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Motor Learning Effects of Two Types of Stressors: Implications for Practice Specificity

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MOTOR LEARNING EFFECTS OF TWO TYPES OF STRESSORS:
IMPLICATIONS FOR PRACTICE SPECIFICITY

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ABSTRACT

Various types of stress have been found to have both positive and negative effects on motor performance (Szalma & Hancock, 2011; Van Gemmert & Van Galen, 1997). One potential explanation for these diverse findings is that stress increases the amount of neuromotor noise in the system (Van Gemmert, 1997). Low levels of stress may have an activating effect on the system which may improve motor performance whereas larger levels of stress decrease motor performance. Research has also suggested that increases in stress increase effort (Hockey, 1997) which may in turn facilitate motor learning (Lee, Swinnen, & Serrien, 1994). The primary purpose of this dissertation was to examine potential effects of cognitive and physical stress on motor learning. Chapter 1 provides some background information on stress and it also introduces some theories developed to explain the relationship between stress and human motor performance. Chapter 2 describes a study on the potential effects of cognitive stress on motor learning. It was found that additional cognitive stress hindered motor performance ($p < .001$) but did not impede motor learning of a timed aiming task when the cognitive stressor was removed ($p > .05$). The second experiment (chapter 3) is about the effects of physical stress (80dBs of continuous white noise) on motor learning. Results revealed that increased physical noise negatively affected reaction time ($p < .05$) on a timed aiming task but did not affect other performance measures ($p > .05$). During a no stress transfer test the group that practiced with the increased physical stress had marginally longer reaction times ($p = .06$). In chapter 4 a study about specificity of practice and stress (cognitive and physical) is presented. In this chapter stress was added during a transfer test to see if learning was specific to the environment (stress or no stress) during practice. The addition of cognitive stress during transfer significantly diminished motor performance ($p < .001$), but the addition of physical stress seemed not to affect motor

performance ($p > .05$). Chapter 5 provides discussion on the results from the three experiments. The results are discussed in the context of practice specificity and the neuromotor noise theory.

CHAPTER 1: INTRODUCTION

General Introduction

The purpose of this chapter is to discuss some of the relevant literature to this dissertation. The chapter will briefly discuss stress and some of the effects of stress on motor performance. In addition, the theories on stress and motor performance most relevant to this dissertation will also be discussed. The chapter will then look at some of the literature on how increased effort is a potential medium to increase motor learning, and how the specificity of practice hypothesis potentially plays a role in stress and learning. The last portion of this chapter provides an overview of the following chapters.

Stress

Defining stress has proven to be a challenge over the years and has been defined in various ways in different scientific fields. Some literature has viewed stress as a stimulus whereas other literature has looked at it as a response (Baum, 1990; Baum & Grunberg, 1991). To further complicate the task of adequately defining stress, research has examined both acute and chronic stress. Most of the literature on human motor performance examines acute stress where some form of stress or stressor is added to the experimental protocol.

One definition of stress indicates that it is a biological state in which the adaptive capabilities of the organism are reached or exceeded (McGrath, 1976; Wedford, 1973). Based on this definition stress would be viewed as a negative event in which the organism is unable to adjust to the demands being placed upon it. However, research has shown that in some instances stress may enhance performance (Jick & Payne, 1980; Van Gemmert & Van Galen, 1997). Therefore, the stimulus based definition of stress is more useful to the field of human motor

performance because it suggests that stress is a response to any task that requires an increase in effort (Cox, 1978).

There are three types of stress that have been identified in the literature; emotional stress, cognitive stress, and physical stress. Emotional stress is the consequence of a negative emotional event (Christianson, 1992). It has been associated with things like worry, anxiety, personal problems and/or emotional distress (Van Gemmert, 1997). Increased emotional stress often results in decreased motor performance (Adam & Van Wieringen, 1988; Calvo, Alamo, & Ramos, 1990; Eysenck, 1992) and memory impairment (Christianson, 1992). One potential explanation for the decreased performance with emotional stress is that the performer adopts strategies specific to reducing the stress and lacks the attentional capacity to adequately perform the required task (Eysenck, Derakshan, Santos, & Calvo, 2007).

The second stress type is cognitive stress which occurs when the amount of attentional capacity needed is increased. Cognitive stress has also been referred to as mental work load (Young, Brookhuis, Wickens, & Hancock, 2015). Cognitive stress or mental work load occurs when individuals are asked to perform two (or more) tasks simultaneously that each (or all) require(s) a portion of the attentional capacity. We are capable of performing more than one task simultaneously as long as the attentional capacities are not exceeded. If they are exceeded, performance detriments will be elicited (Kahneman, 1973; Wickens, 2002).

The third type of stress is physical stress. Physical stress occurs from environmental stressors such as noise, pollution, sleep deprivation, or temperature. Physical stress may also increase work load if an individual must attend to multiple environmental stimuli or attend to an environmental stressor while performing a motor task. Research investigating the effects of noise on performance has received ample attention with results varying from hindering motor

performance to improving motor performance by decreasing reaction time (Szalma & Hancock, 2011; Van Gemmert & Van Galen, 1997).

In addition to the effects stress has on motor performance, it also influences physiological factors. Stress has been found to increase heart rate (De Ward, 1996) and blood pressure (Rau, 2004). Stress has also been linked to an increase in brain activity (Brookhuis & De Ward, 1993), increased muscle activation in the upper limbs (Van Galen, Muller, Meulenbroek, & Van Gemmert, 2002), and increased activity in certain facial muscles (Hoogendoorn, Hoogendoorn, Brookhuis, & Daamen, 2010). Chronic stress has been tied to more physiological disorders such as cardiovascular and gastric disorders (Von Eiff, Friedrich, & Neuss, 1982; Smith, 1991).

Stress Theory

One perspective that has attempted to explain both the positive and negative effects of stress on motor performance is the neuromotor noise theory (Van Gemmert & Van Galen, 1997). The motor system is inherently noisy and the noise in the system is responsible for variability during movement execution (De Jong & Van Galen, 1997). The neuromotor noise theory suggests that stress has an activating effect on the motor system. The increase in activation due to stress increases the neuromotor noise in the motor and information processing system. To adapt to the increase in noise, the system must filter it out and does so in one of two ways; by increasing cognitive processing time before movement execution, or by exploiting the mechanical properties of the limbs (i. e., increased limb stiffness).

An increase in noise in the system has been shown to be beneficial for performance on simple motor tasks but detrimental to performance on more complex motor tasks. Physical stress has been shown to enhance response time by increasing activation but cognitive stress hinders response time. Both types of stressors have been found to increase limb stiffness which results in

an increase in pen pressure on graphical tasks (Van Gemmert, 1997). It has also been suggested that the human system is more resistant to physical stressors than it is to cognitive stressors (Van Gemmert & Van Galen, 1997).

In addition to the neuromotor noise theory, the cognitive-energetical framework (Hockey, 1997) may help explain the deleterious effects of stress on performance. The framework suggests that performance is monitored by effort and task goals. As stress increases we adjust the amount of effort needed to maintain or improve performance. If effort levels are maximized, task goals may be adjusted to ensure that goals are maintained.

Effort and Motor Learning

It has been suggested that an increase in effort may facilitate motor learning (Lee, Swinnen, & Serrien, 1994). In a paper by Lee, Swinnen, and Serrien (1994), they call attention to three distinct areas of motor learning research where increased effort due to task difficulty may facilitate learning. The three areas discussed are modeling by a novice performer, reduced amounts of augmented feedback, and increased amounts of contextual interference.

Research has shown that watching a novice or learning model is just as beneficial, if not more so, than watching an expert model (McCullagh & Caird, 1990). Watching a learning model that makes mistakes requires an increase in cognitive effort to decide what aspects of the performance should be replicated and which aspects should be changed. This process “actively engages the observer in the problem solving processes” (Lee, Swinnen, & Serrien, 1994, p. 330) which facilitates learning.

The traditional view on augmented feedback suggested that feedback was needed on each performance trial for learning to occur. However, research over the last three to four decades has demonstrated that less than 100% feedback facilitates learning (Salmoni, Schmidt, & Walter,

1984; Winstein & Schmidt, 1990). On trials in which feedback is not provided, the learner must process intrinsic information which increases cognitive effort. In addition, asking an individual to estimate their errors during performance or decide when to receive feedback facilitates learning (Lui & Wrisberg, 1997; Janelle, Kim, & Singer, 1995). In each aforementioned feedback modality, it is assumed that cognitive effort is increased by requiring learners to process both their performance and intrinsic feedback.

The contextual interference research has shown that increasing the amount of interference by practicing one task in the context of other tasks facilitates learning (Shea & Morgan, 1979; Hall, Dominguez, & Cavazos, 1994). This area of research typically compares a group that practices each task in isolation (blocked) and a group that randomly practices the multiple tasks (random). Performance during practice shows that random practice is detrimental to performance; however, when assessing performance during the retention tests, random practice is found to be beneficial for motor learning. The idea is that when performing a new task some effort must be provided and if you continue performing the same task less effort is needed. In contrast, if you vary practice, increased effort is needed on each trial.

The three areas of research discussed in the previous paragraphs: learning from a novice model, reducing the frequency of feedback, and increasing the amount of contextual interference, suggest that cognitive effort is increased because the participant must more fully engage in order to acquire a motor skill. A natural tie in with stress research seems logical because effort is increased under increasing demands of the task or additional stressors. The use of physical or cognitive stress provides an opportunity to increase learners' engagement in the task which presumably will facilitate motor learning. Recent research investigating the effects of dual-task performance on motor learning has shown that practicing tasks simultaneously facilitates

learning of the primary task when performed without the secondary task (Goh, Sullivan, Gordon, Wulf, & Winstein, 2012). In addition, practicing two tasks simultaneously as opposed to the tasks separately facilitates learning when the tasks must be performed together at a later time (Gabbett, Wake, & Abernethy, 2011).

Specificity of Practice Hypothesis

The specificity of practice hypothesis has suggested that skill representations are developed with the sensory information available during practice (Proteau, 1995; Proteau, Marteniuk, & Levesque, 1992). Increased amounts of practice under a specific sensory conditions appears to further increase the strength of the sensorimotor movement representation (Ivens & Marteniuk, 1997). For example, increased amounts of practice with vision leads to decreased performance when the task must be performed without the use of vision (Proteau, Tremblay, & Dejaeger, 1998).

In addition to sensory information, research has also shown a specificity of practice for anxiety (Lawrence et al., 2014) and arousal (Movahedi, Sheikh, Bagherzadeh, Hemayattalab, & Ashayeri, 2007). When individuals practiced a basketball free-throw task under different levels of physical arousal, peak performance was achieved during retention testing when the same physical arousal level was present as in practice (Movahedi, Sheikh, Bagherzadeh, Hemayattalab, & Ashayeri, 2007). In addition, when learning a golf putting task under either high or low anxiety, retention performance is maximized when the same anxiety level is present (Lawrence et al., 2014). Based on these findings, it is reasonable to conclude that if a stress/stressor is present during practice it will become part of the memory representation and future performance will be maximized if the same stress/stressor is present.

Dissertation Outline

The primary purpose of this dissertation is to investigate the effects of physical and cognitive stress on motor learning. An additional aim is to investigate the role that specificity of practice may have on stress. Chapter 1 provides basic background information on stress, how stress may increase effort and learning, and the specificity of practice hypothesis. Chapter 2 describes a study on the effects of cognitive stress (work load) on motor performance and motor learning. The increase in work load negatively affected performance ($p < .001$) but did not influence motor learning either positively or negatively ($p > .05$). Chapter 3 is a study on the effects of physical stress (80dBs of white noise) on motor performance and learning. The increase in physical stress did not negatively affect performance during practice or motor learning ($p > .05$). Chapter 4 describes a study in which the specificity of stress on learning is explored by investigating if practice with a physical or cognitive stressor improves performance when stress is present during a future testing situation. Results suggest that the increase in work load during retention/transfer performance affects performance negatively ($p < .05$) but an increase in physical noise does not affect performance ($p > .05$). Chapter 5 discusses the findings from chapters 2-4 and the implications for stress theory. The chapter also mentions potential limitations and future directions for research.

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CHAPTER 2: COGNITIVE STRESS

Introduction

Stress has been a popular research topic over the last few decades and the literature on cognitive stress or mental workload has steadily increased (Young, Brookhuis, Wickens, & Hancock, 2015). Stress in a general sense is any increase in load on an organism even if the task demands are being fulfilled (Cox, 1978). This definition of stress is important because it adequately defines stress whether performance changes or not. Stress or mental work load increases when a performer is required to attend to multiple stimuli or perform tasks concurrently. This divides the attentional resources available to the performer (Kahneman, 1973; Wickens, 2002; 2008). Wickens (2002) describes cognitive stress as "the relation between the demand for resources imposed by a task and the ability to supply those resources by the operator" (p. 161).

If an increase in mental load exceeds the available attentional resources, performance decrements are likely to be elicited (Mathews et al., 2008). In a review of literature on dual task performance with the primary task being balance, it was concluded that the attentional demands of balance are related to both the difficulty of both concurrent tasks (Woollacott & Shumway-Cook, 2002). For example, individuals perform poorer balancing on an unstable surface while counting backwards verbally as opposed to imagining counting backwards. The increase in difficulty of the secondary task (adding an additional motor component by counting backwards) decreased primary task performance (Yardley et al., 1999). In addition, when increasing the difficulty of a sporting task while responding to a separate probe reaction time task, performance on the reaction time task decreases (Castiello & Umilta, 1988). In general, the more difficult the

primary or secondary task, the more likely performance on one of the tasks will be negatively affected.

To further illustrate the effects of an increase in difficulty of the primary task, Lam, Maxwell, and Masters (2010) had participants learn a golf putting task from two distances, short and far. They were then asked to verbally respond to a secondary reaction time task while performing the putting task. Half the participants performed the far task and then the short task which resulted in an increase in errors (more difficulty learning environment) and half performed the short and then long task. It was found that the more difficult learning environment led to increases in reaction time of the secondary task. These results suggest that a more difficult learning environment leads to a decrease in attentional capacities available for a secondary task; thus, decreasing performance.

It is assumed that few performance detriments will occur when cognitive stress increases in highly skilled performers (Bargh, 1994; Beilock, Carr, MacMahon, & Starkes, 2002). For example, skilled badminton players did not display slower reaction times to a probe reaction time task when performing a badminton task simultaneously (Abernethy, 1988). Leavitt (1979) suggests that performance of the primary task becomes automatic after eight years of practice and participants will see no performance detriments when performing the two tasks simultaneously. However, not every study has led to the conclusion that expert performers do not need to allocate some attentional resources to the primary task. To illustrate this, expert performers in both pistol and rifle shooting did not perform significantly different from novice performers on a secondary RT task (Landers, Qi, & Courtet, 1985; Rose & Christina, 1990).

One area of research where increased cognitive stress has been beneficial is skill acquisition (Roche et al., 2007). As discussed previously, a primary task becomes automatic and

requires very little attention with increasing amounts of practice. Gabbett, Wake, and Abernethy (2011) had individuals practice a two-on-one drawing and passing rugby task that required participants to make a decision on when or if to pass the ball. They also performed a tone recognition task either simultaneously with the draw and pass task or they practiced the tasks one at a time. Those that practiced the tasks together performed better on a retention test that required the tasks to be performed simultaneously. In addition, dual task practice facilitated motor learning of the primary task when the secondary task was removed (Goh, Sullivan, Gordon, Wulf, & Winstein, 2012). Furthermore, participants that showed enhanced learning of the primary task showed performance decrements during the practice phase with both tasks. These results are similar to some findings of research on contextual interference where random practice leads to poorer performance during practice than blocked practice but enhanced performance during retention.

The primary purpose of this study is to further investigate the effects of an increase in mental workload on motor learning. The increase in stress or workload is assumed to increase effort in order to maintain or potentially improve performance (Hockey, 1997). Increases in cognitive effort are assumed to facilitate motor learning (Lee, Swinnen, & Serrien, 1994). If additional workload does increase participant effort then motor learning should be facilitated. A secondary aim is to determine whether the neuromotor noise theory is able to predict the results (Van Gemmert & Van Galen, 1997). The theory suggests that an increase in stress increases noise in the human motor system. The noise is either filtered out by increasing processing times or by exploiting the biomechanical properties of the motor system. This does not mean however that stress always negatively affects performance. Small amounts of stress has an activating effect on the motor system that results in decreased reaction times. Based on the neuromotor

noise theory, it is hypothesized that increasing mental workload will result in decreased performance. However, when the increased workload is removed, performance should improve.

Method

Participants

Prior to participation, individuals read and signed the consent form approved by the Louisiana State University Institutional Review Board (Appendix A). Individuals then filled out a demographic and health questionnaire (Appendix B). Any person that reported psychological or neurological disorders or trouble with the use of the upper limbs was excluded from participation. In addition, all individuals reported having normal or corrected-to-normal vision and hearing. Following attrition due to the exclusion criteria, 24 individuals participated in the study aged between 20 and 23 (M = 20.88, SD = 0.95). All volunteers received extra credit for participating in one of their kinesiology classes at the University.

Task and Equipment

At the beginning of the experiment participants were randomly assigned to one of two conditions. The primary skill, aiming at the target within exactly two seconds, was learned in this experiment. The aim was to determine if learning a new task would be affected if work load was increased due to a secondary task during acquisition, therefore a between subject design had to be used. The first condition required participants to perform the graphical aiming task with a barrier avoidance requirement described below (AT). The second condition performed the same task but to increase cognitive stress/work load, they were also required to perform a secondary task of counting backwards by threes during the procedure (WL). Participants were seated at a desk with a WACOM Intuos3 12 × 19 digitizing tablet (48.26 cm × 30.48 cm) that was connected to a computer (Dell XPS 720) with a 46.99 cm × 29.21 cm monitor. All participants

used a non-inking electronic pen (WACOM ZP-130) during the experiment (Figure 1). The digitizing tablet recorded the X and Y position of the pen tip with a sampling rate of 200 Hz and a spatial resolution of 0.0005 cm. MovAlyzeR (Neuroscript LLC, Tempe, Arizona, USA) controlled the data collection and presentation of the conditions.

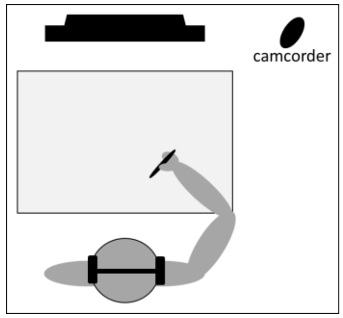

Figure 1: Experimental set-up showing the placement of the equipment and participant.

The graphical aiming task with barrier avoidance requirement (Figure 2) required participants to draw from one target to another in exactly two seconds while avoiding two rectangular barriers. During a trial, the targets and barriers appeared on the monitor and the participant had between 2.5 and 3.75 seconds before the go signal to place the tip of the pen on the start target (lower target, radius = 0.15 cm). The participant then waited for a go signal (end target turned green, radius = 0.15 cm) and they were instructed to initiate their movement as quickly as possible. Participants then drew around the left side of the first barrier (8.5 cm × 0.6 cm), between the two barriers, and then around the right side of the second barrier (8.5 cm × 0.6 cm) to reach the end target (higher target, radius = 0.15 cm). All participants were instructed to complete the task in exactly two seconds. The group that also had to count backwards by threes was given a random number that appeared on the screen two seconds before the second screen with the home position, target and barriers for the aiming task were presented (see Figure 2, screen 1 and 2). They were required to start counting as soon as the number appeared. They then continued counting during the trial and had to keep counting after the completion of the task.

This was done to ensure that participants were performing both tasks simultaneously and not only thinking of the numbers needed during the drawing. Participants counted between 9 and 11 digits during a trial. A trial concluded when the end target was contacted which made the target disappear. Any trial in which the pen was lifted off the tablet before completion of the trial, the participant did not count while performing the aiming task, did not start on the start target, or hit a barrier was repeated.

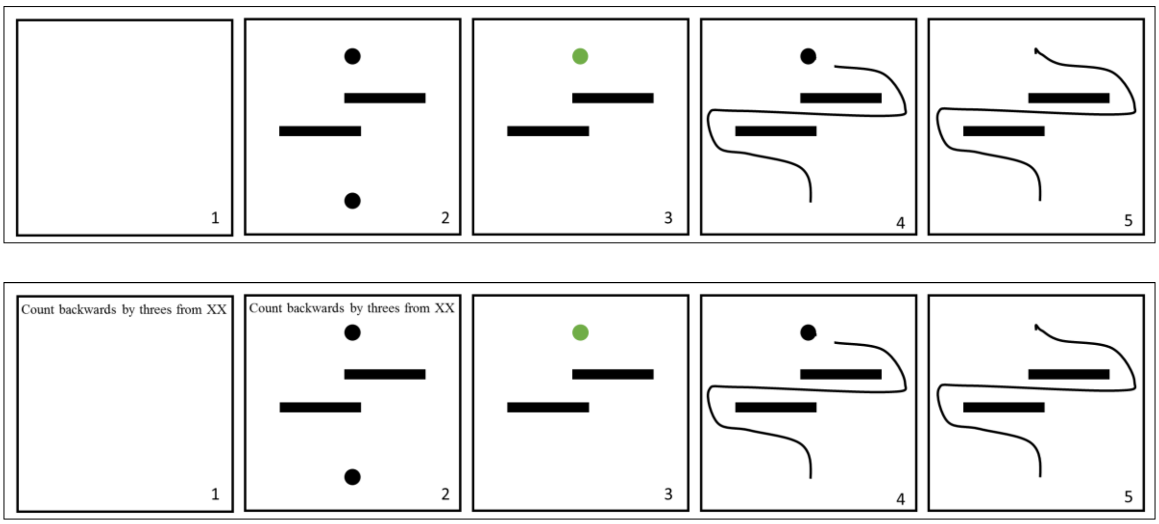

Figure 2: The top diagram shows the sequence of the task for the Aiming Task group and the bottom diagram shows the task for the Work Load group. (1) Blank screen or instruction to count backwards, (2) Aiming task appeared on the screen and participants placed the pen tip in the starting target, (3) target turned green, (4) participant initiated movement, (5) target was reached to conclude the trial.

Procedure

Participants signed the informed consent and filled out the demographic and health questionnaire. They then completed the Perceived Stress Scale (Appendix C, Cohen, Kamarck, & Mermelstein, 1983) upon entering the lab. Participants were explained that they would use an electronic pen and a digitizing tablet that recorded the position of the pen tip. They were then shown the task and explained how to perform the task. Participants were instructed to place the tip of the pen in the center of the start target and wait for the end target to turn green. As soon as

the target turned green they were told to start their movement as quickly as possible and draw around the left side of the first barrier and then around the right side of the second barrier.

Following instruction of the task, participants performed three practice trials to ensure they clearly understood the task and they were offered the opportunity to ask questions about anything that was not clear. They were asked to hold the pen with the normal grip they used while writing. It was then explained that participants had to wear noise cancelling head phones (Bose QuietComfort 2) and would have the movements of their hand recorded by a camcorder (Canon Vixia HF R300). Participants were then told that the goal of the task was to perform each trial in exactly 2000 milliseconds and that they would randomly receive feedback about their movement time on the monitor. Feedback was randomly provided on two of every six trials (33%).

During acquisition individuals performed 60 trials of the aiming task. Following acquisition, participants took a five minute break and filled out a modified version of the NASA task-load index (Appendix D; Hart, 2006). This was done to see if a difference in work load existed between the aiming task and the aiming task while counting backwards by threes. Participants then performed six retention trials where the same task under the same conditions as acquisition was completed. Another five minute break was taken followed by six retention/transfer trials where the secondary task of counting was removed (see Table 1).

Table 1: Both groups with the task being performed during acquisition, retention, and retention/transfer.

Group	Acquisition	Retention	Retention/Transfer
Control	Aiming Task	Aiming Task	Aiming Task
Cognitive Stress	Aiming Task with verbal counting	Aiming Task with verbal counting	Aiming Task

Data Analysis

The data collected by MovAlyzeR was processed with a custom made Matlab-program (Mathworks Inc., Natick, Massachusetts, USA). The position signals of the pen tip were dual pass filtered with a Butterworth fourth order filter with a cut off frequency of 7 Hz. Both the onset and offset of the pen movement was determined by 5% of the peak velocity. The dependent variables analyzed were constant error (CE), absolute error (AE), variable error (VE), average and peak acceleration (AA and PA), path length (PL), normalized jerk (NJ), and axial pen pressure (PP). The goal of the task was to perform the task in two seconds so AE, CE, and VE provided data on the timing accuracy. To calculate AE, CE, and VE, movement time (MT) had to be first calculated. MT was defined as the beginning of movement to the end of movement. The initiation and termination of the movement were determined by using 5% of the peak velocity. CE is the difference between the actual and goal MT which provides bias information (CE=T-MT). AE is the absolute difference between the actual and goal MT which provides a general idea of timing accuracy (AE=|CE|). VE provides consistency around the average MT (VE=√(∑(MT mean – MT trial)^2/N). AA, PA, NJ, and PL provided data on the efficiency of the movement. Acceleration is the second derivative of displacement and provided information on the estimated force required to propel the pen over the surface of the tablet. Jerk is the rate of change in acceleration and NJ is jerk normalized for path length and duration (see Van Gemmert, Teulings, & Stelmach, 1998). RT and PP were collected to measure the increases in processing times and the biomechanical adaptations due to the increased mental load.

The 60 acquisition trials were analyzed in ten blocks of six. All dependent variables were analyzed with separate mixed factors ANOVAs with groups as the between factor and blocks as the within factor (i.e., 2 groups × 10 blocks). To analyze retention and retention/transfer, separate

mixed factors ANOVAs were applied to each dependent variable with the groups as the between factors and the first block of acquisition and the retention or retention/transfer block as the within factors (i.e., 2 group × 2 blocks). When a significant block × group interaction was observed, independent t-tests with a Bonferroni correction were applied to the data. The composite scores for the Perceived Stress Scale and the NASA task-load index were each totaled. Separate independent t-tests were performed to look for group differences.

Results

AT had an average Perceived Stress Scale of 17.75 and WL had an average score of 15.42. The independent sample t-test did not reveal a significant difference between the groups ($t = -.91$, $p > .05$). This indicates that prior to participating in the experiment; the groups did not have a significantly different level of stress. On the NASA task-load index AT scored on average 58.08 and WL scored 68.50. As expected the independent sample t-test revealed a significant difference after the acquisition session on task-load ($t = 2.26$, $p < .05$) with WL indicating significantly greater task-load (Figure 3).

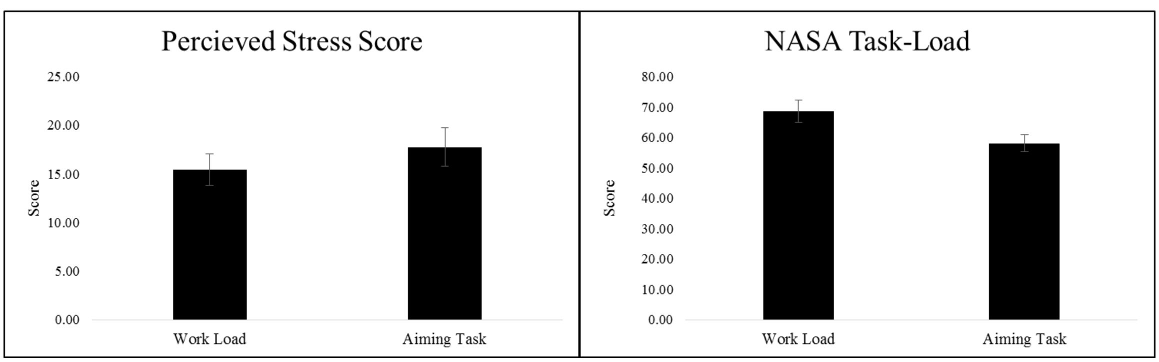

Figure 3: Percieved Stress Scores (left) and NASA task-load index scores (right) for both groups with standard error bars.

Acquisition

Absolute Error. AE significantly decreased from the beginning of acquisition to the end of acquisition (Figure 4). This was supported by the significant main effect of block, $F(9, 198)$ =

21.02, $p < .001$, $\eta p^2 = .49$. WL had higher error scores than AT, $F(1, 22) = 10.19$ $p <. 01$, $\eta p^2 = .32$. The group × block interaction was not significant ($p > .05$).

Constant Error. Figure 4 shows the average CE during each block of acquisition (Figure 4). The amount of CE was positive, indicating the aiming movements were too slow, this bias significantly decreased during acquisition which was supported by the main effect of block $F(9, 198) = 23.44$ $p < .001$, $\eta p^2 = .52$. WL displayed larger CE (i.e., a bias to move too slow) during acquisition than AT, $F(1, 22) = 10.54$, $p < .01$, $\eta p^2 = .32$. No significant group × block interaction was found ($p > .05$).

Variable Error. Both groups became more consistent during acquisition (Figure 4). This was supported by the significant decrease in VE, $F(9, 198) = 16.17$ $p <. 001$, $\eta p^2 = .42$. WL was significantly less consistent than AT, $F(1, 22) = 12.43$, $p < .01$, $\eta p^2 = .36$. No significant group × block interaction was found ($p > .05$).

Average Acceleration. Participants also significantly increased AA from the beginning to the end of acquisition, $F(9, 198) = 31.61$, $p < .001$, $\eta p^2 = .59$. Significantly greater AA was shown for the AT group, $F(1, 22) = 7.75$, $p <. 05$, $\eta p^2 = .26$. The group × block interaction was also significant, $F(9, 198) = 2.66$, $p <. 05$, $\eta p^2 = .11$ (Figure 5).

Peak Acceleration. Figure 5 shows the average PA during each block of acquisition. Participants significantly increased PA during acquisition, $F(9, 198) = 15.92$, $p < .001$, $\eta p^2 = .42$. Unlike AA, the main effect for group was not significant ($p > .05$). The group × block interaction also failed to reach significance ($p > .05$).

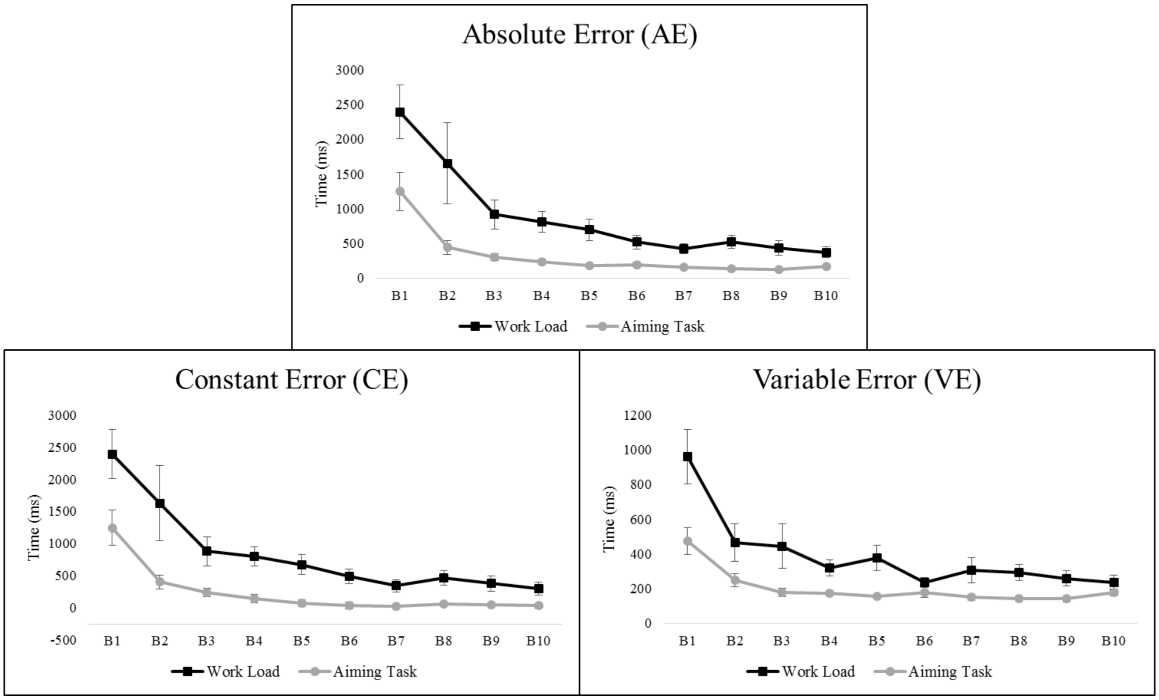

Figure 4: The average AE (top), CE (bottom right), and VE (bottom left) for each group during acquisition block with standard error bars.

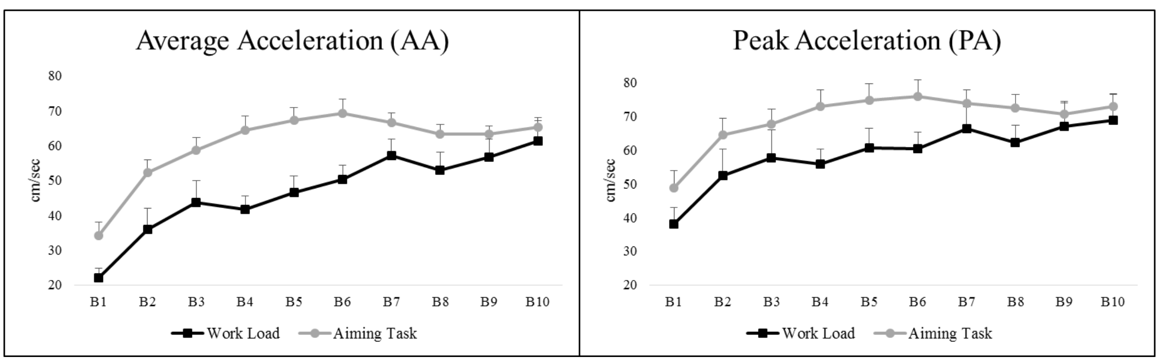

Figure 5: The AA (left) and PA (right) for WL and AT during each acquisition block with standard error bars.

Normalized Jerk. Figure 6 displays the average NJ for each block of acquisition. Groups significantly decreased NJ from the beginning to the end of acquisition. This was supported by a significant main effect of block, $F(9, 198) = 8.97$, $p < .01$, $\eta p^2 = .29$. The AT group also displayed significantly less NJ than the WL group, $F(1, 22) = 6.73$, $p < .05$, $\eta p^2 = .23$. The group × block interaction was not significant, $F(9, 198) = 2.25$, $p >. 05$.

Path Length. For PL, a main effect of block was observed with groups increasing the length from the first to the sixth acquisition block, $F(9, 198) = 5.36$, $p < .01$, $\eta p^2 = .20$. After the sixth block WL continued to increase in length but AT began to decrease in length (Figure 6). This is supported by the significant group × block interaction, $F(9, 198) = 5.04$, $p < .01$, $\eta p^2 = .19$. No significant main effect for group was found ($p > .05$).

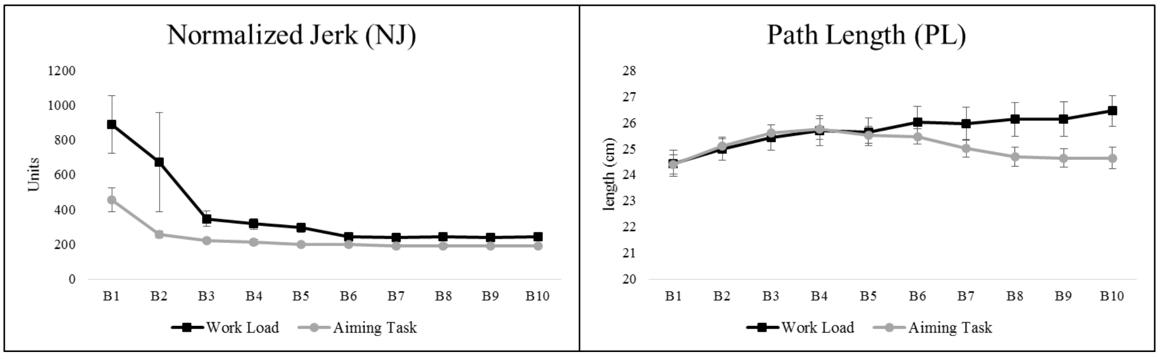

Figure 6: Average NJ (left) and PL (right) for WL and AT during each block of acquisition with standard error bars.

Reaction Time. Figure 7 shows the average RT for both groups during acquisition. RT did not significantly increase or decrease during acquisition. This was supported by the lack of a significant main effect of block ($p > .05$). A significant main effect of group was observed with WL having greater RTs than AT, $F(1, 22) = 9.73$, $p < .01$, $\eta p^2 = .31$. The group × block interaction failed to reach significance ($p > .05$).

Pen Pressure. Figure 7 shows the average PP for both groups during each block of acquisition. The main effect of block was significant, $F(9, 198) = 5.03$, $p < .01$, $\eta p^2 = .19$, which was driven by the AT group decreasing PP. The main effect of group was not significant ($p > .05$). The group × block interaction shown in Figure 7 was significant, $F(9, 198) = 5.53$, $p < .01$, $\eta p^2 = .20$. The interaction was driven by a greater reduction of PP for AT and the lack of PP reduction for WL.

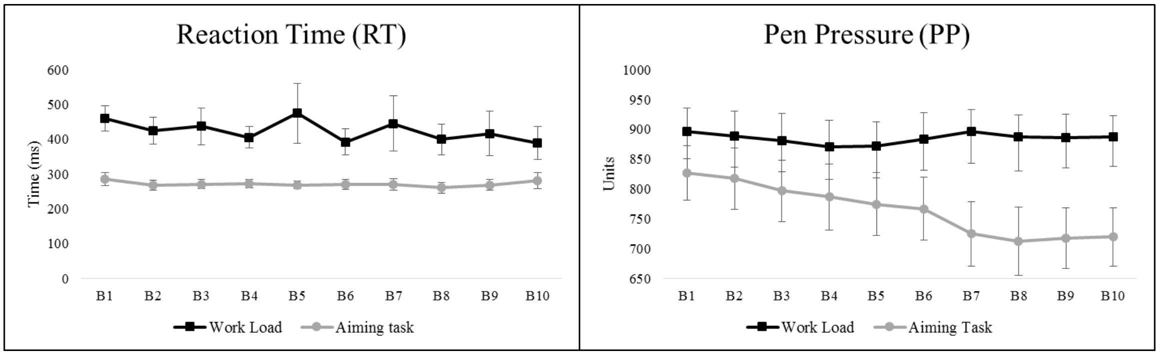

Figure 7: Average RT (left) and PP (right) during each block of acquisition with standard error bars.

Retention

Absolute Error. Groups significantly decreased AE from the beginning of acquisition to retention (Figure 8). This was supported by the significant main effect of block, $F(1, 22) = 47.71$, $p < .001$, $\eta p^2 = .68$. WL had significantly more AE than AT, $F(1, 22) = 8.13$, $p < .01$, $\eta p^2 = .$ There was no significant interaction ($p > .05$).

Constant Error. Figure 8 shows the average CE during the first block of acquisition and retention. Groups significantly decreased CE to zero, i.e. showed less bias, from the beginning of acquisition to retention, $F(1, 22) = 54.14$, $p < .001$, $\eta p^2 = .71$. WL had significantly more CE than AT, $F(1, 22) = 8.53$, $p < .01$, $\eta p^2 = .28$. There was no significant group × block interaction ($p > .05$).

Variable Error. Groups significantly decreased variability from acquisition to retention (Figure 8). This was supported by a significant effect of block for VE, $F(1, 22) = 41.26$, $p < .001$, $\eta p^2 = .65$. The WL group displayed significantly greater VE, $F(1, 22) = 9.32$, $p < .01$, $\eta p^2 = .30$, than the AT group. The block × group interaction was also significant, $F(1, 22) = 5.04$, $p < .05$, $\eta p^2 = .21$. The independent t-tests revealed that groups significantly differed during the first block of acquisition ($p < .001$) but not retention ($p > .05$). Both groups decreased VE from the beginning of acquisition to retention ($p < .05$).

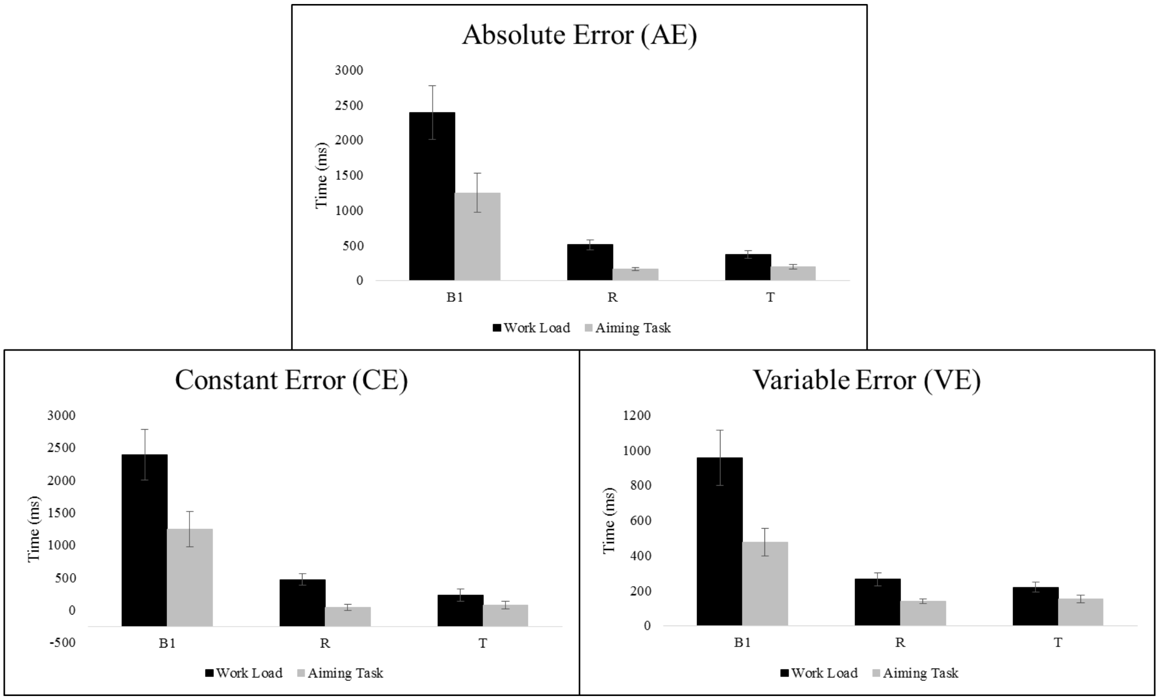

Figure 8: Average AE (top), CE (bottom left), and VE (bottom right) for both groups during the first block or acquisition, retention, and transfer with standard error bars.

Average Acceleration. Groups significantly increased AA from the beginning of acquisition to retention (Figure 9). This observation was supported by a significant main effect of block, $F(1, 22) = 80.29$, $p < .001$, $\eta p^2 = .79$. There was also a significant main effect of group with WL having lower AAs, $F(1, 22) = 6.33$, $p < .05$, $\eta p^2 = .22$. No significant group × block interaction was observed for AA ($p > .05$).

Peak Acceleration. Groups significantly increased PA from the beginning of acquisition to retention (Figure 9). This observation was supported by a significant main effect of block, $F(1, 22) = 49.18$, $p < .001$, $\eta p^2 = .69$. The main effect of group for PA was not significant ($p > .05$), and no significant group × block interaction was observed ($p > .05$).

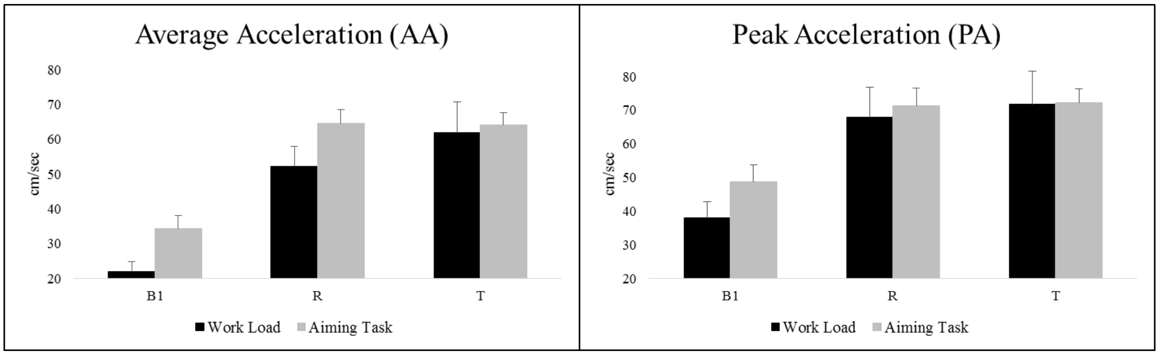

Figure 9: AA (left) and PA (right) for both groups during the first block or acquisition, retention, and transfer with standard error bars.

Normalized Jerk. Groups displayed significantly less NJ during retention than the beginning of acquisition (Figure 10). This was supported by a significant main effect of block, $F(1, 22) = 26.74$, $p < .001$, $\eta p^2 = .55$. WL also had greater NJ than AT, $F(1, 22) = 6.67$, $p < .05$, $\eta p^2 = .23$. The group × block interaction was also significant, $F(1,22) = 4.58$, $p < .05$, $\eta p^2 = .17$. The independent t-tests revealed significant group differences during the first block of acquisition ($p < .01$) but not the retention block ($p > .05$). WL significantly decrease NJ from the first block of acquisition to the retention block ($p < .001$), but AT did not significantly decrease NJ from acquisition to retention ($p > .05$). This may have occurred due to a floor effect where AT was not able to further reduce NJ.

Path Length. The main effect of block was significant, $F(1, 22) = 6.84$, $p < .05$, $\eta p^2 = .24$, but the main effect of group was not, ($p > .05$). The group × block interaction was significant, $F(1,22) = 4.84$, $p < .05$, $\eta p^2 = .18$. The independent Bonferroni corrected t-tests failed to show significant differences from the beginning of acquisition to retention or between groups on either block ($p > .05$) (see Figure 10).

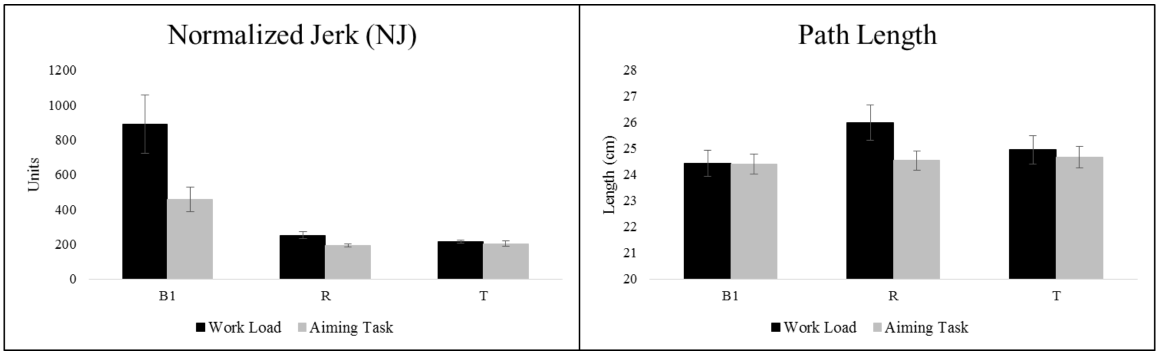

Figure 10: Average NJ (left) and PL (right) for both groups during the first block or acquisition, retention, and transfer with standard error bars.

Reaction Time. Groups did not significantly decrease RT from the beginning of acquisition to retention ($p > .05$) (Figure 11). WL did have significantly higher RTs, which was supported by the significant main effect of group, $F(1, 22) = 18.20$, $p < .001$, $\eta p^2 = .45$. The interaction was not significant ($p > .05$).

Pen Pressure. Figure 11 shows the average PP during the first block of acquisition and retention. The main effect of block was not significant ($p > .05$) and neither was the main effect of group ($p > .05$). Despite a seemingly decrease of pen pressure for AT while WL seems to stay the same from baseline to retention, the group × block interaction failed to reach significance as well ($p > .05$).

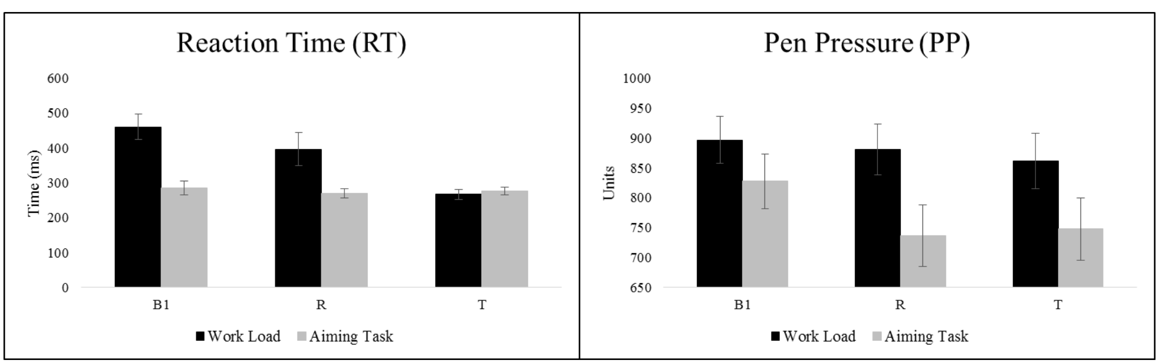

Figure 11: Average RT (left) and PP (right) for both groups during the first block or acquisition, retention, and transfer with standard error bars.

Transfer

Absolute Error. AE significantly decreased from the beginning of acquisition to transfer (Figure 8). This was supported by the significant main effect of block, $F(1, 22) = 44.27$, $p < .001$, $\eta p^2 = .67$. WL had significantly more AE than AT, $F(1, 22) = 7.15$, $p < .05$, $\eta p^2 = .25$. The group × block interaction was also significant, $F(1, 22) = 4.39$, $p < .05$, $\eta p^2 = .17$. The independent t-tests revealed significant group differences during the first block of acquisition ($p < .01$) but not during transfer ($p > .05$). Both groups did improve from the beginning of acquisition to transfer ($p < .05$).

Constant Error. CE significantly decreased from the beginning of acquisition to transfer, $F(1, 22) = 55.10$, $p < .001$, $\eta p^2 = .72$. WL had significantly more AE than AT, $F(1, 22) = 6.19$, $p < .05$, $\eta p^2 = .22$. The group × block interaction was also significant, $F(1, 22) = 4.85$, $p < .05$, $\eta p^2 = .18$. The independent t-tests revealed significant group differences during the first block of acquisition ($p < .01$) but not during transfer ($p > .05$). Both groups significantly decreased CE from the beginning of acquisition to transfer ($p < .01$) (see Figure 8).

Variable Error. Groups significantly decreased variability from acquisition to transfer (Figure 8). This was supported by a significant main effect of block for VE, $F(1, 22) = 38.40$, $p < .001$, $\eta p^2 = .64$. The WL group displayed significantly greater VE, $F(1, 22) = 8.61$, $p < .01$, $\eta p^2 = .28$, than the AT group. The group × block interaction was also significant, $F(1, 22) = 5.89$, $p < .05$, $\eta p^2 = .21$. The independent t-tests revealed that groups significantly differed during the first block of acquisition ($p < .01$) but not transfer ($p > .05$). Both groups significantly decreased VE from the beginning of acquisition to transfer (WL, $p < .001$; AT, $p = .05$).

Average Acceleration. Groups significantly increased AA from the beginning of acquisition to transfer (Figure 9). This observation was supported by a significant main effect of

block, $F(1, 22) = 62.54$, $p < .001$, $\eta p^2 = .74$. The main effect of group was not significant and neither was the group × block interaction ($p > .05$).

Peak Acceleration. Groups significantly increased PA from the beginning of acquisition to transfer (Figure 9). This observation was supported by a significant main effect of block, $F(1, 22) = 49.30$, $p < .001$, $\eta p^2 = .69$. The main effect of group for PA was not significant ($p > .05$). No significant group × block interaction was found ($p > .05$).

Normalized Jerk. Groups displayed significantly less NJ during transfer than the beginning of acquisition (Figure 10). This was supported by a significant main effect of block, $F(1, 22) = 27.52$, $p < .001$, $\eta p^2 = .56$. WL also had greater NJ than AT, $F(1, 22) = 5.62$, $p < .05$, $\eta p^2 = .20$. The group × block interaction was also significant, $F(1,22) = 5.66$, $p < .05$, $\eta p^2 = .21$. The independent t-tests revealed significant group differences during the first block of acquisition ($p < .01$) but not the transfer block ($p > .05$). WL significantly decrease NJ from the first block of acquisition to the transfer block ($p < .001$), but AT did not ($p > .05$).

Path Length. Figure 10 shows the average PL during the first block of acquisition and transfer. Groups did not significantly change PL from the beginning of acquisition to transfer ($p > .05$). The main effect of group and the group × block interaction failed to reach significance ($p > .05$).

Reaction Time. Groups significantly decrease RTs from the beginning of acquisition to transfer, $F(1, 22) = 23.83$, $p < .001$, $\eta p^2 = .52$, (see Figure 11). This finding was driven by the reduction of RT by WL. The main effect of group was significant with WL having greater RTs, $F(1, 22) = 11.77$, $p < .01$, $\eta p^2 = .35$. The group × block interaction was also significant, $F(1,22) = 19.60$, $p < .001$, $\eta p^2 = .47$. The independent t-tests revealed that WL significantly decreased RTs

from acquisition to transfer ($p < .001$) but AT did not ($p > .05$). The groups significantly differed during the first block of acquisition ($p < .001$) but not during transfer ($p > .05$).

Pen Pressure. Figure 11 shows the average PP during the first block of acquisition and transfer. The main effect of block and the main effect of group did not reach significance ($p > .05$). In addition, despite a trend that seems to indicate that the pen pressure decreases for AT, while WL stayed relatively flat, the group × block interaction failed to reach significance as well ($p > .05$).

Discussion

The primary purpose of this chapter was to investigate the effects of increased mental workload (cognitive stress) on the acquisition and learning of a graphical aiming task with a barrier avoidance requirement. All participants learned a task that required them to draw from one target to another, with the goal being to do it in exactly two seconds. Half the participants had their mental workload increased by performing a secondary task that required them to count backwards by threes while simultaneously performing the primary aiming task.

During the acquisition phase, groups significantly improved their performance for the dependent variables: absolute error (AE), constant error (CE), variable error (VE), average acceleration (AA), peak acceleration (PA) normalized jerk (NJ), path length (PL), and pen pressure (PP). No improvement was observed during acquisition for reaction time (RT). The group with increased work load performed significantly worse on all dependent variables except PA and PL.

The pattern of findings of PL and PP during acquisition merit additional discussion. For the variable PL, groups significantly increased PL during the first six blocks of acquisition. At that point, the group that only performed the aiming task (AT) began to decrease PL whereas the

group with additional work load (WL) continued to increase PL. At the beginning of practice participants focused on decreasing the MT which resulted in an increase in PL as they attempted to move faster (decrease movement time). Once they became more efficient in their movement timing, the AT group focused on decreasing PL to have more efficient movements. This pattern shows that the AT group became both accurate in their timing accuracy and efficient in their movements. The increased work load required participants to continue improving movement timing accuracy so they never worked on improving PL efficiency. Participants also differed in their pattern of acquisition for PP. The additional work load increased PP throughout acquisition. The group without additional workload decreased PP throughout acquisition. These results are typical in motor learning research where learners become more accurate in their movement timing and more efficient in their movements during practice (Stelmach, 1969; Winstein & Schmidt, 1990; Wulf, Shea, & Lewthwaite, 2010)

Participants improved from their baseline performance (first block of acquisition) to retention performance for each dependent variable except RT and PP. The additional work load caused performance detriments during retention for each dependent variable except NJ and PL. The results for acquisition and retention suggest that the increase in mental work load diminishes motor performance. Decreased performance due to an increase in cognitive stress has been previously reported. For example balance performance decreases when simultaneously counting backwards (Woollacott & Shumway-Cook, 2002).

During transfer, the additional workload was removed so both the WL group and AT group only performed the graphical aiming task (i.e., the AT group performed a second retention task). During the transfer test the groups did not significantly differ from one another. This indicates that stress negatively affected the acquisition of the motor task; however, performance

variables are no longer negatively affected when the stressor is removed. It has been suggested that transfer is a more useful measure to indicate learning as it shows that the skill is adaptable to various contexts or task variations (Johnson, 1961). Therefore, if we solely consider the transfer performance pattern of findings, stress did not affect motor learning indicating that practicing with or without stress has no negative or beneficial effects, i.e., stressors do affect motor performance, but do not affect motor learning.

These findings fail to support the hypothesis that additional workload would facilitate motor learning. However, the presentation of additional work load in the current experiment does not seem to hinder the learning of the primary motor task. One explanation is that for dual task practice to facilitate motor learning the two tasks being performed must engage in similar cognitive processes (Goh et al 2012). The tasks in the present study engage different cognitive areas, i.e., verbal and cognitive (Wickens, 2002; 2008).

A second aim of the study was to explore whether the neuromotor noise theory would provide a framework to explain the results. The theory suggests that when the additional stressor is present then PP should increase. RT may increase if the activating properties of the stressor are nullified by the need to increase processing time to cope with the increased noise in the system. If an increase in processing time is not needed to cope with the increased noise in the system then RT may decrease. Our findings support the neuromotor noise theory because the increase in work load decreased performance (acquisition and retention) in both RT and PP. Previous research suggests that cognitive stress should increase processing time, thus increasing RT (Van Gemmert & Van Galen, 1997; Van Gemmert & Van Galen, 1998). When the additional work load was removed, RT returned to a similar level as a group that practiced without the additional work load.

Our findings also support the theory that an increase in stress increases effort. The data from the NASA task-load suggest that the presentation of the secondary backwards counting task did significantly increase the work load. The cognitive-energetical framework (Hockey, 1997) suggests that when stress is increased the performer must increase effort to compete with the demands of the task. If the increase in effort is not sufficient to complete the goal of the task, the performer will update task goals so that they are obtainable. A possible explanation for these results is that learners were not able to increase effort to meet the demands of the task so they adjusted task goals to a level that was obtainable. The lower task goal may explain why greater motor learning was not reported. To support this increased effort leading to increased learning, the amount of learning differed between the groups. WL learned more (improved more from the beginning of practice to retention/transfer) than the AT group. However, this effect was primarily caused by the WL performance at the beginning of acquisition, thus a ceiling effect for the performance of AT may have caused that WL improved more.

Future research should focus on the effects of other stress types on motor learning because research has shown that different stressors effect motor performance differently (Van Gemmert & Van Galen, 1997). It is possible that the secondary task used in this study was too difficult and thus it possibly did not allow the learners to adequately focus on the primary motor task. Van Gemmert and Van Galen (1997) found that cognitive stress hindered performance more so than physical stress (auditory noise). It is possible that if auditory noise is used to increase work load/stress performance may improve and motor learning may be facilitated.

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CHAPTER 3: PHYSICAL STRESS

Introduction

According to the cognitive-energetical framework (Hockey, 1997), stress increases effort to temporarily improve performance or maintain performance levels. If one is unable to adjust performance to meet the goals of the task, the individual needs to adjust task goals to a level that is obtainable. The previous chapter investigated the effects of an increase in mental workload (i.e., cognitive stress) on the learning of a graphical timing task. It was assumed that the increase in work load would increase the effort of the learner and facilitate motor learning. The results from the previous chapter suggest that an increase in mental workload does hinder motor performance, but does not positively or negatively affect motor learning. A possible explanation for these results is that learners were not able to increase effort to meet the demands of the task so they adjusted task goals to a level that was obtainable. The lower task goal would explain why greater motor learning was not reported.

These results are at odds with the findings by Goh, Sullivan, Gordon, Wulf, and Winstein (2012). They found that dual task practice was beneficial to motor learning of the primary task. The secondary task that was used in the previous chapter was more difficult that the simple reaction time task used in Goh et al. (2012). It is possible that a less difficult secondary task or a lesser form of stress will facilitate motor learning.

Van Gemmert and Van Galen (1997) found that cognitive stress (increased work load) is more detrimental to performance than physical stress. Physical stress also increases mental load when an individual attends to multiple stimuli in the environment (Van Gemmert & Van Galen, 1994; 1998). This may occur by attending to two different stimuli, such as an auditory stimulus and a visual stimulus, or attending to an environmental stimulus while performing a motor task.

Physical stressors may include environmental stimuli such as pollution, high and low temperatures, or auditory noise. Physical stressors also include sleep deprivation and even the time of day. One physical stressor that has received a lot of attention over the years is physical noise (Broadbent, 1971).

Auditory noise has been shown to have both positive and negative effects on human performance (Broadbent 1979; Hockey, 1979; Van Gemmert, 1997; Welford, 1973). The effect of noise has been investigated on a multitude of tasks such as industrial assembly tasks (Levy-Leboyer, 1989), simple and choice reaction time tasks (Button, Behm, Holmes, & Mackinnon, 2004; Kyriakides & Leventhall, 1977), number writing tasks (Van Gemmert & Van Galen, 1997), puzzle tracing tasks (Percival & Loeb, 1980), rotary pursuit tasks (Simpson, Cox, & Rothschild, 1974), and graphical aiming tasks (Van Gemmert & Van Galen, 1994; 1997; 1998). Noise can be described as any unwanted sound (Matthews, Davies, Westerman, & Stammers, 2008).

The results on noise and motor performance have been somewhat ambiguous. At times noise has hindered performance and at times improved motor performance (Van Gemmert, 1997). Some potential explanations to explain why noise negatively affects performance is that it distracts the performer, reduces the attentional capacity of the performer, or increases stress (Matthews et al., 2008). Noise has also been found to affect physiological functions that may also contribute to decreased human performance, such as increases in blood pressure (Cohen, Evens, Krantz, & Stokols, 1980), heart rate (Carter & Beh, 1989; Parrot, Petiot, Lobreau, & Smolik, 1992), and eventually it may even lead to hypertension (Stanfeld & Matheson, 2003).

Typically when noise is presented at levels at or above 95dBs performance is deteriorated (Staal, 2004). For example, 95dB of noise negatively affects manual dexterity and the ability to

manipulate a tool (Nassiri et al., 2013). 95dBs also negatively affects continuous rotary pursuit tracking performance (Harteley, 1981) and number writing (Van Gemmert & Van Galen, 1997). When noise is below 95dBs, the effects of noise on motor performance is not as clear. Research has shown that noise below 95dBs may have a positive or a negative effect (Staal, 2004). For example, noise between 80 and 85dBs improved performance on a motor tracking task (Hockey, 1970; Gawon, 1982), impaired performance (Simpson, Cox, & Rothchild, 1974), and had no effect on motor performance (Abel, 2009). Similar ambiguous results have been found for choice RT tasks, with noise below 95dBs decreasing RT (Keuss, Van der Zee, & Van den Bree, 1990; Kyriakides, & Leventhall, 1977), increasing RT (Kyriakides, & Leventhall, 1977), and having no effect on RT (Corcoran, 1962).

Potential explanations for these ambiguous results can be explained by the neuromotor noise theory (Van Gemmert & Van Galen, 1997) and to a lesser extent the Yerkes-Dodson law (Yerkes & Dodson, 1908). The presentation of auditory noise affects the arousal of the participant. This arousal then activates the system which leads to increases in neuromotor noise in the system. If a performer is under aroused then the increase in activation with accompanying neuromotor noise should have a positive effect on performance. If the performer is at an optimal arousal level or over aroused, the increase in activation with its increase in neuromotor noise should hinder motor performance. An increase in effort can suppress the effects of an increase in arousal by disconnecting the direct pathway between arousal and activation.

One area of research that has received little attention is the effects of auditory noise on motor learning and how the results may provide additional support for the neuromotor noise theory. Therefore the purpose of the present study is to investigate the effects of physical stress in the form of auditory noise on motor learning. It is assumed that the addition of auditory noise

will increase the noise in the system, which signals the system to increase effort to channel arousal trying to obtain optimal activation levels for the task at hand. The increase in effort results in an increase of attention focus on relevant cues and goal directed behaviors (Gaillard, 2008). Therefore, it is hypothesized that motor learning will be facilitated when auditory noise is present due to increased effort. To address secondary questions posed previously, a second purpose of the study is to investigate the neuromotor noise theory through reaction time and pen pressure. The addition of auditory noise should result in increased amounts of pen pressure as result of a biomechanical adaptation to cope with the accuracy constraints of the aiming task (i.e., an increase in neuromotor noise leads to decreases in the efficiency of trajectory formation and decreases in end point accuracy). Furthermore, the increase in non-specific activation in the motor system as result of auditory noise possibly does decrease the time to initiate the movement (i.e., decreases in reaction time) due to reaching activation levels earlier than without the increased activation levels.

Method

Participants

Prior to participation, individuals read and signed the consent form approved by the Louisiana State University Institutional Review Board (Appendix A). Individuals then filled out a demographic and health questionnaire (Appendix B). Any person that reported psychological or neurological disorders or trouble with the use of the upper limbs was excluded from participation. In addition, all individuals reported having normal or corrected-to-normal vision and hearing. Following attrition due to the exclusion criteria, 24 individuals participated in the study aged between 20 and 25 years of age (M = 21.00, SD = 1.32). All volunteers received extra credit for participating in one of their kinesiology classes at the University.

Task and Equipment

At the beginning of the experiment participants were randomly assigned to one of two conditions. The first condition required participants to perform the same graphical aiming with obstacle avoidance task used in the previous chapter (AT). The second condition required participants to perform the same task but to increase physical stress, white noise was added (WN). For the auditory noise continuous white noise presented at 80dBs was used. The auditory noise was played using SimplyNoise (Reactor LLC). The same equipment used in the previous experiment (Chapter 2) was also used in the current study.

Procedure

Half of the participants were randomly placed into the physical stress group, i.e., aiming task with white noise (WN), and the other half were placed into the aiming task (AT) group, i.e., aiming task without auditory noise. Both groups completed the Perceived Stress Scale before participating in the study (Appendix C). The same procedure used in the previous experiment for the aiming task was used in the current experiment. During acquisition WN heard the 80dBs of continuous white noise while performing the aiming task and AT only performed the aiming task. Following acquisition both groups completed the modified NASA Task-Load Index (Appendix D). Five minutes after acquisition participants completed a six trial retention test that was completed in the same manner as acquisition but without feedback on movement time. Five minutes following retention, six trials of transfer were performed where both groups performed the aiming task without the presentation of noise (i.e., AT performed a second retention test, while WN performed a transfer test). Table 2 shows the task performed by each group during each phase of the experiment. Figure 12 shows the sequence of the aiming task for both WN and AT.

Table 2: Both groups with the task being performed during acquisition, retention, and retention/transfer.

Group	Acquisition	Retention	Retention/Transfer
Control	Aiming Task	Aiming Task	Aiming Task
Physical Stress	Aiming Task with 80dBs of noise	Aiming Task with 80dBs of noise	Aiming Task

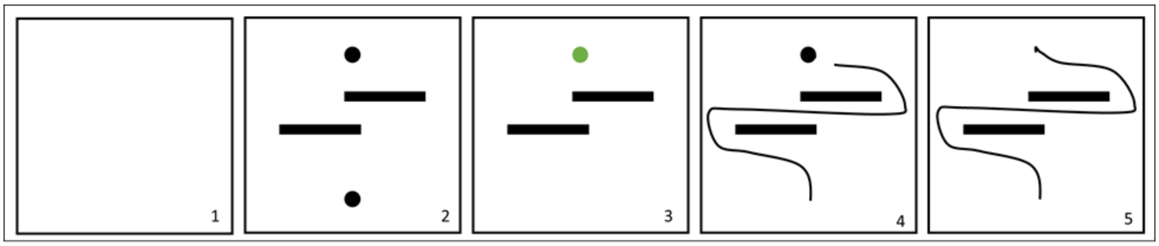

Figure 12: Diagram shows the sequence of the task for both groups. (1) Blank screen or , (2) Aiming task appeared on the screen and participants placed the pen tip in the starting target, (3) target turned green, (4) participant initiated movement, (5) target was reached to conclude the trial.

Data Analysis

The processing and analyses of the data in the current study was the same as used in the previous experiment (Chapter 2).

Results

The Perceived Stress Scale (PSS) scores were not significantly different for the WN (M = 19.75, SD = 6.51) and the AT (M = 15.17, SD = 4.63) groups, $t(22) = 1.99$, $p > .05$ (Figure 13). In addition, the scores reported on the NASA Task-Load Index were not significantly different for the WN (M = 55.08, SD = 17.14) and the AT (M = 58.58, SD = 13.03) groups, $t(22) = -.56$, $p > .05$ (Figure 13).

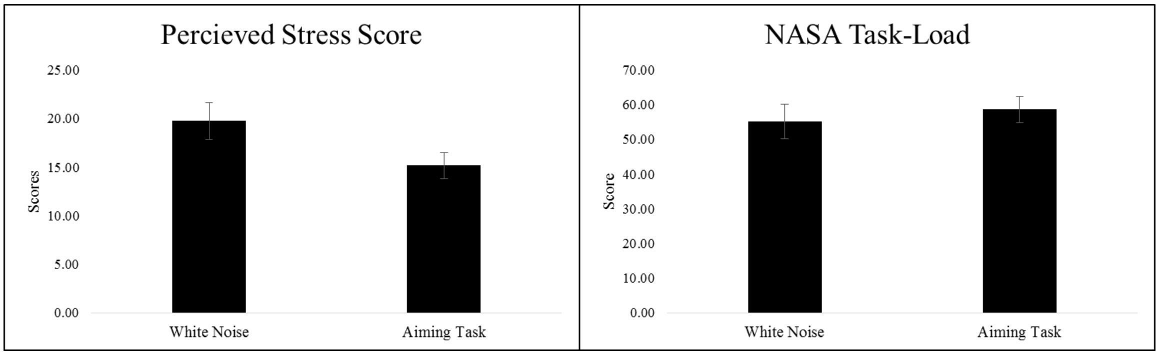

Figure 13: Percieved Stress Scores (left) and NASA task-load scores (right) for both groups with standard error bars.

Acquisition

Movement Time Errors. Both groups decreased MT from the beginning to the end of acquisition (Figure 14). This was supported by the main effect of block for AE, $F(9, 198) = 27.05$, $p < .001$, $\eta p^2 = .55$. Furthermore, AE did not show a significant group effect ($p > .05$), nor did it show a significant group × block interaction ($p > .05$). In addition, the same pattern of results was observed for CE, and VE. The main effects of block were both significant showing decreased error from the beginning to the end of acquisition, CE, $F(9, 198) = 29.59$, $p < .001$, $\eta p^2 = .57$, and VE, $F(9, 198) = 33.13$, $p < .001$, $\eta p^2 = .60$. There were no significant differences between WN and AT for any of the error measurements ($p > .05$). The group × block interactions were also not significant ($p > .05$).

Average Acceleration. Groups significantly increased their AA from the beginning to the end of acquisition ($F(9, 198) = 27.08$, $p <.001$, $\eta p^2 = .55$) but did not significantly differ from one another ($p > .05$). The group by block interaction was not significant ($p > .05$) (Figure 15).

Peak Acceleration. Groups significantly increased PA from the beginning to the end of acquisition ($F(9, 198) = 9.76$, $p <.001$, $\eta p^2 = .31$). Neither the main effect of group nor the group by block interaction were significant ($p > .05$) (Figure 15).

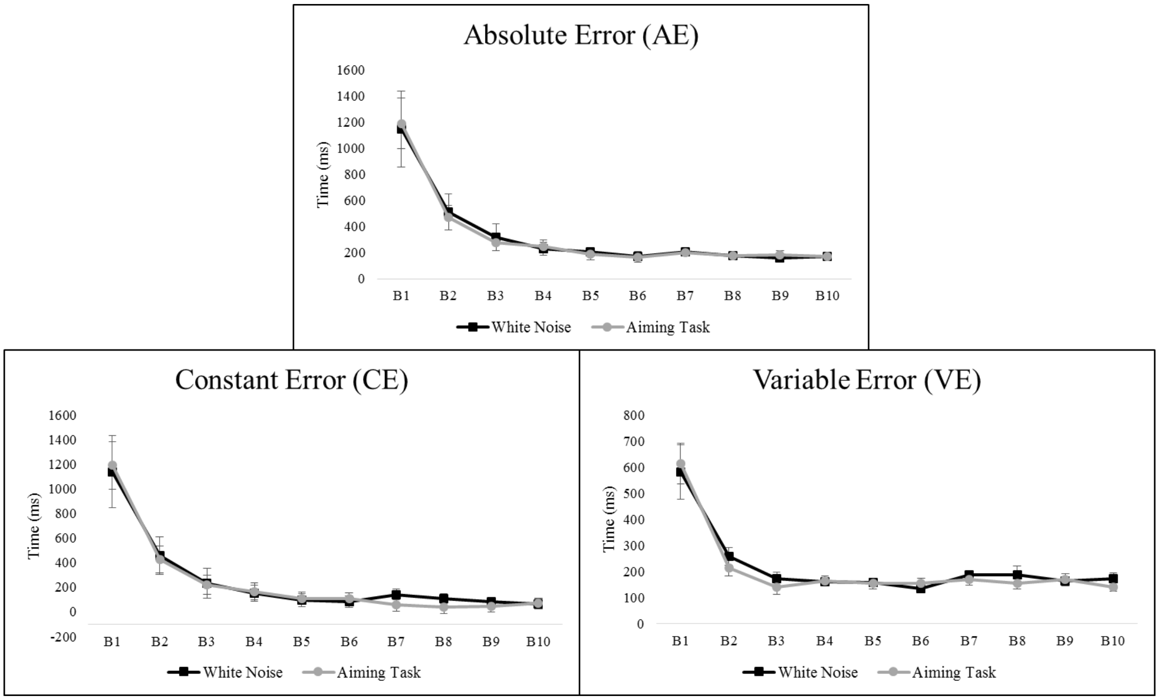

Figure 14: Average AE (top), CE (bottom left), and VE (bottom right) for each group during each acquisition block with standard error bars.

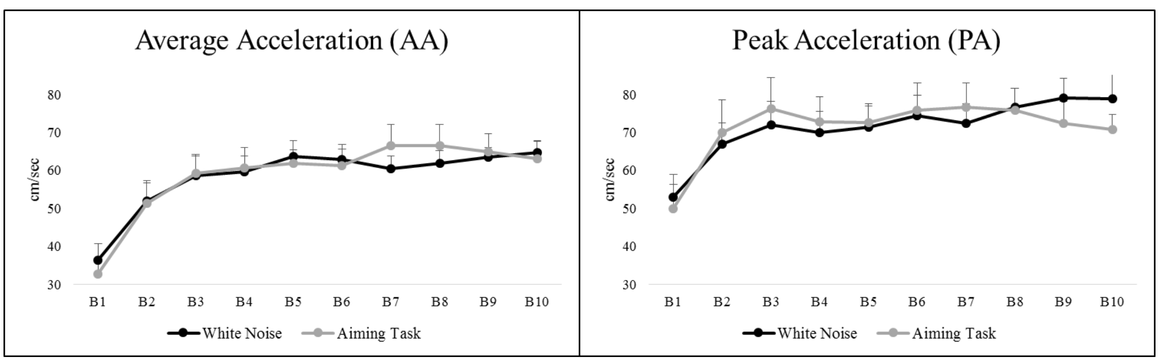

Figure 15: AA (left) and PA (right) for each group during acquisition with standard error bars.

Normalized Jerk. Both groups demonstrated smoother movements from the beginning to the end of acquisition (Figure 16). This observation was supported by the significant main effect of block, $F(9, 198) = 32.10$, $p < .001$, $\eta p^2 = .59$, and the absence of a significant group × block interaction, $F(9, 198) = .17$, $p > .05$. The groups did not perform significantly different from one another ($p > .05$).

Path Length. Groups increased PL from the beginning to the end of acquisition (Figure 15). This was supported by the significant main effect of block, $F(9, 198) = 9.76$, $p < .001$, $\eta p^2 = .31$. Both the main effect of group and the group × block interaction were not significant ($p > .05$) (Figure 16).

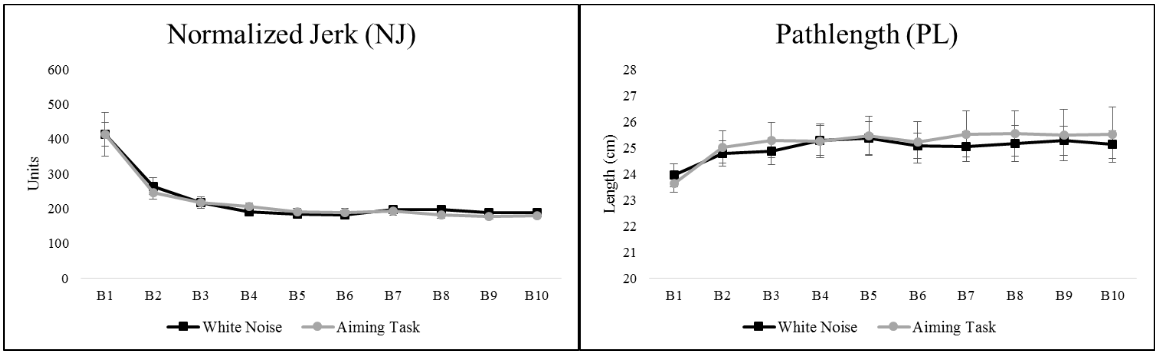

Figure 16: Average NJ (left) and PL (right) during each block of acquisition with standard error bars.

Reaction Time. Groups did not significantly decrease RT during practice (Figure 17). This was supported by the absence of a significant main effect of block ($p > .05$). The WN group did display significantly greater RTs throughout acquisition. This observation was supported by the significant main effect of group, $F(1, 22) = 7.54$, $p < .05$, $\eta p^2 = .26$, and the lack of a significant group × block interaction ($p > .05$).

Pen Pressure. Groups significantly decreased PP from the beginning to the end of acquisition (Figure 17). This was supported by a significant main effect of block, $F(9, 198) = 8.67$, $p < .001$, $\eta p^2 = .28$. Both the main effect of group and group by block interaction failed to reach significance ($p > .05$).

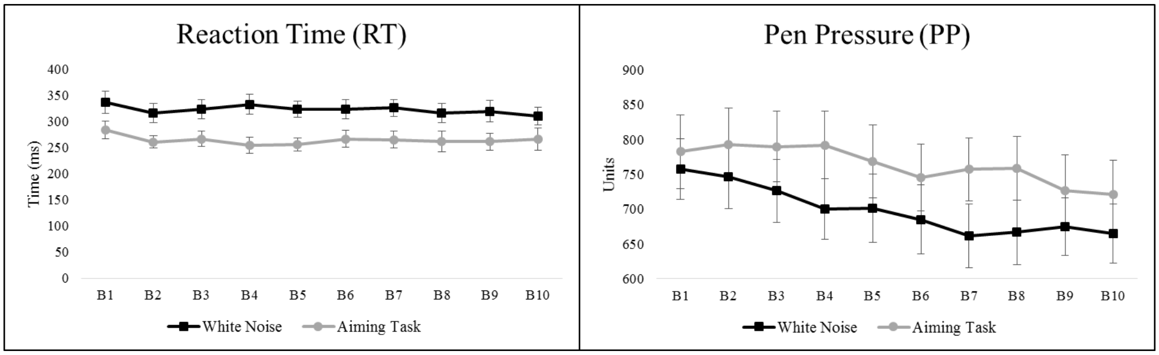

Figure 17: Average RT (left) and PP (right) during each block of acquisition with standard error bars.

Retention

Movement Time Errors. Both groups decreased MT from the beginning to the end of acquisition (Figure 18). This was supported by the main effect of block for AE, $F(1, 22) = 34.74$, $p < .001$, $\eta p^2 = .61$. Furthermore, AE did not show a significant group effect ($p > .05$), nor did it show a significant group × block interaction ($p > .05$). In addition, the same pattern of results was observed for CE, and VE. The main effects of block were both significant showing decreased error from the beginning to the end of acquisition, CE, $F(1, 22) = 38.87$, $p < .001$, $\eta p^2 = .64$, and VE, $F(1, 22) = 54.82$, $p < .001$, $\eta p^2 = .71$. There were no significant differences between WN and AT for CE or VE ($p > .05$). The group × block interactions were also not significant ($p > .05$).

Average Acceleration. Groups significantly increased AA from the first block of acquisition to the retention block ($F(1, 22) = 85.95$, $p <.001$, $\eta p^2 = .80$). The main effect of group was not significant and neither was the group by block interaction ($p >.05$) (Figure 19).

Peak Acceleration. Groups significantly increased PA from the first block of acquisition to the retention block ($F(1, 22) = 15.94$, $p <.001$, $\eta p^2 = .42$). The main effect of group was not significant and neither was the group by block interaction ($p >.05$) (Figure 19).

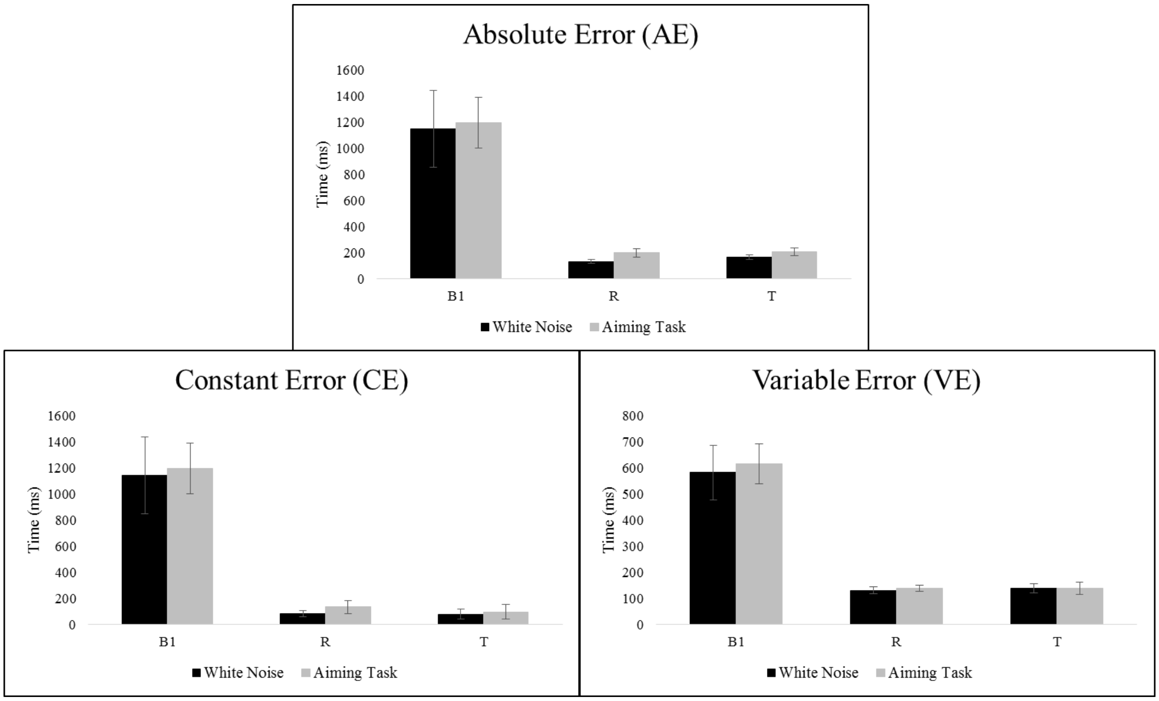

Figure 18: Average AE (top), CE (bottom left), and VE (bottom right) for both groups during the first block of acquisition, retention, and transfer with standard error bars.

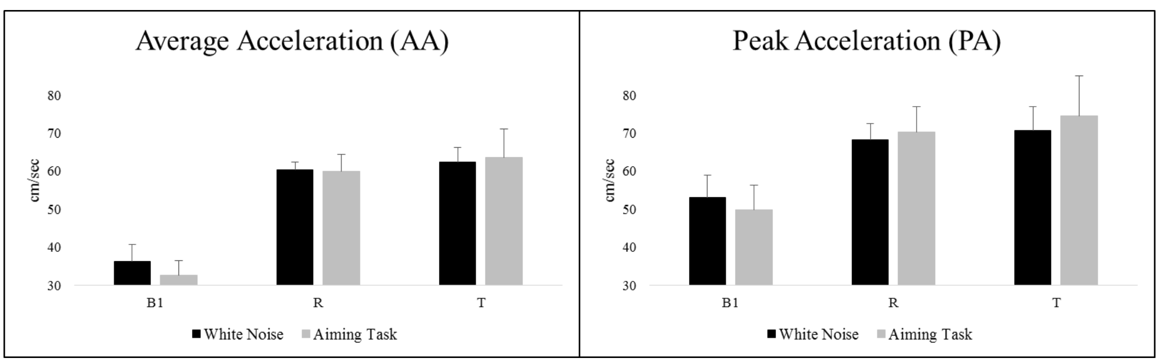

Figure 19: AA (bottom left) and PA (bottom right) for both groups during the first block of acquisition, retention, and transfer with standard error bars.

Normalized Jerk. Both groups demonstrated smoother movements from the beginning of acquisition to retention (Figure 20). This observation was supported by the significant main effect of block, $F(1, 22) = 38.70$, $p < .001$, $\eta p^2 = .64$, and the absence of a significant group × block interaction, $F(1, 22) = .01$, $p > .05$. The groups did not perform significantly different from one another ($p > .05$).

Path Length. Groups increased PL from the beginning to the end of acquisition (Figure 18). This was supported by the significant main effect of block, $F(1, 22) = 15.94$, $p = .001$, $\eta p^2 = .42$. Both the main effect of group and the group × block interaction were not significant ($p > .05$) (Figure 20).

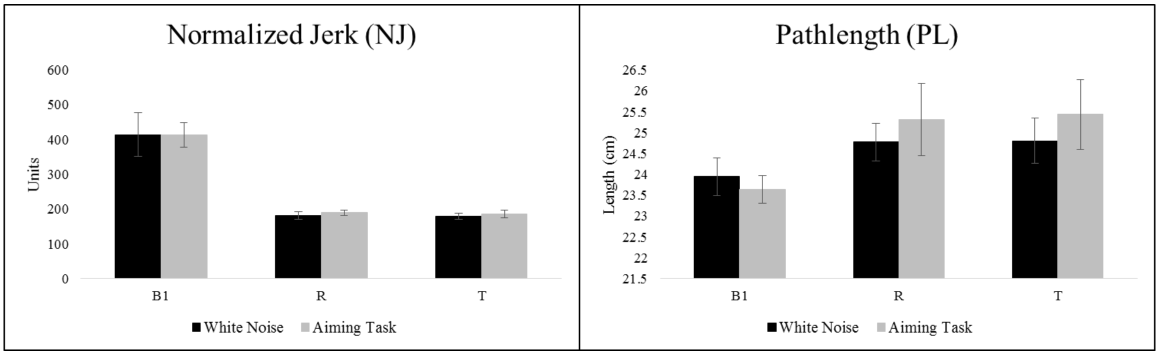

Figure 20: Average NJ (left) and PL (right) for both groups during the first block of acquisition, retention, and transfer with standard error bars.

Reaction Time. Groups did decrease RT from the beginning of acquisition to retention (Figure 21). This was supported by the significant main effect of block, $F(1, 22) = 5.86$, $p < .05$, $\eta p^2 = .21$. The WN group displayed significantly greater RTs, as evidenced by the significant main effect of group, $F(1, 22) = 4.96$, $p < .05$, $\eta p^2 = .08$. The group × block interaction was not significant ($p > .05$).

Pen Pressure. Groups significantly decreased PP from the beginning of acquisition to retention (Figure 21). This was supported by a significant main effect of block, $F(1, 22) = 13.04$, $p = .002$, $\eta p^2 = .37$. Both the main effect of group and the group by block interaction were not significant ($p > .05$).

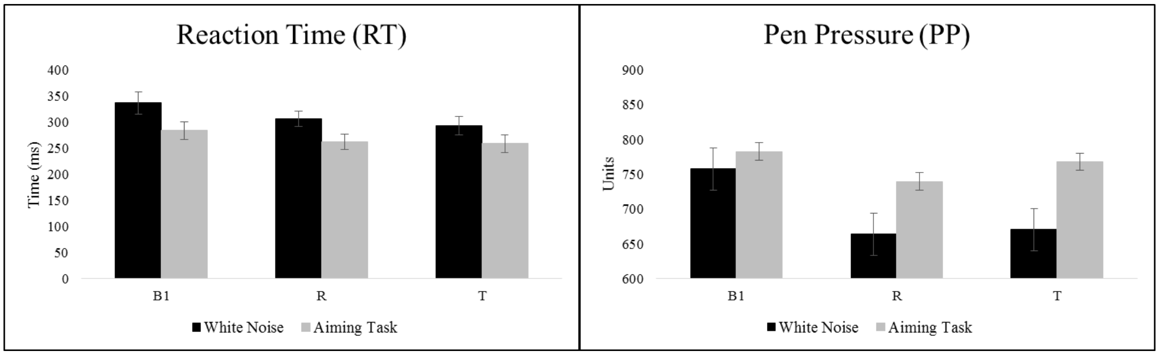

Figure 21: Average RT (left) and PP (right) for both groups during the first block of acquisition, retention, and transfer with standard errors.

Transfer

Movement Time Errors. Both groups decreased MT from the beginning to the end of acquisition (Figure 18). This was supported by the main effect of block for AE, $F(1, 22) = 30.79$, $p < .001$, $\eta p^2 = .58$. Furthermore, AE did not show a significant group effect ($p > .05$), nor did it show a significant group × block interaction ($p > .05$). In addition, the same pattern of results was observed for CE, and VE. The main effects of block were both significant showing decreased error from the beginning to the end of acquisition, CE, $F(1, 22) = 37.44$, $p < .001$, $\eta p^2 = .63$, and VE, $F(1, 22) = 50.33$, $p < .001$, $\eta p^2 = .70$. There were no significant differences between WN and AT for CE or VE ($p > .05$). The group × block interactions were also not significant ($p > .05$).

Average Acceleration. Groups significantly increased AA from the first block of acquisition to the transfer block. This was supported by the significant main effect of block ($F(1, 22) = 44.77$, $p < .001$, $\eta p^2 = .67$. Both the main effect of group and group × block interaction were not significant ($p > .05$) (Figure 19).

Peak Acceleration. Groups significantly increased AA from the first block of acquisition to the transfer block. This was supported by the significant main effect of block ($F(1, 22) =

37.56, $p < .001$, $\eta p^2 = .63$. Both the main effect of group and group × block interaction were not significant ($p > .05$) (Figure 19).

Normalized Jerk. Both groups demonstrated smoother movements from the beginning of acquisition to transfer (Figure 20). This observation was supported by the significant main effect of block, $F(1, 22) = 37.56$, $p < .001$, $\eta p^2 = .63$, and the absence of a significant group × block interaction, $F(1, 22) = .01$, $p > .05$. The groups did not perform significantly different from one another ($p > .05$).

Path length. Groups increased PL from the beginning to the end of acquisition (Figure 18). This was supported by the significant main effect of block, $F(1, 22) = 10.16$, $p = .004$, $\eta p^2 = .32$. Both the main effect of group and the group × block interaction were not significant (p > .05) (Figure 20).

Reaction Time. Groups did decrease RT from the beginning of acquisition to transfer (Figure 21). This was supported by the significant main effect of block, $F(1, 22) = 6.01$, $p < .05$, $\eta p^2 = .22$. The PN group displayed marginally significant greater RTs, $F(1, 22) = 4.08$, $p = .06$, $\eta p^2 = .16$. The group × block interaction was not significant ($p > .05$).

Pen Pressure. Groups significantly decreased PP from the beginning of acquisition to transfer (Figure 21). This was supported by a significant main effect of block, $F(1, 22) = 6.57$, $p < .05$, $\eta p^2 = .23$. Both the main effect of group and the group by block interaction were not significant ($p > .05$).

Discussion

The primary purpose of the present experiment was to investigate the effects of physical stress on motor skill performance and learning. To accomplish this half of the participants performed an aiming task with a barrier avoidance requirement while physical stress was

induced by presenting 80dBs of continuous white noise. The other half of the participants performed the same task but in the absence of continuous white noise.

During acquisition, groups significantly improved their performance for the dependent variables: absolute error (AE), constant error (CE), variable error (VE), average acceleration (AA), peak acceleration (PA), normalized jerk (NJ), path length (PL), and pen pressure (PP). No improvement was observed during acquisition for reaction time (RT). Unlike the addition of cognitive stress (chapter 2), the addition of physical stress did not impact performance either positively or negatively for AE, CE, VE, AA, PA, NJ, PL, and PP. The addition of white noise did cause increased RT.

It was hypothesized that the presentation of white noise would lead to greater motor learning. It was anticipated that the increase in physical stress would lead to an increase in the amount of effort the learner needed to put forth to accomplish the goal of the task. This increase in effort would then in turn facilitate motor learning. This hypothesis was not supported because the results during both retention and transfer failed to find a difference between the groups for all dependent variables except RT. For RT, groups significantly differed during retention but when the additional noise was removed during transfer the groups did not significantly differ.

Previous research suggested that physical noise at 80dBs and 95dBs had an activating effect on the motor system that decreased processing times which resulted in decreased reaction times (Keuss, Van der Zee, & Van den Bree, 1990; Van Gemmert & Van Galen, 1997). In addition to the activating effect of noise, research has also shown that noise at or above 95dBs hinders motor performance (Button, Behm, Holmes, & Mackinnon, 2004; Nassiri et al., 2013). Our data suggest that physical stress (80dBs of continuous white noise) had no effect on motor performance during acquisition, retention, or transfer. This finding, that physical stress does not

affect performance, has not been shown frequently in the literature but some studies have reported similar findings (Simpson, Cox, & Rothschild, 1974; Kyriakides & Leventhall, 1977). One potential explanation for these results is that individuals habituated to the continuous auditory noise. It is possible that an intermittent auditory noise or a tone during one aspect of performance may elicit a different result (Van Gemmert & Van Galen, 1998). It is also possible that low intensity of 80dBs of auditory noise is not sufficient to affect performance either positively or negatively in a relative simple timed aiming task as used in the current experiment. A higher intensity may increase arousal and therefore increase effort which would lead to improvements in motor learning.

In addition, the results of the NASA task-load index suggest that work load was not increased when adding 80dBs of white noise to the barrier-avoidance-aiming task. This offers another potential explanation as to why the white noise did not have an effect on performance or learning. If the additional auditory noise did not increase work load then the learners would not need additional effort to complete the task, so learning would not be facilitated.

A secondary aim of this study was to investigate the neuromotor noise theory. It was assumed that the 80dBs of noise would have an activating effect on the motor system that would result in a decrease in RT. The results from this experiment showed that RT was significantly greater for the group with the additional white noise. This indicates that the white noise affected processes needed to initiate the movement possibly as result of an increase of neuromotor noise in the system.

Future research should be geared towards different types and intensities of noise. More specifically, noise that is more difficult to habituate to or auditory noises which increase work load should be explored. A more direct investigation of the increase in activation and its

accompanying neuromotor noise when performing a fine motor should also be examined. One study used electromyography to investigate the relationship between increased stress and muscle activation when performing an aiming movement. It was found that greater cocontraction existed with an increase in both physical and cognitive stress (Van Galen, Muller, Meulenbroek, & Van Gemmert). Research should continue to investigate various noise types and intensities and the effects of muscle activation to better understand how stress effects performance and muscle activation.

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CHAPTER 4: PRACTICE SPECIFICITY

Introduction

Research suggests that mental representations of a practiced motor skill are developed with the available sensory information used during practice (Proteau, 1995; Proteau, Marteniuk, & Levesque, 1992). This means that sensory information becomes part of the “motor program” and the specific sensory information is needed to accurately reproduce the desired motor skill. For example, Ivens and Marteniuk (1997) asked participants to perform rapid arm movements to different targets. Some participants performed these arm movements with vision or when vision was removed. In addition, those that practiced the rapid arm movements without vision were separated into a low practice amount or a high practice amount. The authors found that the group without vision and the higher amount of practice performed the poorest during a transfer test with vision. These results suggest that available sensory information becomes part of the movement representation or “motor program”. When the sensory information does not match the conditions during practice, performance will be hindered. Furthermore, when individuals learned to walk a 20m line that was 2.5cm wide (precision walking task) with or without vision and with low or high amounts of practice, those with more practice without vision performed the poorest on a transfer test with vision (Proteau, Tremblay, & Dejaeger, 1998). Evidence supporting the specificity of practice hypothesis has also been found in various tasks such as weight lifting (Tremblay & Proteau, 1998), visual tracking (Coull, Tremblay, & Elliott, 2001), one handed ball catching (Tremblay & Proteau, 2001), and an underhand volleyball serve (Travlos, 2010).

Movahedi, Sheikh, Bagherzadeh, Hemayattalab, and Ashayeri (2007) proposed a practice specificity based model of arousal. They suggest that learning is specific to the arousal level of the performer. Based on practice specificity one would assume that the arousal during practice

must match the same arousal level during a future performance. However, various arousal theories contradict the expected findings of specificity of practice. The inverted-U theory (Yerkes & Dodson, 1908) suggests that performance reaches an optimal level when arousal is at a mid-level and drive theory suggests that performance increases as arousal increases (Hull, 1943). To better understand the relationship between arousal and specificity of practice, Movahedi et al., (2007) had participants learn a basketball free throw under either high arousal levels or low arousal levels. They found that when arousal levels during retention/transfer were the same as the practice conditions performance was best. These results suggest that specificity of practice extends to research on arousal.

Research has also investigated the relationship between performer anxiety and specificity of practice. Lawrence et al. (2013) found that when individuals learned a complex rock climbing task with increasing amounts of anxiety, performance on a future test was maximized when the anxiety matched the anxiety levels of practice. These results provide further evidence for a potential relationship between various types of stress and specificity of practice.

Practice specificity has received little attention when looking at increased work load or increased auditory noise (cognitive and physical stressors). One would think that if a learner practices in a condition with additional stressors presented then future performance should be maximized when the same conditions are met. The results from the two previous studies do not align with the idea of practice specificity. The results from the previous experiments found that when the stress was removed in a transfer test, both the additional work load group and the additional white noise group did not perform significantly different than their control group.

The first two experiments investigated the effects of two stress types (increased mental load and white noise) on the performance and learning of a motor skill. The primary finding in

these experiments is that increased amounts of stress or work load do not positively or negatively influence motor learning. In these experiments learners practiced a primary motor task with additional stress and then had the additional stress removed during a transfer test. These results are contrary to specificity of practice. An additional area that still needs to be explored is specificity of practice when learners practice without additional stress and then have a stressor added during a transfer test.

The purpose of this study was to investigate the specificity of practice on increased work load (cognitive stress) and additional auditory noise (physical stress). If stress becomes part of the motor representation, then additional stress needs to be present during practice if the stressor will be present during a future performance. To test this, additional stress will be added during transfer that was not present during acquisition. A secondary aim of this study was confirm the results found in the previous studies.

Method

Participants

Prior to participation, individuals read and signed the consent form approved by the Louisiana State University Institutional Review Board (Appendix A). Individuals then filled out a demographic and health questionnaire (Appendix B). Any person that reported psychological or neurological disorders or trouble with the use of the upper limbs was excluded from participation. In addition, all individuals reported having normal or corrected-to-normal vision and hearing. Following attrition due to the exclusion criteria, 48 individuals participated in the study aged between 19 and 24 years of age (M = 20.33, SD = 0.95). All volunteers received extra credit for participating in one of their kinesiology classes at the University.

Task and Equipment

At the beginning of the experiment participants were randomly assigned to one of four conditions. Two conditions required participants to perform the same graphical aiming with obstacle avoidance task with movement duration requirement used in the previous chapters. The other two conditions were the same as the experimental conditions in chapters 2 and 3. One group was required to simultaneously count backwards by threes while performing the timed aiming task, and the other group was presented with 80dBs of continuous white noise while performing the timed aiming task. The same equipment used in the previous experiments (Chapter 2 and 3) was also used in the current study.

Procedure

Twelve participants were randomly assigned to a group that completed the timed aiming task with the barrier avoidance during acquisition and retention but during transfer they performed the task with the secondary counting task (Transfer to Work Load: TWL). Another twelve participants performed the timed aiming task during acquisition and retention but performed transfer while hearing 80dBs of continuous white noise (Transfer to White Noise: TWN). Twelve participants performed the aiming task while counting backwards by threes during acquisition, retention, and transfer (Work Load: WL) and twelve participants performed the task while hearing white noise (White Noise: WN). Before participating in the study, participants signed the informed consent (Appendix A) and filled out the health and demographic questionnaire (Appendix B). Subsequently, they were asked to count backwards by threes as fast as possible from a random number presented. They were timed in their ability to count backwards by threes for 10 numbers (see Figure 23). Participants then completed the Perceived Stress Scale (Appendix C). In the current experiment the same procedure for the timed aiming

with obstacle avoidance task was used as in the previous experiments. During acquisition WN was presented with the 80dBs of continuous white noise while performing the timed aiming task and WL performed the task while counting backwards by threes. TWN and TWL only performed the timed aiming task. Following acquisition all participants completed the modified NASA Task-Load Index (Hart, 2006; Appendix D). Five minutes after acquisition participants completed a six trial retention test that was completed in the same manner as acquisition but without feedback on movement time. Five minutes following retention, six trials of transfer were performed where WL and WN performed the task in the same manner they performed acquisition and retention. TWL performed the transfer trials while simultaneously performing the counting task, and TWN performed the task while the continuous white noise was presented. Table 3 shows the task performed by each group during each phase of the experiment. Figure 22 shows the sequence of the aiming task for both WN and AT.

Table 3: Both groups with the task being performed during acquisition, retention, and retention/transfer.

Group	Acquisition	Retention	Transfer/Retention
Control 1	Aiming Task	Aiming Task	Aiming Task with verbal counting
Control 2	Aiming Task	Aiming Task	Aiming Task with 80dBs of noise
Cognitive Stress	Aiming Task with verbal counting	Aiming Task with verbal counting	Aiming Task with verbal counting
Physical Stress	Aiming Task with 80dBs of noise	Aiming Task with 80dBs of noise	Aiming Task with 80dBs of noise

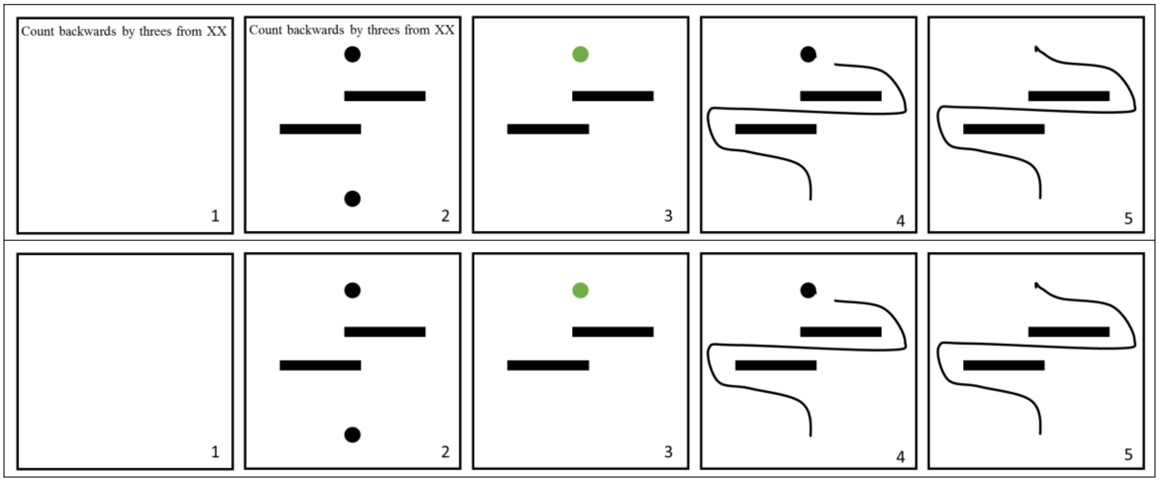

Figure 22: The top diagram shows the sequence of the task for the Work Load group and the bottom diagram shows the task for the Aiming Task group. (1) Blank screen or instruction to count backwards, (2) Aiming task appeared on the screen and participants placed the pen tip in the starting target, (3) target turned green, (4) participant initiated movement, (5) target was reached to conclude the trial.

Data Analysis

The data collected by MovAlyzeR was processed with a custom made Matlab-program (Mathworks Inc., Natick, Massachusetts, USA). The position signals of the pen tip were dual pass filtered with a Butterworth fourth order filter with a cut off frequency of 7 Hz. Both the onset and offset of the pen movement was determined by 5% of the peak velocity. The dependent variables analyzed were absolute error (AE), constant error (CE), variable error (VE), average and peak acceleration (AA and PA), path length (PL), normalized jerk (NJ), axial pen pressure (PP), and reaction time (RT). To calculate AE, CE, and VE; movement time (MT) had to be first calculated. MT was defined as the time period between the onset and offset of the movement (5% of the peak velocity). AE, CE, and VE were calculated in the same manner that was explained in chapter 2 (i.e., CE=T-MT, AE=|CE|, and VE=√(∑(MT mean – MT trial)^2/N)). Acceleration is the second derivative of displacement and provided information on the estimated force required to propel the pen over the surface of the tablet. Jerk is the rate of change in

acceleration and NJ is jerk normalized for size and distance (see Van Gemmert, Teulings, & Stelmach, 1998). RT is the time period from the go-stimulus onset to the initiation of movement.

The 60 acquisition trials were analyzed in ten blocks of six. All dependent variables were analyzed with separate mixed factors ANOVAs with groups as the between factor and blocks as the within factor (i.e., 4 groups × 10 blocks). Bonferroni post hoc tests were performed to analyze any significant main effect of group. To analyze retention and retention/transfer, separate mixed factors ANOVAs were applied to each dependent variable with the groups as the between factors and the first block of acquisition and the retention or retention/transfer block as the within factors (i.e., 4 group × 2 blocks). When a significant block × group interaction was observed, independent t-tests with a Bonferroni correction were applied to the data. The composite scores for the counting ability, Perceived Stress Scale and the NASA task-load index were each totaled. Separate one-way ANOVAs with Bonferroni post hoc tests were performed to determine the presence of possible group differences.

Results

The length of time to count backwards by threes did not significantly differ among groups ($F(3, 47) = 0.14$, $p > .05$). Figure 23 shows the mean counting times with standard error for each group. The Perceived Stress Scale (PSS) scores were not significantly different for WL, TWL, WN, and TWN, $F(3, 47) = 1.17$, $p > .05$ (Figure 24). This indicates that groups did not start the experiment with different levels of emotional stress. Following acquisition, participants completed the NASA Task-load to provide an indication of the workload needed to complete the task (Figure 20). WL had significantly greater NASA Task-load scores than TWL ($p = .002$) and WN ($p = .007$), but not TWN ($p > .05$).

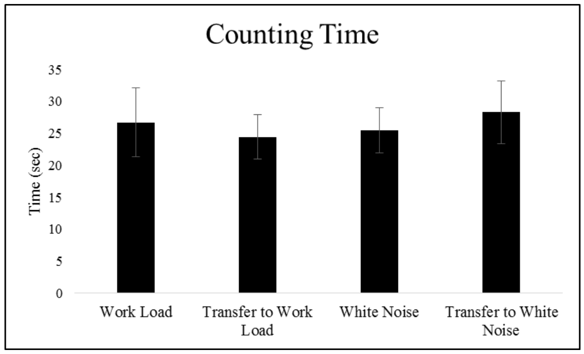

Figure 23: Average completion time to count 10 numbers in sequence backwards by threes with standard error bars.

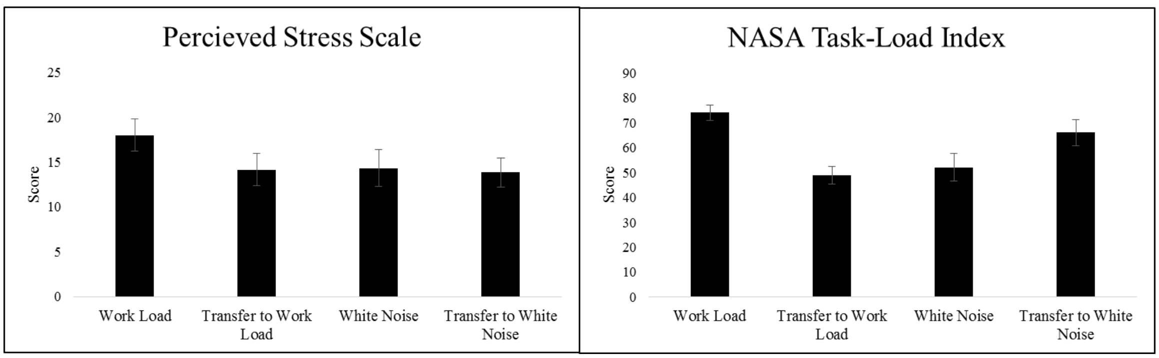

Figure 24: Percieved Stress Scores (left) and NASA task load index scores (right) for each group with standard error bars.

Acquisition

Movement Time Errors. Groups decreased AE from the beginning to the end of acquisition (Figure 25). This was supported by the main effect of block, $F(9, 396) = 61.65$, $p < .001$, $\eta p^2 = .58$. Furthermore, the main effect of group was also significant for AE, $F(3, 44) = 7.60$, $p < .001$, $\eta p^2 = .34$, with WL having more error that the other groups. The group by block interaction was also significant ($F(27, 396) = 8.89$, $p < .001$, $\eta p^2 = .38$). In addition, the same pattern of results was observed for CE, and VE. The main effects of block were both significant showing decreased error from the beginning to the end of acquisition, CE, $F(9, 396) = 62.47$, $p < .001$, $\eta p^2 = .59$, and VE, $F(9, 396) = 26.26$, $p < .001$, $\eta p^2 = .37$. For both CE and VE the main effects of group were significant (CE, $F(3, 44) = 7.81$, $p < .001$, $\eta p^2 = .35$; VE, $F(3, 44) = 15.03$,

$p < .001$, $\eta p^2 = .51$). For both variables WL showed more error that the other three groups. The group by block interactions were also significant for CE ($F(27, 396) = 8.03$, $p < .001$, $\eta p^2 = .35$) and VE ($F(27, 396) = 3.15$, $p < .001$, $\eta p^2 = .18$).

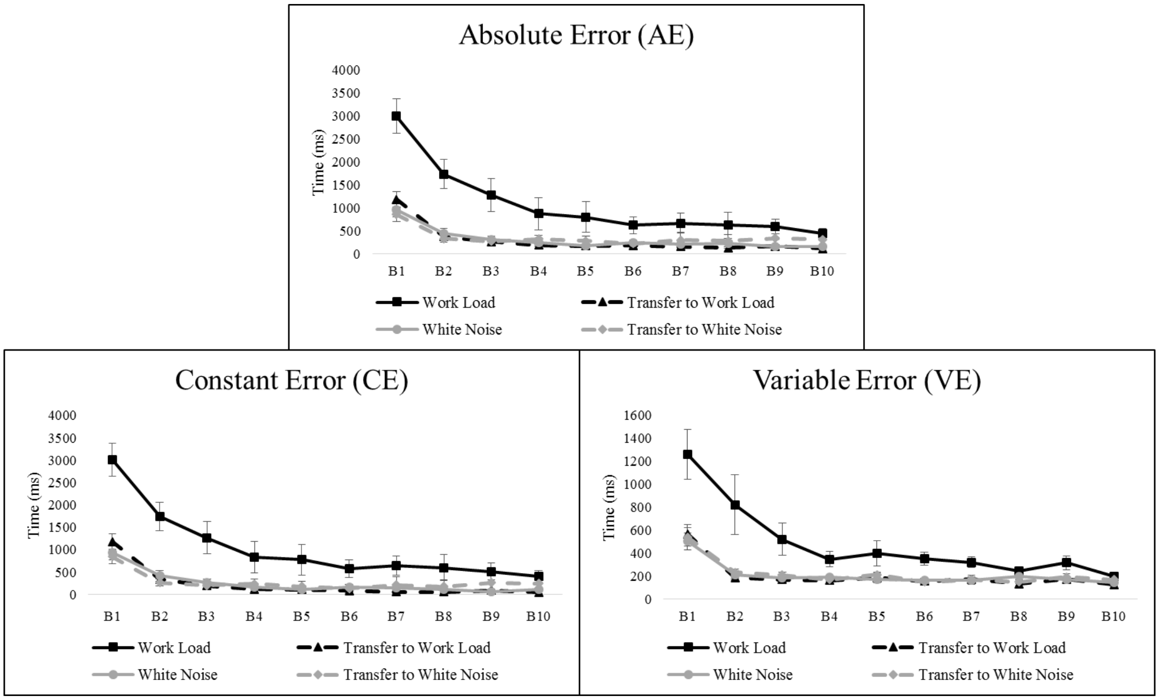

Figure 25: The average AE (top), CE (bottom right), and VE (bottom left) for each group during each acquisition block with standard error bars.

Path Length. The main effect of block was significant with the first acquisition block being significantly different from blocks two through nine, $F(9, 396) = 7.44$, $p < .001$, $\eta p^2 = .15$ (Figure 26). The main effect of group, as well as the group × block interaction were not significant ($p > .05$).

Normalized Jerk. Groups produced significantly smoother movements from the beginning to the end of acquisition (Figure 26). This observation was supported by the significant main effect of block, $F(9, 396) = 18.70$, $p < .001$, $\eta p^2 = .30$. The main effect of group was also significant, $F(3, 44) = 7.00$, $p = .001$, $\eta p^2 = .32$. The post hoc tests revealed that WL

had greater NJ than the other three groups. The group × block interaction was also significant, $F(27, 396) = 5.41$, $p < .001$, $\eta p^2 = .27$.

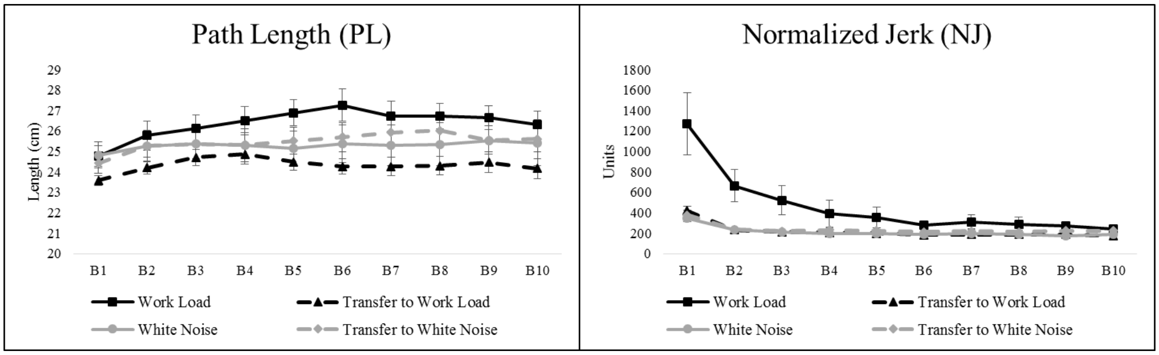

Figure 26: Average PL (left) and NJ (right) for WL, TWL, WN, and TWN during each block of acquisition with standard error bars.

Average Acceleration. The main effect of block for AA was significant ($F(9, 396) = 37.37$, $p < .001$, $\eta p^2 = .46$) with groups increasing their AA from the beginning to the end of acquisition (Figure 27). The main effect of group was also significant ($F(3, 44) = 2.76$, $p = .05$, $\eta p^2 = .16$) with WL having lower AA than TWN. The group by block interaction was not significant ($p > .05$).

Peak Acceleration. The main effect of block for PA was significant ($F(9, 396) = 17.14$, $p < .001$, $\eta p^2 = .28$) with groups increasing their PA from the beginning to the end of acquisition (Figure 27). However, unlike AA, the main effect of group was not significant ($p > .05$). The group by block interaction was also not significant ($p > .05$).

Reaction Time. The main effect of group was significant with a decrease in RT from the beginning to the end of acquisition ($F(9, 396) = 1.97$, $p < .05$, $\eta p^2 = .04$). This was caused by the decrease in RT for WL (Figure 28). The main effect of group was significant ($F(3, 44) = 27.03$, $p < .001$, $\eta p^2 = .65$) and the post hoc tests showed that WL had greater RTs that the other groups. The group by block interaction was also significant, $F(27, 396) = 3.52$, $p < .001$, $\eta p^2 = .19$.

Pen Pressure. Groups significantly decreased PP from the beginning of acquisition to the end, $F(9, 396) = 7.74$, $p < .001$, $\eta p^2 = .15$ (Figure 24). Neither the main effect of group or group by block interaction was significant ($p > .05$).

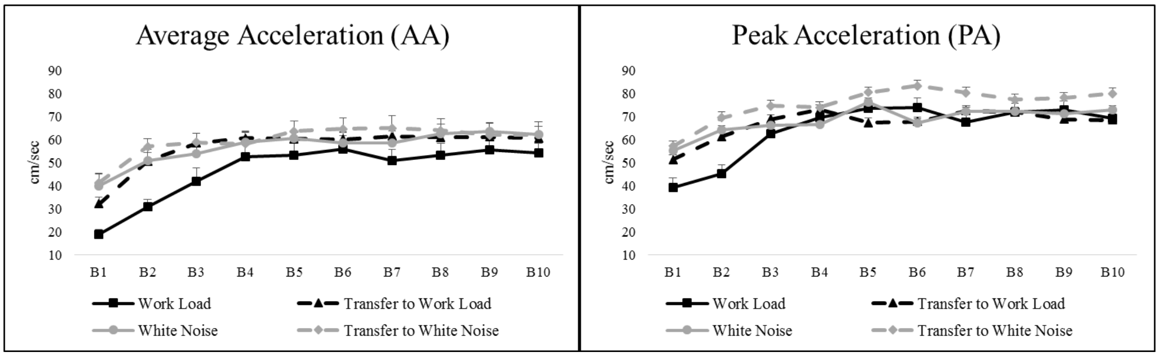

Figure 27: The AA (left) and PA (right) for WL, TWL, WN, ans TWN during each block of acquisition with standard error bars.

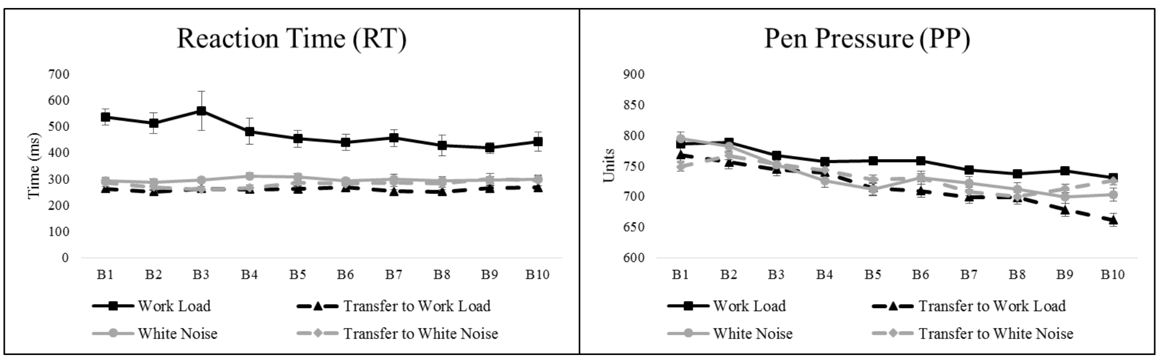

Figure 28: Average RT (left) and PP (right) during each block of acquisition with standard error bars.

Retention

Movement Time Errors. Figure 29 shows the mean AE, CE, and VE during the first block of acquisition and retention. The groups significantly decreased AE which was supported by the main effect of block, $F(1, 44) = 113.56$, $p < .001$, $\eta p^2 = .72$. The main effect of group was significant ($F(3, 44) = 19.23$, $p < .001$, $\eta p^2 = .57$) as was the group by block interaction, $F(3, 44) = 16.44$, $p < .001$, $\eta p^2 = .53$. The independent t-tests revealed that WL had significantly greater AE during the first block of acquisition than the other groups ($p < .001$) but no significant

differences were found during retention ($p > .05$). All groups significantly decreased AE from the beginning of acquisition to retention ($p < .05$).

The main effect of block was significant for CE, $F(1, 44) = 116.62$, $p < .001$, $\eta p^2 = .73$, and VE, $F(1, 44) = 68.71$, $p < .001$, $\eta p^2 = .61$, with groups decreasing error from the first block of acquisition to retention. The main effect of group was also significant for CE, $F(3, 44) = 18.27$, $p < .001$, $\eta p^2 = .56$, and VE, $F(3, 44) = 9.92$, $p < .001$, $\eta p^2 = .40$ with WL having greater error than the other groups. In addition, the group × block interaction was also significant for CE, $F(3, 44) = 15.70$, $p < .001$, $\eta p^2 = .52$, and VE, $F(3, 44) = 6.05$, $p = .002$, $\eta p^2 = .29$. The independent t-tests showed that all groups significantly decreased both CE and VE ($p < .05$). During the first block of acquisition WL had significantly greater CE ($p < .001$) and VE ($p < .01$). During retention there were no significant differences between groups ($p > .05$).

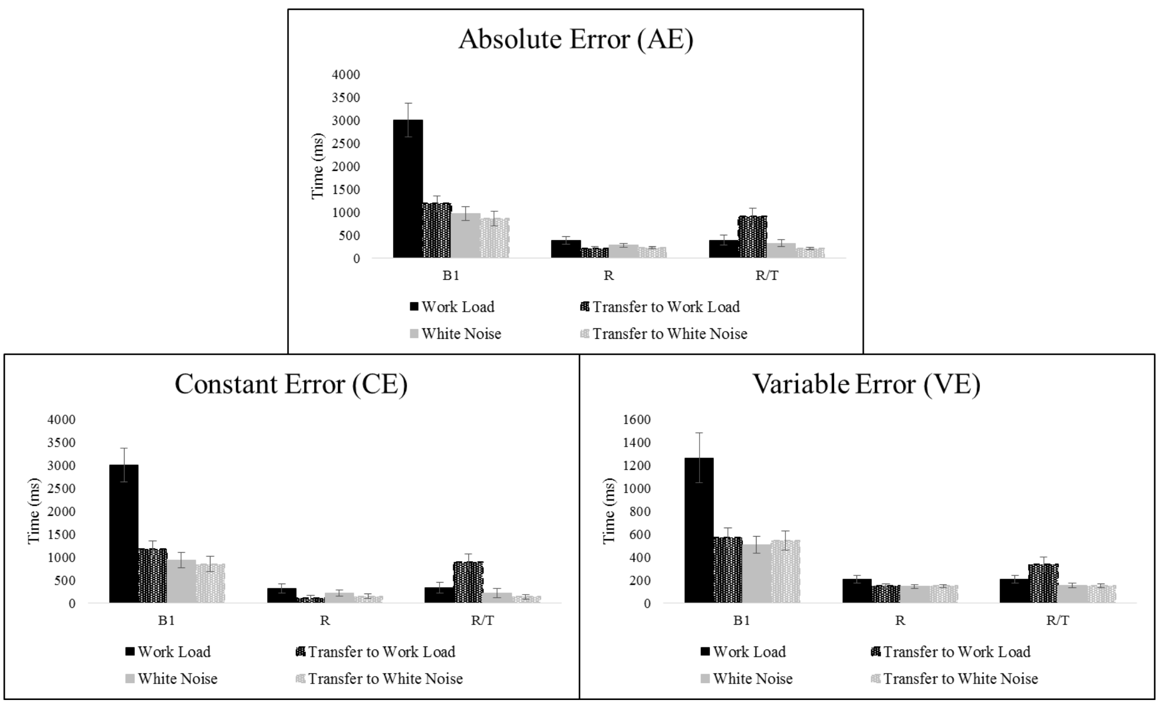

Figure 29: Average AE (top), CE (bottom left), and VE (bottom right) for both groups during the first block or acquisition, retention, and transfer with standard error bars.

Path Length. The main effect of block for PL was significant with longer PLs being produced during retention than the beginning of acquisition ($F(1, 44) = 8.00$, $p < .01$, $\eta p^2 = .15$). The main effect of group and the group by block interaction were not significant ($p > .05$) (Figure 30).

Normalized Jerk. Participants produced smoother movements during retention than at the beginning of acquisition (Figure 30). This was supported by the main effect of block ($F(1, 44) = 25.00$, $p < .001$, $\eta p^2 = .36$). The main effect of group was significant ($F(3, 44) = 8.20$, $p < .001$, $\eta p^2 = .36$) and the post hoc tests revealed that WL had significantly greater NJ. The group by block interaction was also significant ($F(3, 44) = 7.62$, $p < .001$, $\eta p^2 = .34$). This was most likely caused by the decrease in NJ for the WL condition. The independent t-tests revealed that WL had significantly greater NJ during the first block of acquisition than the other groups ($p < .01$) but no group differences were found in retention ($p > .05$). In addition, the independent t-tests revealed that only WL significantly decreased NJ from the beginning of acquisition to retention ($p < .001$).

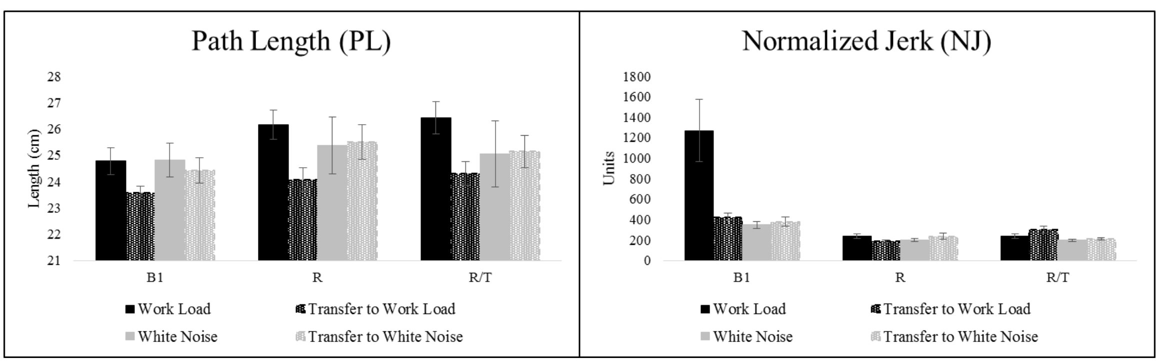

Figure 30: Average PL (left) and NJ (right) for both groups during the first block or acquisition, retention, and transfer with standard error bars.

Average Acceleration. The main effect of group for AA was significant with an increase in AA from the beginning of acquisition to retention ($F(1, 44) = 79.07$, $p < .001$, $\eta p^2 = .64$). The main effect of group was significant ($F(3, 44) = 3.96$, $p < .05$, $\eta p^2 = .21$). The post hoc tests

revealed that WL had significantly less AA than TWN. The group by block interaction was also significant ($F(3, 44) = 2.76$, $p = .05$, $\eta p^2 = .16$). The independent t-tests revealed significantly less AA for WL than WN or TWN during the first block of acquisition ($p < .01$). No significant differences between groups were found during retention ($p > .05$). In addition, all groups significantly increase AA from the beginning of acquisition to retention ($p < .01$) (Figure 31).

Peak Acceleration. The main effect of block for PA was significant with lower PA being recorded during the beginning of acquisition than retention ($F(1, 44) = 34.90$, $p < .001$, $\eta p^2 = .44$. Both the main effect of group and the group by block interaction were not significant ($p > .05$) (Figure 31).

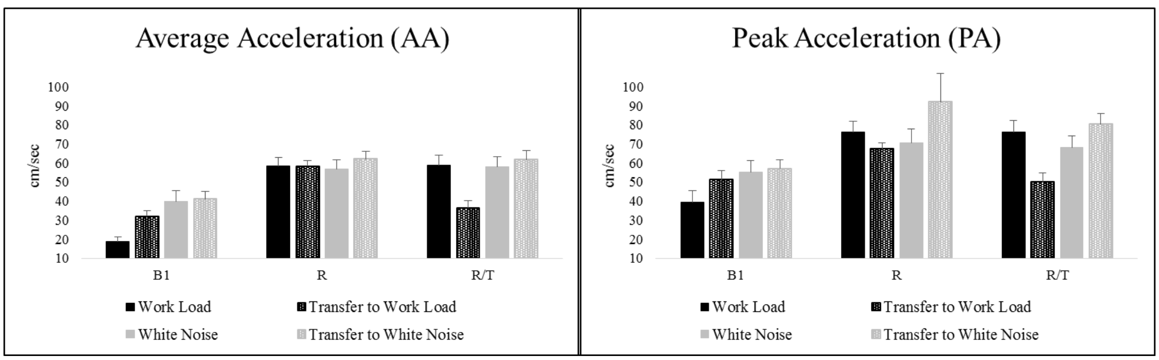

Figure 31: AA (left) and PA (right) for both groups during the first block or acquisition, retention, and transfer with standard error bars.

Reaction Time. The main effect of block for RT was significant ($F(1, 44) = 18.46$, $p < .001$, $\eta p^2 = .30$). This was caused by the decrease in RT for the WL condition. The main effect of group was also significant ($F(3, 44) = 43.25$, $p < .001$, $\eta p^2 = .75$) and the post hoc tests revealed that WL had greater RTs. The group by block interaction was also significant ($F(3, 44) = 12.87$, $p < .001$, $\eta p^2 = .47$). The independent t-tests revealed that only the WL condition improved from the beginning of acquisition to retention by decreasing RT ($p < .001$). WL had significantly higher RTs during the beginning of acquisition ($p < .001$) and retention ($p < .001$) than the other groups (Figure 32).

Pen Pressure. The main effect of block was significant with PP decreasing from the beginning of acquisition to retention ($F(1, 44) = 7.60$, $p < .01$, $\eta p^2 = .15$). Both the main effect of group and the group by block interaction were not significant ($p > .05$) (Figure 32).

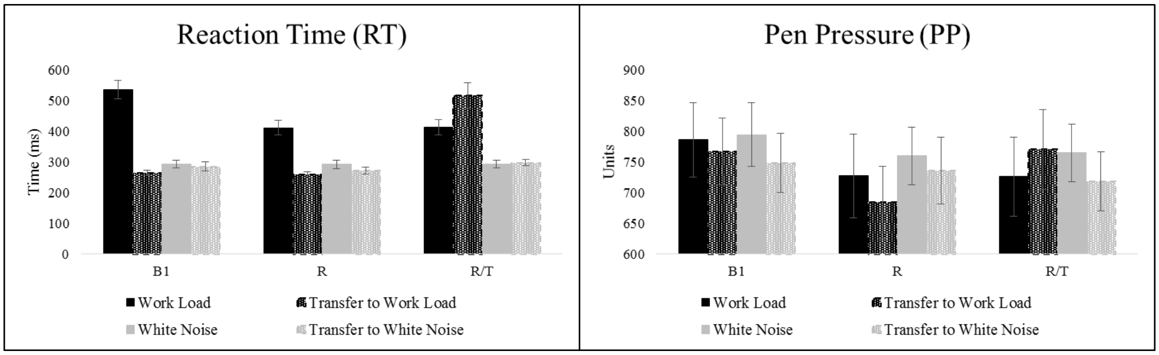

Figure 32: Average RT (left) and PP (right) for both groups during the first block or acquisition, retention, and transfer with standard error bars.

Transfer

Movement Time Errors. Figure 29 shows the mean AE, CE, and VE during the first block of acquisition and transfer. The groups significantly decreased AE which was supported by the main effect of block, $F(1, 44) = 70.58$, $p < .001$, $\eta p^2 = .62$. The main effect of group was significant ($F(3, 44) = 15.67$, $p < .001$, $\eta p^2 = .52$) and the post hoc tests revealed that WL had significantly more AE that all other groups ($p < .001$) and TWL had significantly more AE than TWN ($p < .05$). The group by block interaction was also significant, $F(3, 44) = 17.88$, $p < .001$, $\eta p^2 = .55$. The independent t-tests revealed that WL and TWN decreased AE from baseline to transfer ($p < .05$) and WN marginally decreased AE (p = .06). As mentioned previously, WL had significantly greater AE during the beginning of acquisition ($p < .001$). However, during transfer TWL had significantly more AE than the other groups ($p \leq .01$).

The main effect of block was significant for CE, $F(1, 44) = 69.42$, $p < .001$, $\eta p^2 = .61$, and VE, $F(1, 44) = 60.29$, $p < .001$, $\eta p^2 = .58$, with groups decreasing error from the first block of acquisition to transfer. The main effect of group was also significant for CE, $F(3, 44) = 15.95$,

$p < .001$, $\eta p^2 = .52$, and VE, $F(3, 44) = 7.61$, $p < .001$, $\eta p^2 = .34$ with WL having greater error than the other groups. In addition, the group × block interaction was also significant for CE, $F(3, 44) = 16.52$, $p < .001$, $\eta p^2 = .53$, and VE, $F(3, 44) = 7.99$, $p < .001$, $\eta p^2 = .35$. The independent t-tests for CE showed that WL, WN, and TWN significantly improved from the beginning of acquisition to transfer ($p < .05$). During the first block of acquisition WL had significantly greater CE ($p < .001$) but during transfer TWL had significantly greater CE than the other groups ($p \leq .01$). The independent t-tests for VE showed that WL, WN, and TWN improved from the beginning of acquisition to transfer ($p < .05$). The independent t-tests also revealed that WL had significantly greater VE during the first block of acquisition ($p < .01$) and TWL had significantly more VE during transfer than WN and TWN ($p \leq .01$).

Path Length. The main effect of block for PL was significant with longer PLs being produced during transfer than the beginning of acquisition ($F(1, 44) = 6.04$, $p < .05$, $\eta p^2 = .12$). The main effect of group and the group by block interaction were not significant ($p > .05$) (Figure 30).

Normalized Jerk. Participants produced smoother movements during transfer than at the beginning of acquisition (Figure 30). This was supported by the main effect of block ($F(1, 44) = 22.32$, $p < .001$, $\eta p^2 = .34$). The main effect of group was significant ($F(3, 44) = 7.80$, $p < .001$, $\eta p^2 = .35$) and the post hoc tests revealed that WL had significantly greater NJ than the other groups ($p < .05$) and TWL had significantly more NJ than TWN ($p < .05$). The group by block interaction was also significant ($F(3, 44) = 8.17$, $p < .001$, $\eta p^2 = .36$). The independent t-tests revealed that WL decreased NJ from the beginning of acquisition to transfer ($p < .001$). WL had significantly greater NJ during the first block of acquisition than the other groups ($p < .01$) and TWL had significantly greater NJ than WN and TWN during transfer ($p < .05$).

Average Acceleration. The main effect of group for AA was significant with an increase in AA from the beginning of acquisition to transfer ($F(1, 44) = 37.62$, $p < .001$, $\eta p^2 = .46$). The main effect of group was significant ($F(3, 44) = 8.20$, $p < .001$, $\eta p^2 = .36$). The post hoc tests revealed that TWL had significantly lower AA than WN ($p < .05$) and TWN had significantly greater AA than WL and TWL ($p < .05$). The group by block interaction was also significant ($F(3, 44) = 4.64$, $p < .01$, $\eta p^2 = .24$). The independent t-tests revealed that WL, WN, and TWN significantly increased AA from the beginning of acquisition to transfer ($p < .05$). During the first block of acquisition WL had significantly lower AA than WN and TWN ($p < .01$). During transfer TWL had significantly lower AA than the other groups ($p < .05$). (Figure 31).

Peak Acceleration. The main effect of block for PA was significant with lower PA being recorded during the beginning of acquisition than transfer ($F(1, 44) = 34.90$, $p < .001$, $\eta p^2 = .44$. The main effect of group was significant ($F(3, 44) = 3.20$, $p < .05$, $\eta p^2 = .18$) and the post hoc tests revealed that TLW had significantly lower PA than TWN ($p < .05$). The group by block interaction was also significant ($F(3, 44) = 5.23$, $p < .01$, $\eta p^2 = .26$. The independent t-tests revealed that both WL and TWN significantly increased PA from the beginning of acquisition to transfer ($p < .05$). No significant differences during the first block of acquisition were found ($p > .05$) but during transfer TWL had significantly lower PA than WL and TWN ($p \leq .01$).

Reaction Time. The main effect of block for RT was significant ($F(1, 44) = 7.90$, $p < .01$, $\eta p^2 = .15$). The main effect of group was also significant ($F(3, 44) = 23.67$, $p < .001$, $\eta p^2 = .62$) and the post hoc tests revealed that WL had significantly different RTs than the other three groups ($p \leq .01$) and TWL had significantly different RTs than the other groups ($p \leq .01$). The group by block interaction was also significant ($F(3, 44) = 37.49$, $p < .001$, $\eta p^2 = .72$). The independent t-tests revealed that WL significantly decreased RT from the beginning of

acquisition to transfer ($p < .001$) and TWL significantly increased RT from the beginning of acquisition to transfer ($p < .001$). The independent t-tests revealed that WL had significantly greater RT during the first block of acquisition ($p < .001$). The independent t-tests also revealed that TWL had significantly greater RT than the other groups ($p < .05$) and WL had significantly higher RT than WN and TWN ($p < .05$) during transfer (Figure 32).

Pen Pressure. The main effect of block was not significant (p > .05). In addition, the main effect group and the group by block interaction were not significant (p > .05) (Figure 32).

Discussion

The purpose of this chapter was to investigate the effects of both cognitive (increased mental load) and physical stress (continuous white noise) on practice specificity. It was hypothesized that if additional stressors were present during a transfer test, performance would be best if the practice conditions mirrored the conditions during practice. During this experiment individuals learned to perform an aiming task that required them to draw to a stationary target in as close to two seconds as possible while avoiding two stationary barriers. The experiment consisted of four groups that performed the task with or without one of two stressors. The first group performed the task while simultaneously counting backwards by threes during acquisition, retention, and transfer (work load: WL). The second group performed the task without additional work load during acquisition and retention but performed the task with additional work load during transfer (transfer to work load: TWL). The third group performed the task while 80dBs of continuous white noise was presented during acquisition, retention, and transfer (white noise: WN). The last group performed the task without additional stress during acquisition and retention. During transfer they were presented the continuous white noise (transfer to white noise: TWN).

During the acquisition phase of the experiment, groups became significantly closer to performing the task in the two second criterion time (i.e., lower AE and CE closer to zero) and became more consistent around their average movement time (i.e., lower VE). Groups also produced smoother (i.e., lower NJ) and more efficient movements (i.e., faster peak and average accelerations, and decreased axial pen pressure). The WL group also significantly decreased reaction time during acquisition (i.e., lower RT). WL also had significantly more error in their movement time goal, significantly more normalized jerk and higher pen pressure (NJ and PP respectively), and significantly lower peak and average acceleration (PA and AA, respectively). During retention the same pattern of results was found.

During transfer, the increased stress for TWL negatively affected performance. The TWL group had significantly greater AE and CE than all the other groups. TWL also had more VE than WN and TWN but not WL. TWL also produced movements with greater NJ than WN and TWN, less PA than WL and TWN, and less AA than all the other groups. TWL also had significantly higher RT during transfer. WL had greater RT than WN and TWN.

The results during acquisition and retention support the findings from the previous experiments. The group with the increased work load had poorer timing accuracy and performed the movement less efficiently in chapters two and four (see figures 8, 9, 25, and 27). In the current experiment, the increase in work load during transfer elicited similar results, having poorer performance than the groups without the increase in work load. In addition, the addition of white noise did not significantly hinder timing accuracy or movement efficiency in chapter three or the current experiment (see figures 18, 19, 29, and 31).

In the second chapter, the increase in work load negatively affected performance but during a transfer test without the increase in work load performance was not hindered. In the

third chapter it was found that continuous white noise at 80dBs did not negatively affect timing accuracy and performance also did not differ from a control group during a transfer test without the continuous white noise. Both of these examples are in contrast to specificity of practice (Shea & Kohl, 1990). If the results would have supported specificity of practice then the experimental conditions in chapters two and three should have performed poorer than the control groups because the practice context was different. According to specificity of practice we would assume that the groups with the same context as practice during transfer would perform significantly better on the aiming task but this was not found.

Specificity of practice has been found for practice context (Lubow, Rifkin, & Alek, 1976), arousal (Movahedi et al., 2007) and anxiety (Lawrence et al., 2013). In each case, learners performed better on a transfer test that mirrored the practice context. For example, individuals that learned a basketball free throw under low arousal performed better on a future test with low arousal and individuals that learned the task under high arousal performed better under high arousal (Movahedi et al., 2007).

The specificity of practice hypothesis states that learning is specific to the sensory information available during acquisition of the skill. It also suggests that the sensory information becomes part of the movement representation and is needed reproduce the movement at high performance levels (Proteau, 1995; Proteau, Marteniuk, & Levesque, 1992; Coull, Tremblay, & Elliott, 2001). Practice specificity means that practice conditions should closely resemble both environmental conditions and movement characteristics that will be present during a future performance time (Humphreys, 1976).

The results from the TWL group support specificity of practice because when the context changed performance deteriorated. However, the results from the TWN group did not support

specificity of practice because the added white noise during practice should have deteriorated performance because the performance context changed. In summary we did not support specificity of practice for physical stress with 80dBs of continuous white noise and did not support specificity of practice when a cognitive stressor is removed during transfer testing. We only supported specificity of practice when a cognitive stressor was added during transfer because it significantly hindered performance.

Future directions for research should include additional investigations into specificity of various physical stressors. One limitation to this study was the low level of white noise presented to the participants (80dBs). We used 80 dBs because of the duration that the noise was presented (The European Parliament and The Council of the European Union, 2003). Increased amounts of noise or increased practice may lead to greater dependency on the white noise to reach peak performance levels.

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CHAPTER 5: GENERAL DISCUSSION

Overview of Findings

The purpose of this dissertation was to investigate the effects of a cognitive stressor (work load) and a physical stressor (auditory noise) on motor learning. The framework of the practice context and its relation between stress during acquisition and the assessment also afforded an exploration of the specificity of practice in the context of stressors. An additional purpose of this dissertation was to further investigate the influence of stress on motor learning and how the neuromotor noise perspective may help to explain its relationship.

In chapter two the effects of a cognitive stressor (work load) on motor performance and learning was investigated. Individuals learned a timed graphical aiming task with barrier avoidance. They were asked to perform the task in exactly two seconds. In addition to performing the aforementioned task, half the participants performed a secondary arithmetic task that required them to count backwards by threes from a number presented on the computer screen. It was found that an increase in work load negatively impacted motor performance during acquisition. However, when the stressor was removed during a transfer test, it was found that motor learning was not affected.

Chapter three investigated the effects of auditory noise (a physical stressor) in the form of white noise at 80dBs on motor performance and learning. Individuals learned the same timed graphical aiming task used in the second chapter. Half of the participants performed the task with additional continuous white noise played at 80dBs. The additional auditory noise affected motor performance and learning neither positively nor negatively.

The fourth chapter explored practice specificity in the context of cognitive and physical stressors. The same timed graphical aiming task with barrier avoidance performed in chapters

two and three was used in chapter four. The main difference was that either a physical or cognitive stressor was introduced during transfer testing to individuals that practiced in the absence of an additional stressor. Similar to the results from chapter three, auditory noise did not affect timing errors, NJ, PL, AA, PA, or PP during acquisition, retention, or transfer. The one main difference was that RT was not effected by auditory noise like it was in chapter 3. The group that practiced with additional work load performed significantly worse during acquisition and retention which was similar to chapter 2. When the additional work load was removed during transfer the only dependent variable that was negatively affected was RT which was still significantly greater than the groups that practiced with white noise or practiced without and transferred to white noise. The group that transferred to additional work load had significantly greater AE, CE, AA, and RT that the other groups. The additional work load during transfer also had greater VE, NJ, and PA than the groups that practiced with or transferred to white noise.

Stress and Motor Learning

It was hypothesized that stress during acquisition of a novel motor skill would facilitate motor learning. This hypothesis stemmed from research suggesting that coping with increased stress may result in an increase of effort (Hockey, 1997) and an increase in effort should facilitate motor learning (Lee, Swinnen, & Serrien, 1994). Unfortunately the findings of the experiments did not support the hypothesis that stress during acquisition of a novel motor task facilitates motor learning. The findings do show that a cognitive stressor negatively affects motor performance while a physical stressor in the form of continuous auditory noise does not seem to affect motor performance.

To measure the amount of work load, participants completed an adapted version of the NASA task-load (Hart, 2006). This survey was used to make inferences that effort was increased

when performing the timed aiming task with a stressor. The stress condition that required participants to count backwards by threes significantly increased the amount of task load but the addition of white noise did not raise the reported task load.

The increase in work load and subsequent increase in effort may explain the results for chapter two. In the second chapter the increase in work load negatively affected motor performance and when the stressor was removed during transfer performance was not significantly different than a group that only practiced the aiming task. Hockey (1997) suggests that individuals are capable of maintaining performance, or even improving performance, with an increase in stress. This occurs because the individual increases their effort to cope with the increase in stress. Once the demands of the stressor exceed the limit in which increased effort can maintain performance, the performance will begin to decrease. When this occurs individuals change the goal of the task to a level that is within reach of the resources available. The increase in effort due to the increased work load potentially explains the results from the second chapter. The increase in effort was not enough to cope with the increases in work load during acquisition but the additional effort allowed the individuals to have enough resources available to learn the primary timed aiming task in spite of the concurrent demands needed to cope with the stressor. In the third chapter the addition of white noise (the physical stressor) was not sufficient to increase subjective ratings on the NASA task-load scale. If increased effort was not needed to complete the task, it makes sense that motor learning was not facilitated (nor hindered during acquisition).

Neuromotor Noise Theory

The neuromotor noise theory (Van Gemmert, 1997; Van Gemmert & Van Galen, 1997) provides a comprehensive theory on stress and the subsequent changes to the motor system and

motor performance. The theory suggests that increases in stress increase the amount of neuromotor noise in the system. Low levels of stress may have an activating effect on the system which may improve motor performance. The increase in arousal increases activation which is mediated by effort, which could result in a benefit for performance. If the stress further increases the amount of neuromotor noise in the system gets elevated. The increased neuromotor noise must then be reduced for optimal performance. A reduction of neuromotor noise in the system can be accomplished by either increasing processing time, thus allowing to accumulate signal and to attenuate neuromotor noise, effectively increasing the signal-to-noise ratios, or by making use of the biomechanical filtering properties of the pen-limb system, i.e., increasing stiffness of the executing limb in order to low-pass filter the composite signal reducing or eliminating higher frequency noise signals.

The increases in neuromotor noise due to the addition of a cognitive stressor resulted in increased processing times (reaction time) and biomechanical adaptations (increased pen pressure). However when the stress was removed during a transfer test, performance was no longer hindered. This pattern of findings makes sense because the amount of neuromotor noise would be lessened when the stressor was removed, so adaptations to cope with the increases in neuromotor noise in the system, i.e., an increase in processing time and the biomechanical adaptations, would not be necessary anymore. The addition of the physical stressor also resulted in increases in processing times while the noise was present but it did not result in a biomechanical adaptation like it is suggested by the neuromotor noise perspective on stress during human performance. This may suggest that possibly the system recognized that only one solution is needed to counteract the increase in neuromotor noise in the system and thus "choose" the most efficient solution for the task situation, i.e., increasing reaction time, because

increasing stiffness would require more force production. When the white noise was removed during the transfer test, reaction time for the group that practiced with the white noise was marginally greater. However, the reaction time reported was still less that it was during acquisition or retention when the additional white noise was present.

The neuromotor noise theory is a theory that cannot only explain the effects of stress on motor performance but it can also be used to explain the effects of stress on motor performance during and after the learning experience. When a stressor is removed the amount of neuromotor noise in the motor system is reduced. This allows performance to return to similar performance levels as the level of performance of that skill without additional stress. Results from the final experiment showed that the group that practiced without additional work load but then performed the transfer task with the additional work load performed significantly worse that the group that practiced the task with the additional work load. These results may be explained by suggesting that individuals learn to cope with the increase in neuromotor noise and become more proficient at increasing signal-to-noise ratios.

Specificity of Practice

Specificity of practice suggests that to maximize performance during the assessment, the practice environment should resemble the testing environment as closely as possible (Shea & Kohl, 1990; Movahedi, Sheikh, Bagherzadeh, Hemayattalab, & Ashayeri, 2007). The specificity of practice hypothesis suggests that learning is specific to the sources of sensory information available during practice (Proteau, 1995; Proteau, Marteniuk, & Levesque, 1992). To perform at an optimal level at a later time, the same sensory information should be available during practice.

Based on specificity of practice, it was assumed that when the practice context matched the retention/transfer context performance would be best. The findings from the first experiment

did not support specificity of practice. The group that practiced with additional work load and the group that practiced without additional work load did not significantly differ from one another during a retention/transfer test when no additional work load was present. Specificity of practice would suggest that the group that practiced with the additional work load should perform worse on the task when the work load was removed.

The second experiment also fails to support specificity of practice. The group that practiced the motor task with white noise did not significantly differ in performance on a retention/transfer test without white noise from the group that practiced the motor task without white noise. Based on the concept of practice specificity, performance should have suffered when the white noise was removed.

The findings from the third experiment partially support practice specificity. When performing a retention/transfer test with additional work load, performance was significantly worse for the group that practiced without the additional work load. When looking at all the experiments together, performance is not hindered during a retention/transfer test with additional stress if that stress was present during practice. However, if stress is added during retention/transfer performance will worsen significantly.

Limitations and Future Directions

There are a number of limitations to this dissertation. One limitation is that the same task was used in all the experiments. It is possible that results may be different when different types of motor and/or cognitive tasks are used. This dissertation only explored a timed aiming task. Different types of graphical tasks, gross motor tasks, or cognitively more demanding tasks may have affected performance differently. The intensity of white noise can also be considered another limitation. The majority of stress research that showed an effect of noise on performance

used a higher intensity than what was used in this dissertation but is still found (Kyriakides & Leventhall, 1977; Smith & Miles, 1985). For the presentation of the continuous white noise, we elected to use 80dBs. The European Parliament and The Council of the European Union (2003) mandate that workers are offered hearing protection when the intensity of auditory noise exceeds 80dBs (furthermore, workers are required to wear the offered protection if the intensity level is above 85dBs). Although our experiment did not take eight hours, we still felt that we should adhere to the safety standards set for workers in the interest of protecting the hearing of our volunteer participants. However, this did limit the generalization of our findings because it is possible that higher levels of intensity would result in decreases in performance during acquisition; i.e., alter the results of retention or transfer.

The use of the NASA task-load (Hart, 2006) index is another limitation. The task-load index was used to subjectively measure the amount of load a particular task required. The intent was to use the assessment to make inferences about the amount of effort expended due to the addition of stress during performance of the motor task. It was found that the white noise did not increase task-load which may explain (partly) the results. Even though the lack of finding increases in task-load due to the addition of white noise may fit the pattern of found results, it is still possible that the NASA task-load is not sensitive enough to find an increase in work load when adding white noise. Therefore, it is possible that effort to perform the motor task was altered in spite of a noticeable increase from a subjective task-load demand perspective as measured by the NASA task-load survey.

The population sampled in these experiments was one with college aged adults that are usually familiar with some form of tablets. This can be a limitation because age groups may perform differently due to familiarity with the tablet and stylus and age may change how the

stressor affects performance. Other age groups may also find the task more challenging which would change the reported scores on the NASA task-load index.

Future research should be geared to investigate various types and intensities of both cognitive load and auditory noise. The inverted-U theory (Yerkes & Dodson, 1908) suggests that too little or too much arousal results in decreased performance. Looking at various intensities and therefore various arousal levels, would allow investigation into the inverted-U as proposed by the theory. Increased intensity levels of auditory noise and the use of intermittent auditory noise sources have both been found to have negative effects on motor performance so it makes sense to assume that they may affect motor learning.

Research should also investigate the effects of stress on more applied tasks to see if the results reported in the previous experiments are supported. It is also possible that stress affects fine motor skills differently than gross motor skills or stress may affect open motor skills differently than closed motor skills. Adopting physiological measurements would help to better understand the changes due to stress that occur and how these changes correlate with task performance. This will allow a more comprehensive understanding of the relationship between stress and motor learning.

As already suggested age might be a covariate when investigating the relationship between stress and motor learning. Thus future research should explore whether age affect the relationship between stress, motor performance, and motor learning. Introducing additional stress may prove to be detrimental to both younger and older age groups than the age group used in the current experiments. This dissertation also did not investigate the third type of stressor mentioned in the introduction (i.e., emotional stress). No differences were found in the perceived

emotional stress of the participants prior to participation but it is possible that individuals with higher emotional stress may perform differently than individuals with lower emotional stress.

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APPENDICES

Appendix A: Consent Form

CONSENT FORM

Title of Study: The effects of mental load and auditory noise on motor skill learning.

Performance Site: Fine Motor Control & Learning Laboratory (Room 71 and 74 HP Long Fieldhouse).

Contacts: The following investigators are available for questions about this study Monday – Friday, 9:30am – 4:30pm.

Mr. Christopher Aiken, M.Sc. (caiken2@tigers.lsu.edu)
Dr. Arend Van Gemmert (gemmert@lsu.edu)
Fine Motor Control & Learning Laboratory (225) 578-9142

Purpose of the Study: To investigate the possible effects of mental load and auditory noise on motor skill learning.

Participant Inclusion: Healthy individuals from the community of Baton Rouge, including the college community, who are between the age of 18 and 40 years old.

Participant Exclusion: Individuals who do not have normal or corrected-to-normal vision and/or hearing; Individuals who report psychological, or neurological, or other altered physical conditions affecting control of the upper dominant limbs. Individuals who are pregnant.

Number of Participants: 200

Study Procedures: You will be asked to read and sign the informed consent and then you will be asked to fill out the Perceived Stress Scale, and a short demographic questionnaire. After filling out these forms you will be seated comfortably in a chair in front of a screen and digitizer tablet (records movements made with a pen) and you will receive an explanation of how the digitizer works. You will use the tablet to draw a line with a pen to connect two targets on the computer screen in a specified amount of time, while a film camera will also record your hand movements and your voice while performing the task. You may also be asked to wear noise cancellation head phones through which you will hear white noise at 80 decibels (similar to common household appliances like a dishwasher), or you will be asked to perform a second task (answer a mathematical equation) while drawing from one target to the next. After you have performed the task for a while you will get a rest of 5 minutes, before you are asked to perform the task for a two short periods of time with a 5 minute rest also interspersed between these two short periods. During the first 5 minutes rest you will be asked to fill out the NASA Task Load Index. Participation in the study will last approximately 2 hours.

Benefits: No direct benefits will be offered to individuals not belonging to the college community. Individuals belonging to the college community may be awarded extra credit for research participation in one of their classes.

Risk/Discomforts: There are no foreseen risks because participation in the current study involves no more risk than normally associated with writing or drawing on a daily basis and hearing sounds that are similar to household appliances. There is the inadvertent risk that anonymity will not be kept. However, every effort will be made to ensure confidentiality is maintained. All data and participant information will be kept separate and in a password protected computer. Signed consent forms will be kept in a locked cabinet in a locked room.

Right to Refuse: Participants may choose to withdraw or not participate in the study at any time without penalty or loss of any benefit that may be entitled.

Privacy: Results of the study may be published; however no names or identifying information will be included. Identities will remain confidential unless discloser is required by law. Data will be kept confidential unless release is legally compelled.

Financial Information: No financial compensation for participation will be obtained.

Signatures: The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about subjects' rights or other concerns, I can contact Dr. Robert C. Mathews, Institutional Review Board, (225) 5788692, irb@lsu.edu, www.lsu.edu/irb. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with signed copy of this consent if signed by me.

Participants Signature ______________________________

Date ____

Appendix B: Participate Record Form

Participant Record Form

Date: _________.

Participant code: ____________________.

Gender: ___________________.

Age: ______________________.

Do you consider yourself belonging to one of the following ethnic groups: Hispanic, Spanish, or Latino (Yes/No)? ____________________.

Which racial group describes you best?: Alaskan Native American Indian, Asian, Native Hawaiian, Other Pacific Islander, African American, Caucasian (White), More than one group, Other:

____

Vision (Do you have problems in daily life with your eye-sight): ___________________

Hearing (Do you have hearing problems in normal conversations): _______________

Do you have any psychological, or neurological conditions: ______________________

Do you have any altered physical conditions that affect your upper-limb motion: ______

Are you able to hold the pen in normal pen-grip (dynamic tripod grasp): ____________

Are you left or right handed: ____

Appendix C: Perceived Stress Scale

Perceived Stress Scale

The questions in this scale ask you about your feelings and thoughts **during the last month**. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.

Name ____ Date _________

Age ________ Gender (*Circle*): **M F** Other ______________________________

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?....................................	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?..	0	1	2	3	4
3. In the last month, how often have you felt nervous and “stressed”?	0	1	2	3	4
4. In the last month, how often have you felt confident about your ability to handle your personal problems?..	0	1	2	3	4
5. In the last month, how often have you felt that things were going your way?...	0	1	2	3	4
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4
7. In the last month, how often have you been able to control irritations in your life?..	0	1	2	3	4
8. In the last month, how often have you felt that you were on top of things?.....	0	1	2	3	4
9. In the last month, how often have you been angered because of things that were outside of your control?	0	1	2	3	4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?...........................	0	1	2	3	4

Please feel free to use the *Perceived Stress Scale* for your research. The PSS Manual is in the process of development, please let us know if you are interested in contributing.

Appendix D: Adapted NASA Task-Load Index

NASA Task Load Index ***(adapted from Hart and Staveland's NASA Task Load Index (TLX) method)***

Participant Code:	Experiment:	Date:

Mental Demand — How mentally demanding was the task?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Very low — Low — Below average — Average — Above average — High — Very high

Physical Demand — How physically demanding was the task?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Very low — Low — Below average — Average — Above average — High — Very high

Temporal Demand — How hurried or rushed was the pace of the task?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Very low — Low — Below average — Average — Above average — High — Very high

Performance — How successful were you in accomplishing what you were asked to do?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Very low — Low — Below average — Average — Above average — High — Very high

Effort — How hard did you have to work to accomplish your level of performance?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Very low — Low — Below average — Average — Above average — High — Very high

Frustration — How insecure, discouraged, irritated, stressed, and annoyed were you?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Very low — Low — Below average — Average — Above average — High — Very high

Appendix E: IRB Approval Sheet

ACTION ON PROTOCOL APPROVAL REQUEST

LSU
Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu | lsu.edu/irb

TO: Arend Van Gemmert
Kinesiology

FROM: Robert C. Mathews
Chair, Institutional Review Board

DATE: March 19, 2013
RE: **IRB#** 3379

TITLE: The effects of mental load and auditory noise on motor skill learning

New Protocol/Modification/Continuation: New Protocol

Review type: Full ___ Expedited X   **Review date:** 3/20/2013

Risk Factor: Minimal X Uncertain ______ Greater Than Minimal_______

Approved X **Disapproved**_________

Approval Date: 3/20/2013 **Approval Expiration Date:** 3/21/2014

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 80

Protocol Matches Scope of Work in Grant proposal: (if applicable)_______

By: Robert C. Mathews, Chairman ________________

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. SPECIAL NOTE:

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

Application for Approval of Projects Which Use Human Subjects

This application is used for projects/studies that cannot be reviewed through the exemption process.

LSU

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu
lsu.edu/irb

- Applicant, Please fill out the application in its entirety and include two copies of the competed application as well as parts A-F, listed below. Once the application is completed, please submit to the IRB Office for review and please allow ample time for the application to be reviewed. Expedited reviews usually takes 2 weeks. Carefully completed applications should be submitted 3 weeks before a meeting to ensure a prompt decision.

- A Complete Application Includes All of the Following:
  - **(A)** Two copies of this completed form and two copies of part B thru F.
  - **(B)** A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
  - **(C)** Copies of all instruments to be used.
    - *If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
  - **(D)** The consent form that you will use in the study (see part 3 for more information.)
  - **(E)** Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. **Training link:** (http://phrp.nihtraining.com/users/login.php)
  - **(F)** IRB Security of Data Agreement: (http://research.lsu.edu/files/item26774.pdf)

1) Principal Investigator*: Arend Van Gemmert, PhD **Rank** Assistant Professor

*PI **must be** an LSU Faculty Member

Dept: Kinesiology **Ph:** (225) 578-9142 **E-mail:** gemmert@lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each

Christopher Aiken, M.S. School of Kinesiology, Graduate Assistant II
(702) 521-3775; caiken2@lsu.edu

IRB# 3379 LSU Proposal #_____

- Full
- ✓ Expedited
- ✓ Human Subjects Training
- ✓ Complete Application

3) Project Title: The effects of mental load and auditory noise on motor skill learning

4) Proposal Start Date: 3/25/2013 **5) Proposed Duration Months:** 12

6) Number of Subjects Requested: 80 **7) LSU Proposal #:**

8) Funding Sought From:

Study Approved By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Approval Expires: 3/24/2014

ASSURANCE OF PRINCIPAL INVESTIGATOR named above

I accept personal responsibility for the conduct of this study (including ensuring compliance of co-investigators/co-workers) in accordance with the documents submitted herewith and the following guidelines for human subject protection: The Belmont Report, LSU's Assurance (FWA00003892) with OHRP and 45 CFR 46 (available from http://www.lsu.edu/irb). I also understand that copies of all consent forms **must be maintained at LSU for three years after the completion of the project.** If I leave LSU before that time, the consent forms should be preserved in the Departmental Office.

Signature of PI __________ Date 3/11/2013

ASSURANCE OF STUDENT/PROJECT COORDINATOR named above. If multiple Co-Investigators, please create a "signature page" for all Co-Investigators to sign. Attach the "signature page" to the application.

I agree to adhere to the terms of this document and am familiar with the documents referenced above.

Signature of Co-PI (s) __________ Date 3/11/2013

CONSENT FORM

Title of Study: The effects of mental load and auditory noise on motor skill learning.

Performance Site: Fine Motor Control & Learning Laboratory (Room 48 HP Long Fieldhouse and Room 15 Hatcher Hall).

Contacts: The following investigators are available for questions about this study Monday – Friday, 9:30am – 4:30pm.

Mr. Christopher Aiken, M.Sc. (caiken2@tigers.lsu.edu)
Dr. Arend Van Gemmert (gemmert@lsu.edu)
Fine Motor Control & Learning Laboratory (225) 578-9142

Purpose of the Study: To investigate the possible effects of mental load and auditory noise on motor skill learning.

Participant Inclusion: Healthy individuals from the community of Baton Rouge, including the college community, who are between the age of 18 and 40 years old.

Participant Exclusion: Individuals who do not have normal or corrected-to-normal vision and/or hearing; Individuals who report psychological, or neurological, or other altered physical conditions affecting control of the upper dominant limbs. Individuals who are pregnant.

Number of Participants: 80

Study Procedures: You will be asked to read and sign the informed consent and then you will be asked to fill out the Perceived Stress Scale and a short demographic questionnaire. After filling out these forms you will be seated comfortably in a chair in front of a screen and digitizer tablet (records movements made with a pen) and you will receive an explanation of how the digitizer works. You will use the tablet to draw a line with a pen to connect two targets on the computer screen in a specified amount of time. You may also be asked to wear noise cancellation head phones through which you will hear white noise at 80 decibels (similar to common household appliances like a dishwasher), or you will be asked to perform a second task (answer a mathematical equation) while drawing from one target to the next. 24 hours following data collection, you will return to the testing site for additional testing. Participation in the study will last approximately 1 hour on the first day of data collection and about 20 minutes the second day.

Benefits: No direct benefits will be offered to individuals not belonging to the college community. Individuals belonging to the college community may be awarded extra credit for research participation in one of their classes.

Risk/Discomforts: There are no foreseen risks because participation in the current study involves no more risk than normally associated with writing or drawing on a daily basis and hearing sounds that are similar to household appliances. There is the inadvertent risk that anonymity will not be kept. However, every effort will be made to ensure confidentiality is maintained. All data and participant information will be kept separate and in a password protected computer. Signed consent forms will be kept in a locked cabinet in a locked room.

Right to Refuse: Participants may choose to withdraw or not participate in the study at any time without penalty or loss of any benefit that may be entitled.

Privacy: Results of the study may be published; however no names or identifying information will be included. Identities will remain confidential unless discloser is required by law. Data will be kept confidential unless release is legally compelled.

Financial Information: No financial compensation for participation will be obtained.

Signatures: The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about subjects' rights or other concerns, I can contact Dr. Robert C. Mathews, Institutional Review Board, (225) 578-8692, irb@lsu.edu, www.lsu.edu/irb. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with signed copy of this consent if signed by me.

Participants Signature ______________________________

Date ____

Study Approved By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Approval Expires: 3/21/2014

Project Report and Continuation Application

(Complete and return to IRB, 130 David Boyd Hall.
Direct questions to IRB Chairman Robert Mathews 578-8692.)

LSU

Institutional Review Board
Dr. Robert Mathews, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
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irb@lsu.edu | lsu.edu/irb

IRB#: 3379 **Your Current Approval Expires On:** 2/21/2014

Review type: Expedited **Risk Factor:** Minimal **Date Sent: 2/3/2014**

PI: Arend Van Gemmert **Dept:** Kinesiology **Phone:** 225-578-9142

Student/Co-Investigator: Christopher Aiken

Project Title: The effects of mental load and auditory noise on motor skill learning

Number of Subjects Authorized: 80

Please read the entire application. Missing information will delay approval!

I. PROJECT FUNDED BY:________N/A________________________ LSU proposal #__N/A_

II. PROJECT STATUS: Check the appropriate blank(s); and complete the following:

_X_ 1. **Active**, subject **enrollment continuing**; # subjects enrolled: _53__
___ 2. **Active**, subject **enrollment complete**; # subjects enrolled: ____
___ 3. **Active**, subject **enrollment complete**; work with subjects continues.
___ 4. **Active, work with subjects complete**; data analysis in progress.
___ 5. Project **start postponed**
___ 6. **Project complete;** end date __/__/__
___ 7. **Project cancelled**; no human subjects used.

III. PROTOCOL: (Check one).

_X__ Protocol continues as previously approved
___ Changes are requested*

- *List (on separate sheet) any changes to approved protocol.*

IV. UNEXPECTED PROBLEMS: (did anything occur that increased risks to participants):

- State number of events since study inception: _0__ since last report: _0__
- If such events occurred, describe them and how they affect risks in your study.
- Have there been any **previously unreported** events? Y/N _N__ ?
  (If YES, attach report describing event and any corrective action).

V. CONSENT FORM AND RISK/BENEFIT RATIO:

Do new knowledge or adverse events change the risk/benefit ratio? Y/N_N__;
Is a corresponding change in the consent form needed? Y/N_N__

VI. ATTACH A BRIEF, FACTUAL SUMMARY of project progress/results to show continued participation of subjects is justified; or to provide a final report on project findings. **See attached summary**

VII. ATTACH CURRENT CONSENT FORM (only if subject enrollment is continuing); and check the appropriate blank:

_X__ 1. Form is unchanged since last approved
___ 2. Approval of revision requested herewith: (identify changes)

Signature of Principal Investigator:____________________ **Date:** _2/3/2014__

IRB Action: ✓ Continuation approved; **Approval Expires:** 2/4/15	
___ Disapproved	
___ File closed	
Signed ________________	Date 2/5/14

ACTION ON PROTOCOL APPROVAL REQUEST

Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu | lsu.edu/irb

TO: Arend Van Gemmert
Kinesiology

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: October 31, 2014

RE: **IRB#** 3379

TITLE: The effects of mental load and auditory noise on motor skill learning

New Protocol/Modification/Continuation: Modification

Brief Modification Description: Increase the number of participants to 200. Adding the NASA Task Load Index to the protocol. Adding a film camera to time-lock hand movements with answers to the arithmetic questions. Dropping the retention session 24 hours after acquisition. Adding Seth Fontenot as co-investigator.

Review type: Full ____ Expedited __X__ **Review date:** 10/30/2014

Risk Factor: Minimal __X__ Uncertain ______ Greater Than Minimal______

Approved __X__ **Disapproved** ________

Approval Date: 10/30/2014 **Approval Expiration Date:** 2/4/2015

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 200

LSU Proposal Number (if applicable): ________

Protocol Matches Scope of Work in Grant proposal: (if applicable) ________

By: Dennis Landin, Chairman DLandin

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.

All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb

ACTION ON PROTOCOL CONTINUATION REQUEST

LSU

Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu | lsu.edu/irb

TO: Arend Van Gemmert
Kinesiology

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: January 27, 2015

RE: IRB# 3379

TITLE: The effects of mental load and auditory noise on motor skill learning

New Protocol/Modification/Continuation: Continuation

Review type: Full ___ Expedited _X_ **Review date:** 1/26/2015

Risk Factor: Minimal ___X___ Uncertain ________ Greater Than Minimal______

Approved_____X_____ **Disapproved**__________

Approval Date: 1/26/2015 **Approval Expiration Date:** 1/25/2016

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 200

LSU Proposal Number (if applicable): __________

Protocol Matches Scope of Work in Grant proposal: (if applicable) ___

By: Dennis Landin, Chairman ____DLandin____

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. SPECIAL NOTE:

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

Appendix F: Master Reference List

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VITA

Christopher was born and raised just outside of Las Vegas in Henderson, NV. After graduating from high school in 2000, he attended the University of Nevada, Las Vegas. After attending UNLV for one year, Christopher moved to São Paulo, Brazil to serve a two year mission for the Church of Jesus Christ of Latter Day Saints. Upon returning he resumed his academic career and he graduated from UNLV with a B. A. is psychology in 2007. Christopher continued to pursue his education and attended the University of Tennessee, Knoxville where he received his M. S. in Kinesiology with a concentration in Sport Psychology and Motor Behavior under the direction of Dr. Jeffrey Fairbrother. Christopher then elected to attend Louisiana State University to pursue his PhD in Kinesiology with an emphasis in Motor Control and Learning under the direction of Dr. Arend Van Gemmert. While at LSU, Christopher worked as a graduate assistant and taught Beginning Golf (KIN 1125) and Introduction to Motor Learning (KIN 3513). In 2013 he received the Outstanding Student Paper Award from the American Kinesiology Association for his paper titled “The effects of self-controlled video feedback on the learning of the basketball set shot”. He was also awarded the LSU Graduate School Dissertation fellowship in 2015 and selected as an American Kinesiology Association Doctoral Scholar. Christopher has accepted a position as an assistant professor in the Integrative Physiology and Health Science department at Alma College in Alma, MI.