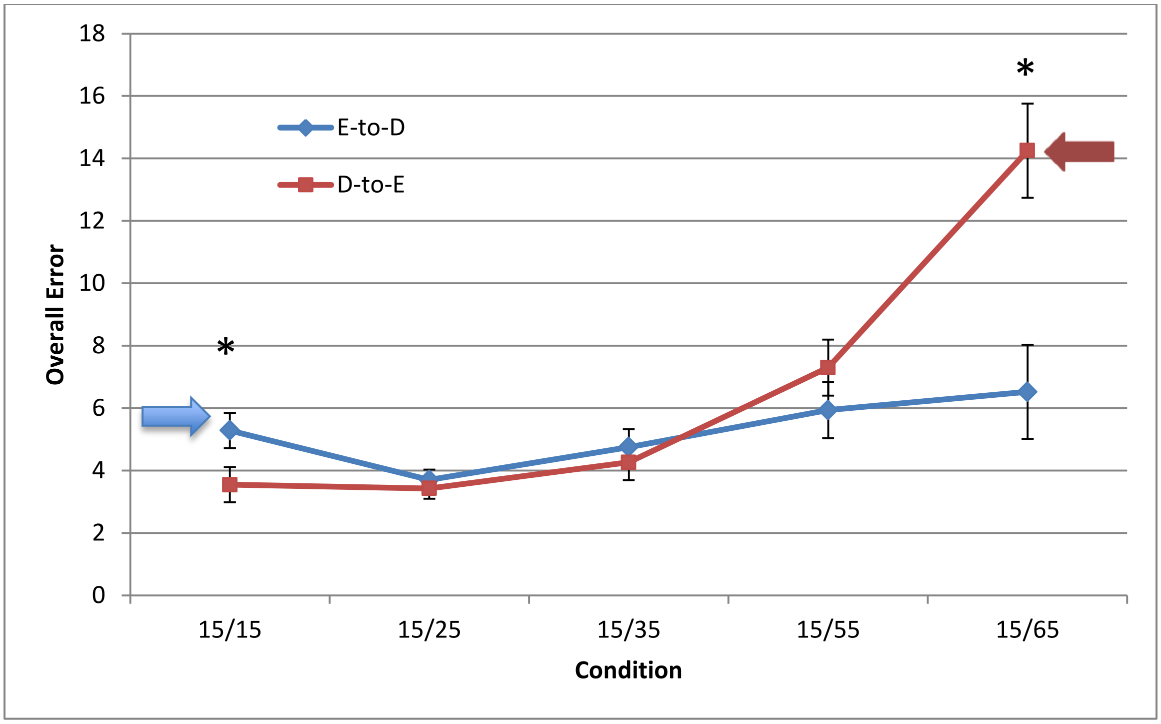

Figure 6. Acquisition phase, non-dominant hand overall error (±*SE*) for easy-to-difficult (E-to-D; $n = 12$) and difficult-to-easy (D-to-E; $n = 12$) groups in various conditions. There was a significant difference between groups at the 15°-15° and 15°-65° conditions ($p < .05$, indicated with an *). Arrows indicate the order of the conditions for each group.

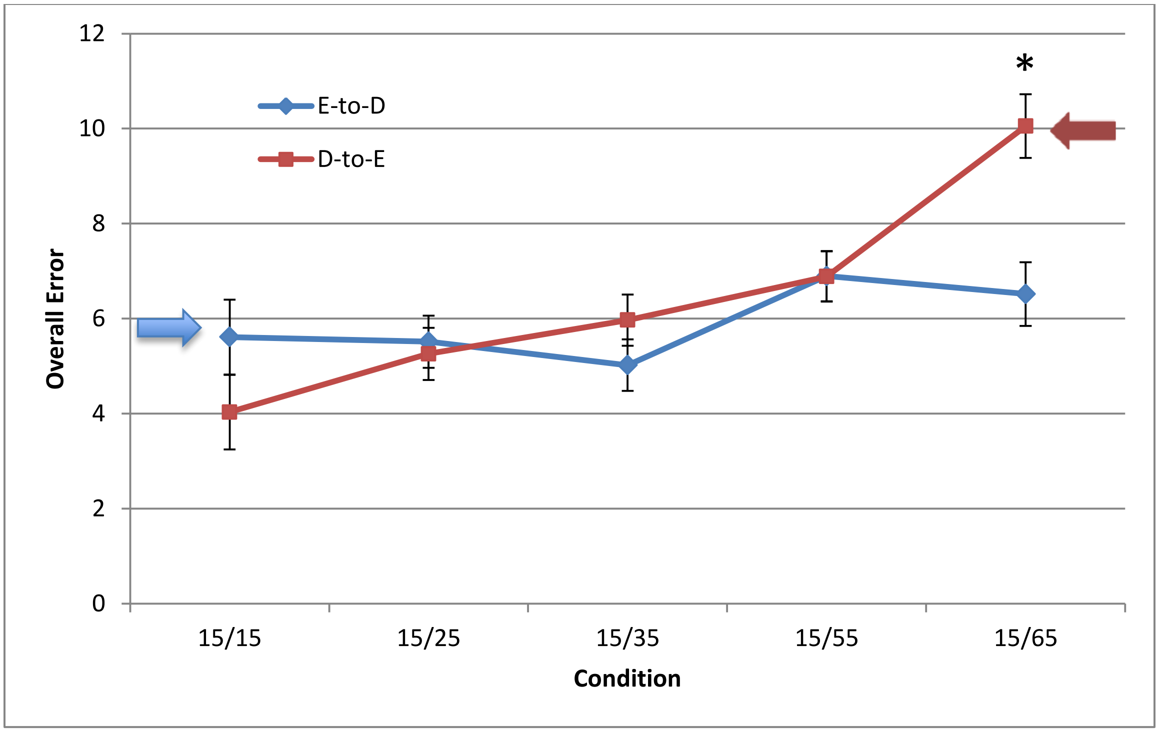

Figure 7. Acquisition phase, dominant hand overall error (±*SE*) for easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups in various conditions. There was a significant difference between groups at the 15°-65° condition (*p* <.05, indicated with an *). Arrows indicate the order of the conditions for each group.

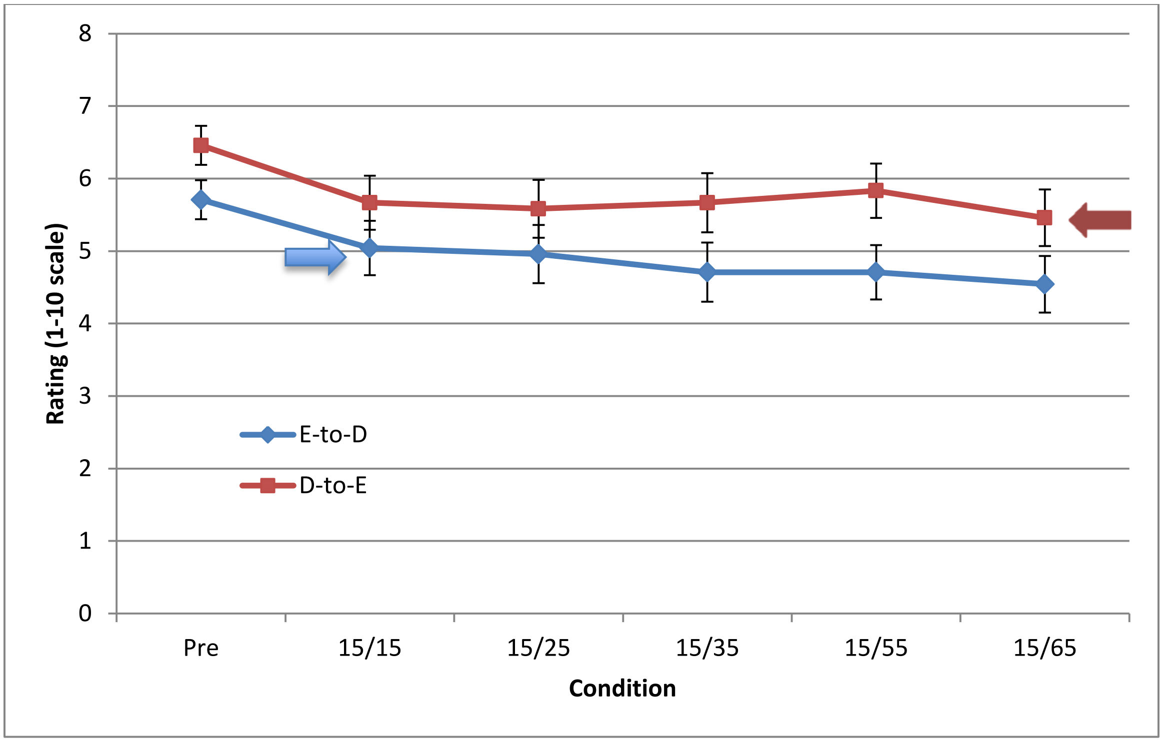

Figure 8. Ratings (±*SE*) given by the easy-to-difficult (E-to-D; n = 12) and difficult-to-easy (D-to-E; n = 12) groups before training and after various conditions in response to the question: "How would you rate your ability to perform motor skills on a scale of 1-10? 1 being far worse than most people, 5 being average, and 10 being far better than most people." The pre-question was significantly different from all of the other blocks ($p < .05$). Arrows indicate the order of the conditions for each group.

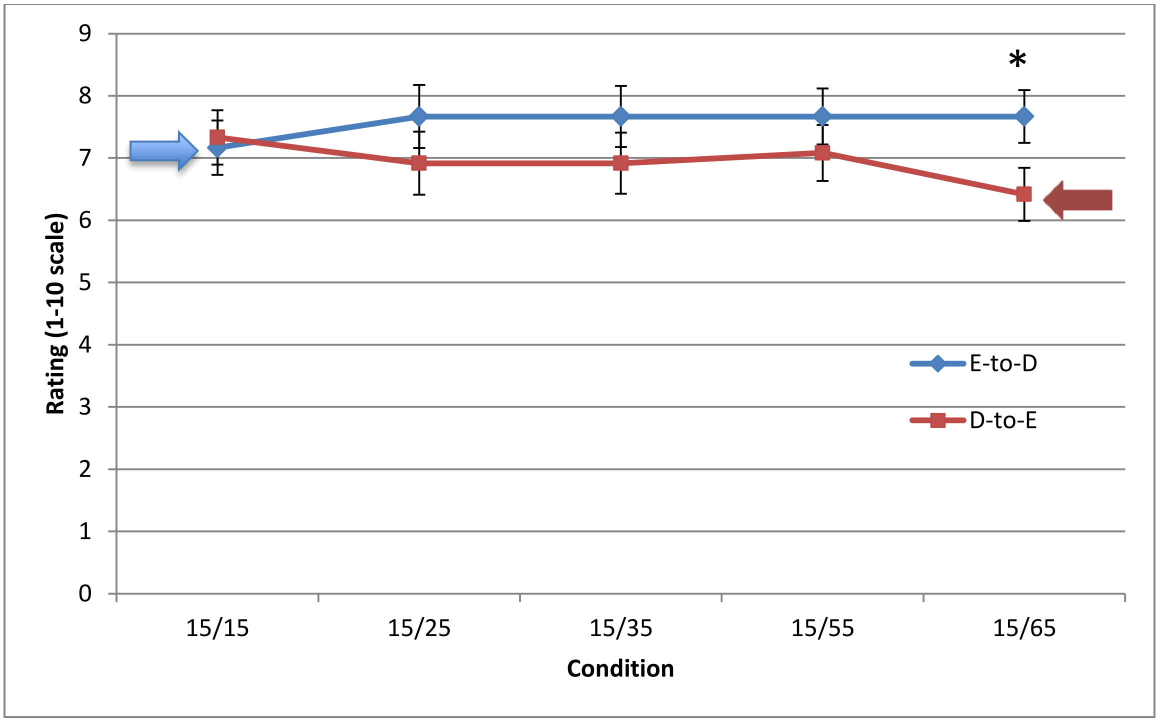

Figure 9. Ratings (±*SE*) given by the easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups after various conditions in response to the question: “On a scale of 1-10, how confident are you in your ability to complete an easier task? 1 being not at all confident, 5 being fairly confident, and 10 being completely confident?” The groups differed significantly at the 15°-65° condition ($p < .05$, indicated with an *). Arrows indicate the order of the conditions for each group.

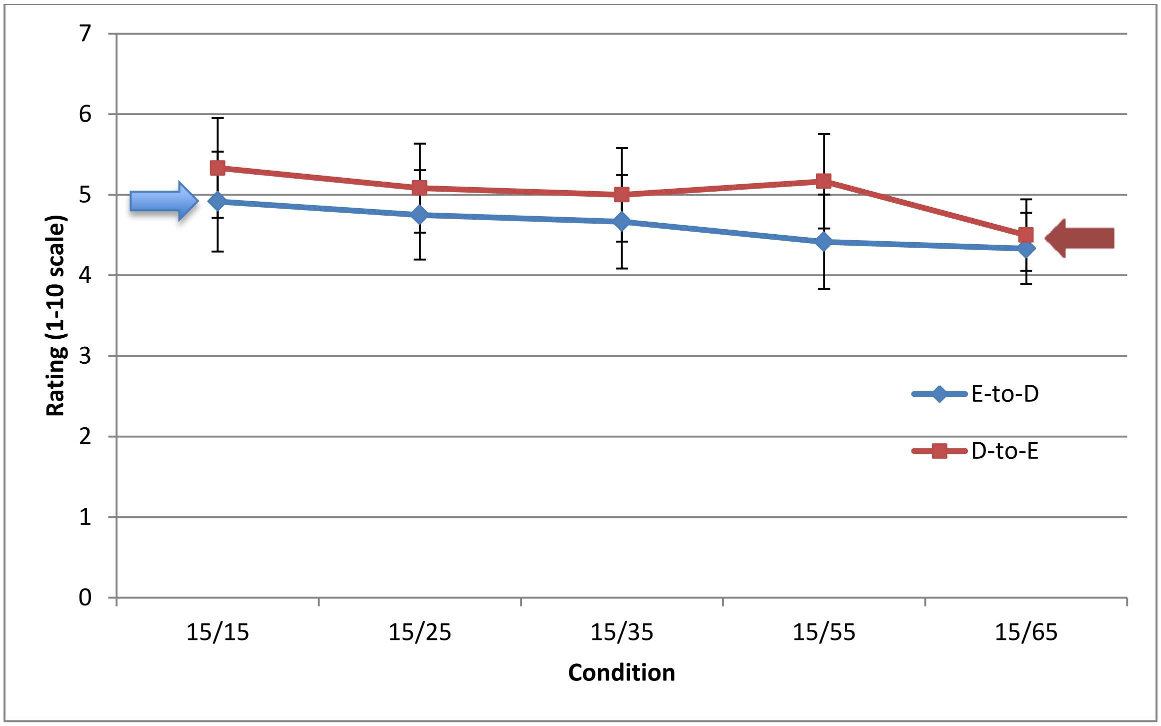

Figure 10. Ratings (±*SE*) given by the easy-to-difficult (E-to-D; $n = 12$) and difficult-to-easy (D-to-E; $n = 12$) groups after various conditions in response to the question: "On a scale of 1-10, how confident are you in your ability to complete a more difficult task? 1 being not at all confident, 5 being fairly confident, and 10 being completely confident?" There was no significant difference between groups, but the responses to the 15°-15° condition were significantly different from the responses to the 15°-65° condition ($p < .05$). Arrows indicate the order of the conditions for each group.

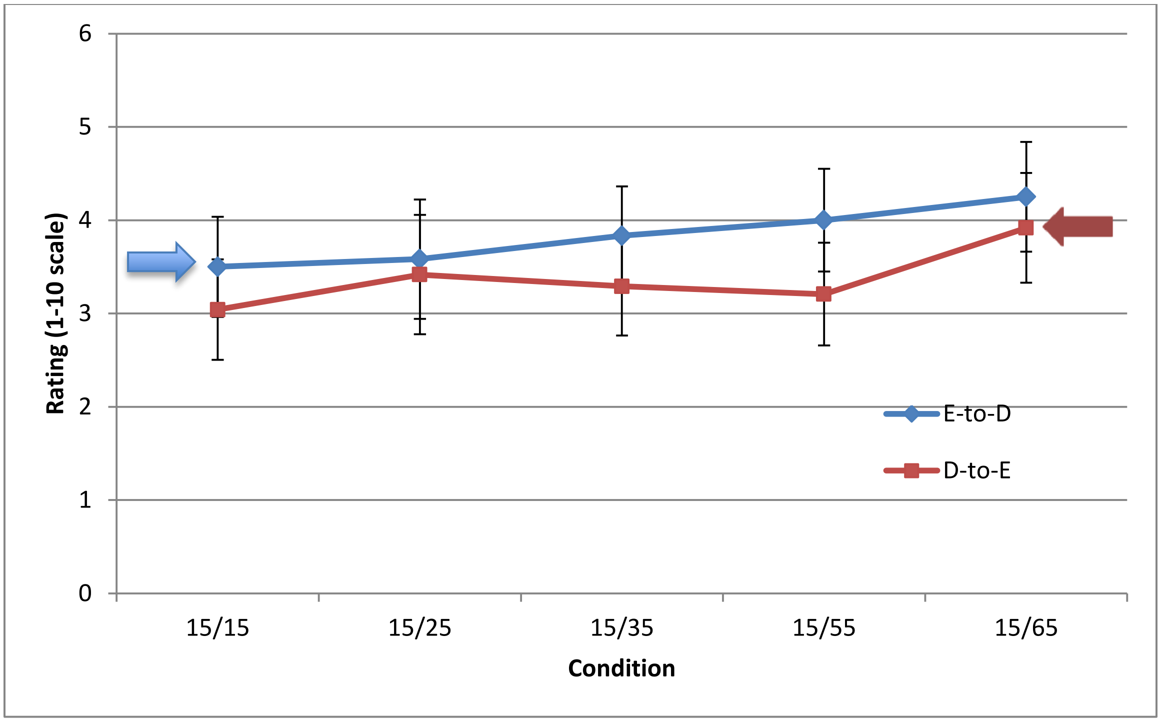

Figure 11. Ratings (±*SE*) given by the easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups after various conditions in response to the question: "On a scale of 1-10, how would you rate your frustration on the last set of practice? 1 being not at all frustrated, 5 being average frustration, and 10 being extremely frustrated." There was no significant effect of condition or group. Arrows indicate the order of the conditions for each group.

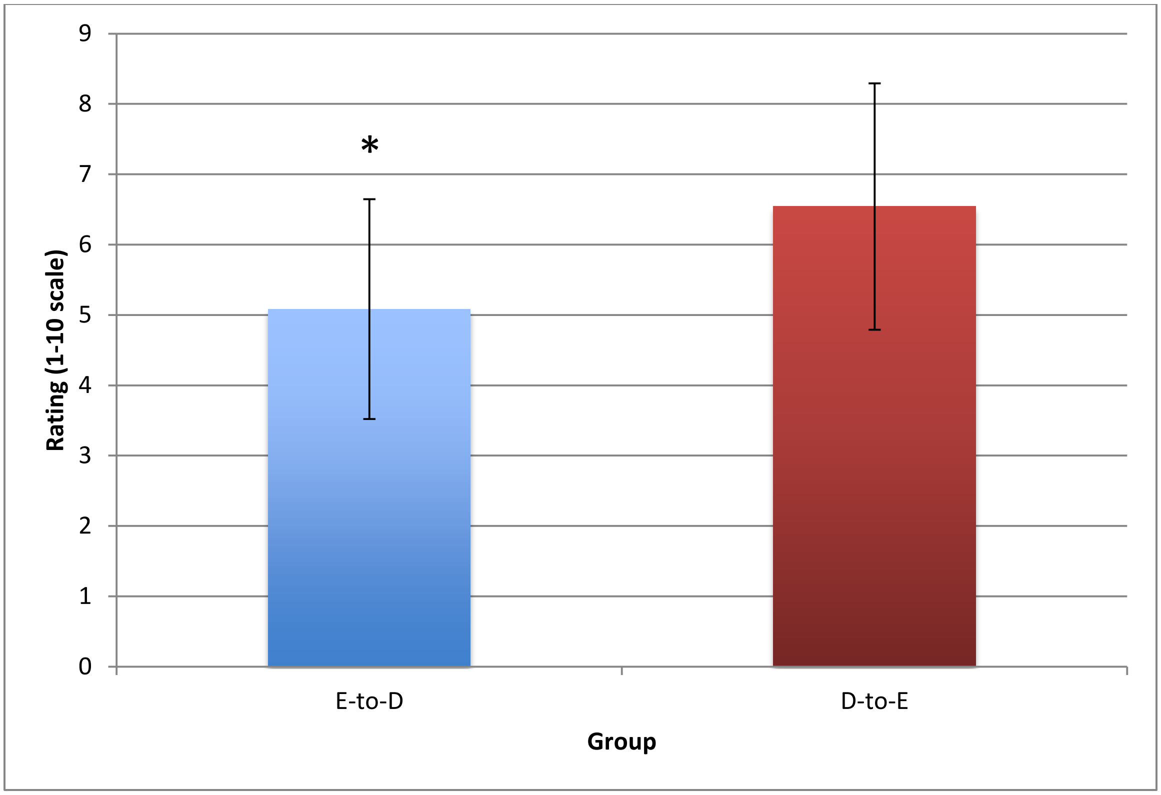

Figure 12. Ratings (±*SE*) given by the easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups after completion of acquisition in response to the question: “On a scale of 1-10, how well do you feel you’ll be able to remember these movements when you come in again for a retention test? 1 being my retention will be poor and 10 being my retention will be excellent?” There was a significant difference between groups, with the difficult-to-easy group showing a greater level of confidence (p <.05, indicated with an *).

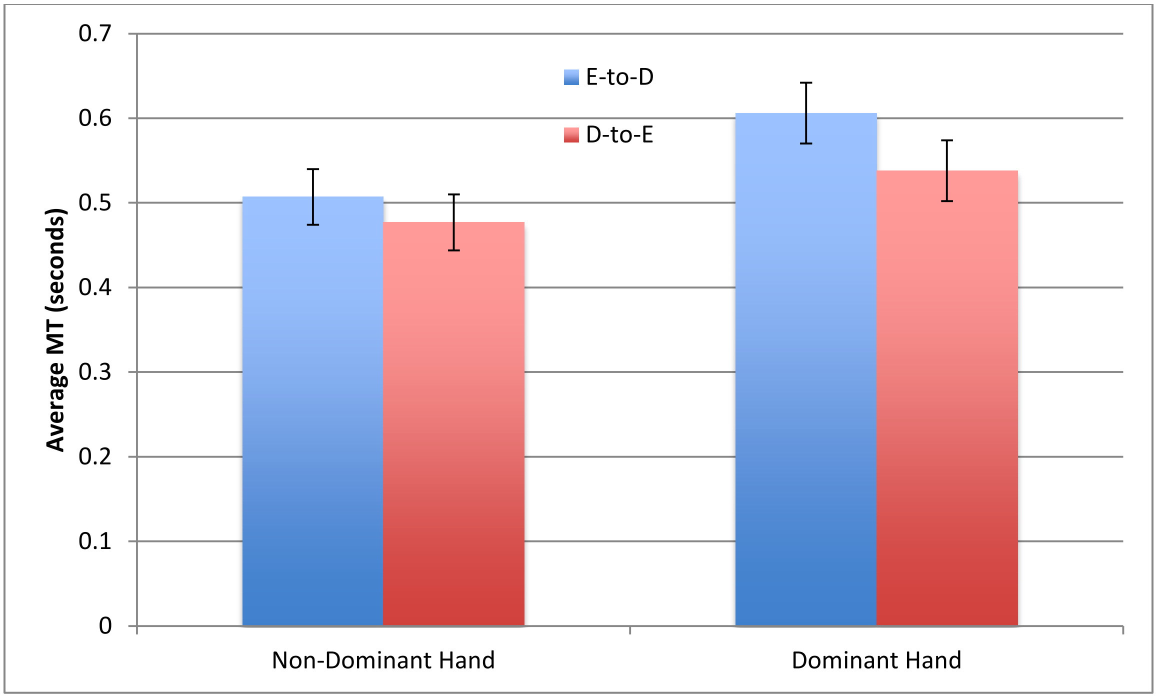

Figure 13. Retention test average movement time (MT; ±*SE*) for easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups with both hands. There was a Hand x Group interaction, but the post-hoc test was not powerful enough to show the difference.

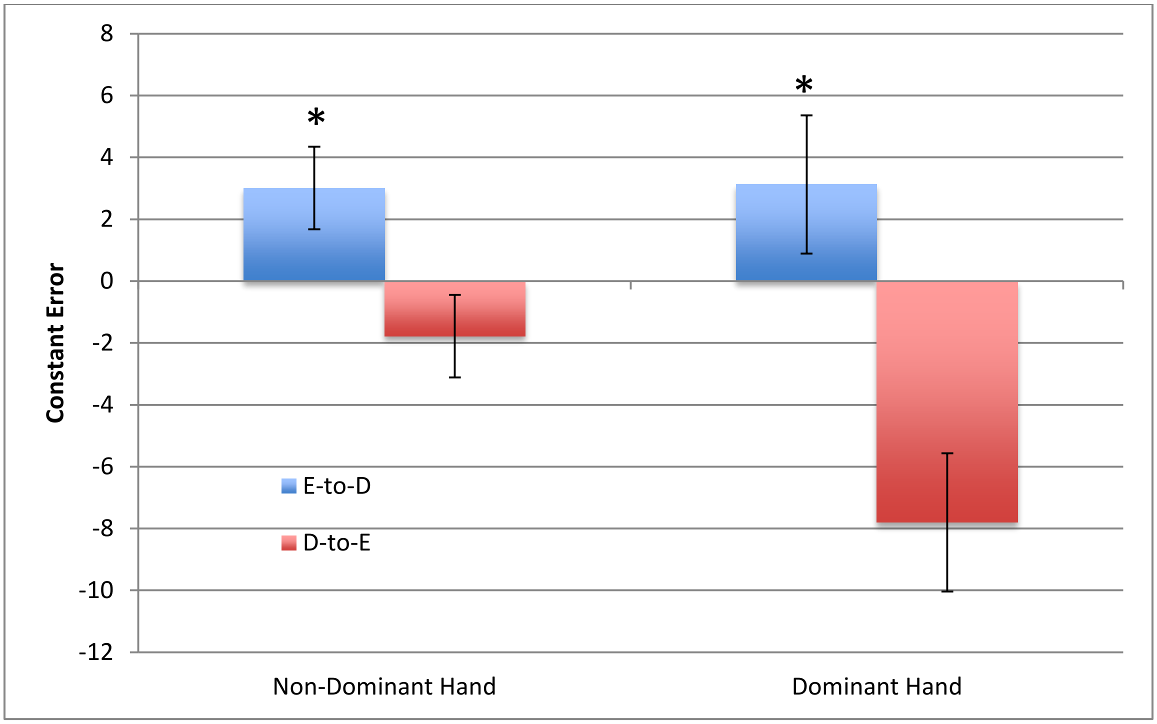

Figure 14. Retention test average constant error (±*SE*) for easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups with both hands. There was a significant difference between groups for both the non-dominant and the dominant hand (*p* <.05, indicated with an *).

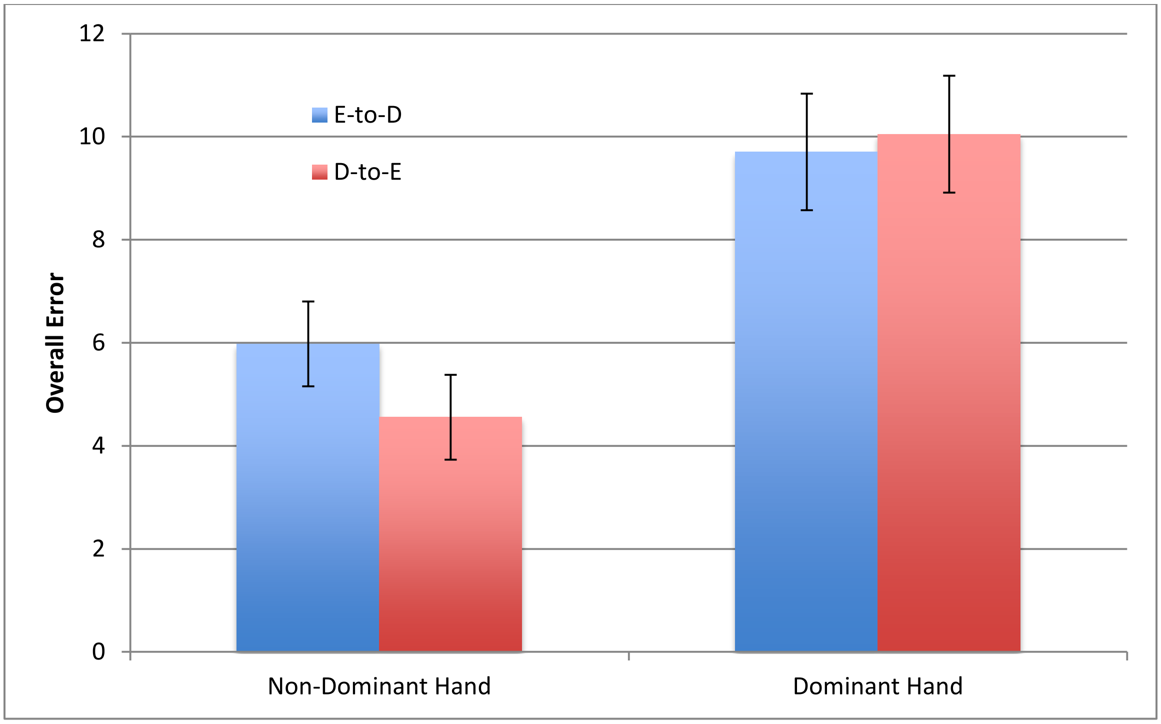

Figure 15. Retention test average overall error (±*SE*) for easy-to-difficult (E-to-D; n = 12) and difficult-to-easy (D-to-E; n = 12) groups with both hands. There was an interaction of hand, but the post-hoc test did not show a significant difference between groups.

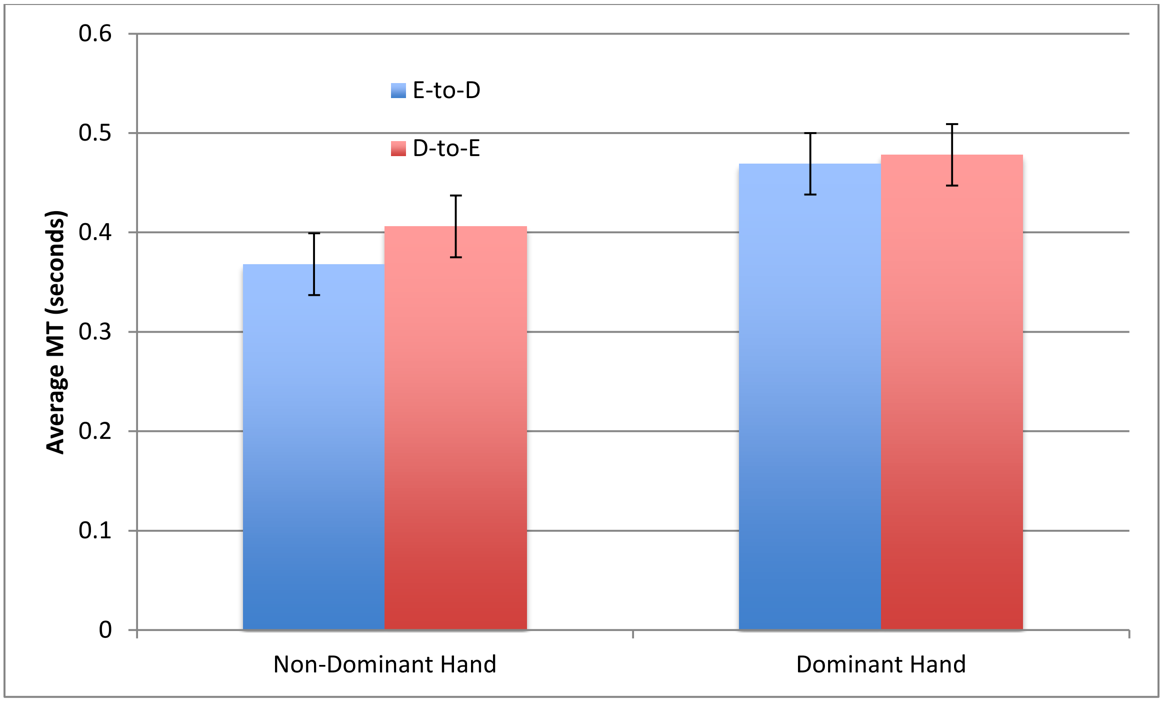

Figure 16. Transfer test average movement time (MT; ±*SE*) for easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups with both hands. Though there was a Hand x Group interaction, the post-hoc analysis did not show a significant difference between groups.

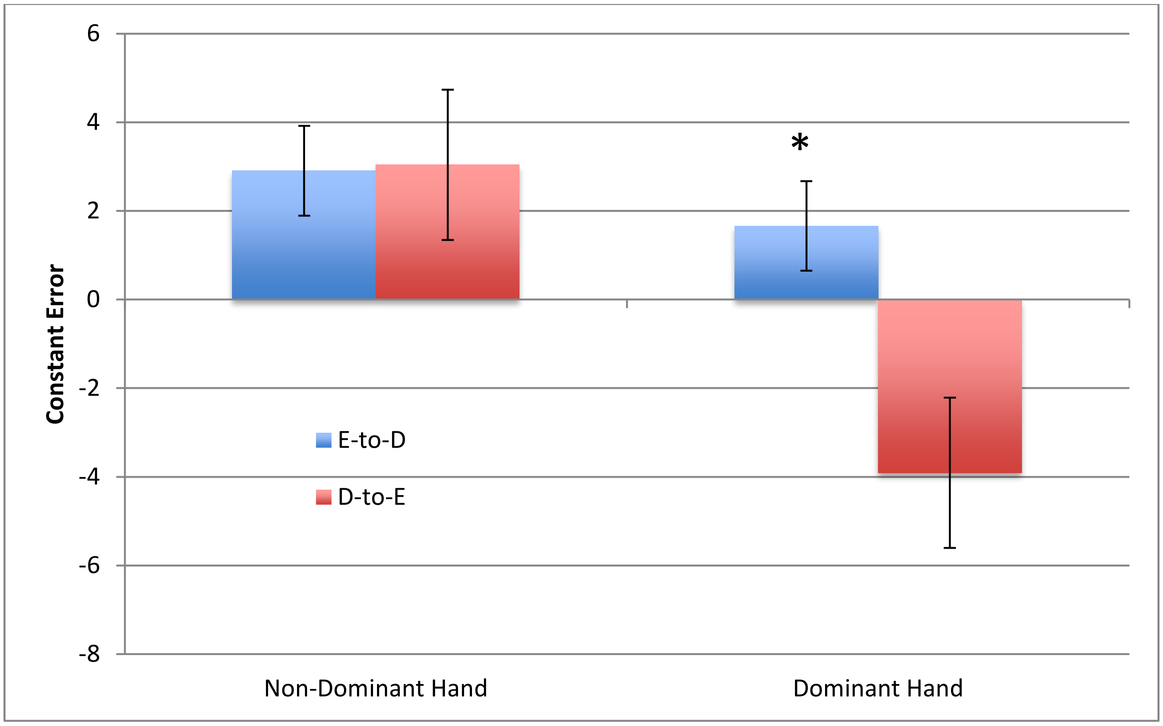

Figure 17. Transfer test average constant error (±*SE*) for easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups with both hands. There was a significant difference between groups for the dominant hand (*p* <.05, indicated with an *).

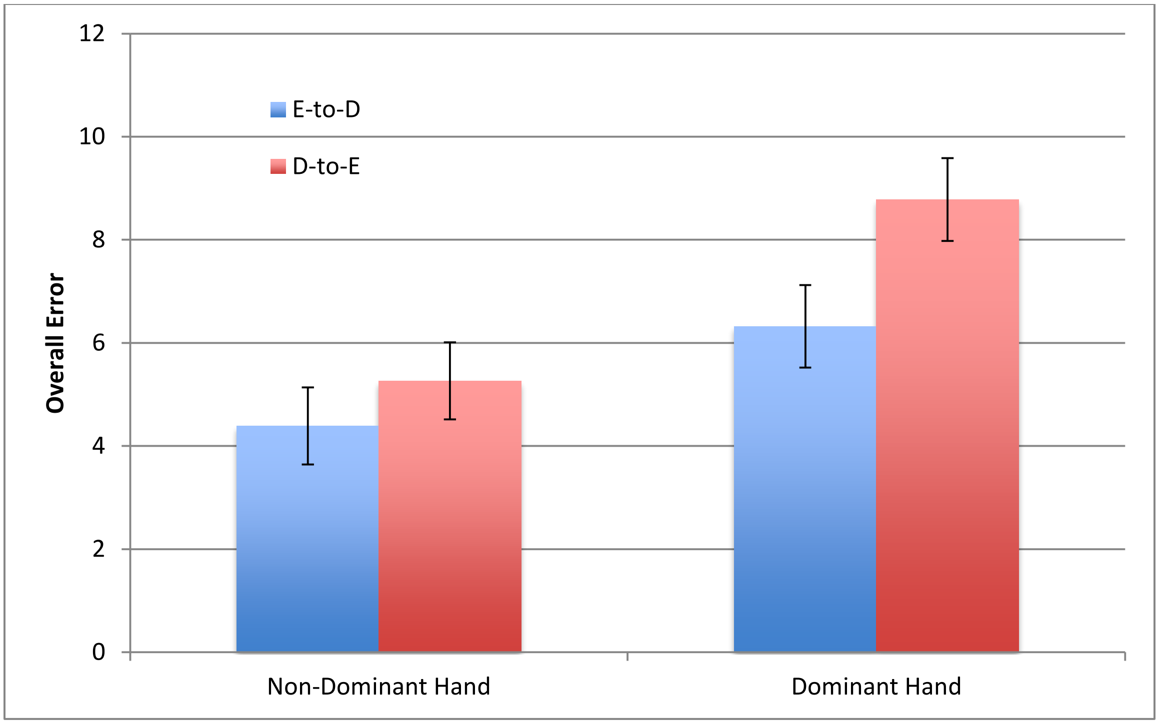

Figure 18. Transfer test average overall error (±*SE*) for easy-to-difficult (E-to-D; *n* = 12) and difficult-to-easy (D-to-E; *n* = 12) groups with both hands. There was an effect of hand, but not of group.