Learning to Prepare Hauling Systems for Rope Rescue

by © Brenna McWilliams

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ABSTRACT

Introduction: While there is a good understanding of how anxiety impacts skill performance, we understand less about how anxiety affects the learning process. We attempted to create an environment that caused anxiety by having people practice the skill of preparing rope rescue hauling systems (3:1 & 5:1) at height. **Methods**: Participants were assigned to a Low practice group, that completed training in a general classroom setting; and a High practice group, that trained at a 14m height. Retention tests, to assess learning, were completed one week after practice. All participants were tested on the hauling systems at an elevated height and in a classroom setting. A checklist of each element of the hauling systems was used to assess configuration performance error scores. Movement time (MT) of the preparation was recorded for each trial. Cognitive anxiety was examined through a Likert Scale delivered after each trial. Somatic anxiety was observed using a Zephyr Bioharness system, which measured heart rate (HR) and heart rate variability (HRV). **Results**: Configuration performance during practice was lower for the High practice group compared to the Low practice group. Perceived anxiety decreased with practice. During retention, which reflected learning, perceived anxiety was higher for the low practice location (classroom) compared to the high practice (elevated) testing location. MT was longest for the complex 5:1 system when performing at height. **Conclusion**: The current study is one of the first studies to assess rope rescue skills and anxiety induced by different complexities and environments. Performance at height, when there are cognitive challenges (the difficulty associated with completing the 5:1 system) is impaired. However, training at height does not appear to influence this effect. As well, trainees should practice all complexities or specific skills that need to be learned multiple times.

Key words: task complexity, anxiety, performance, environment, training, rope rescue

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
bpm	Beats Per Minute
CI	Contextual Interference
EI	Emotional Intelligence
g	grams
HR	Heart Rate
HRV	Heart Rate Variability
M	Mean
m	meter
mm	millimeter
ms	millisecond
MT	Movement Time
NIH	National Institute of Health
SD	Standard Deviation
STAI	State-Trait Anxiety Inventory
sec	seconds

Chapter 1: Review of Literature

1.1 Introduction

Learning is an activity that humans participate in from birth to death. As human beings, our lives are based on learning new skills and advancing existing skills. The skills that humans can learn seem to have an endless capacity. Motor learning is defined by Magill as, "the change in the capability of a person to perform a skill that is inferred from practice or experience and is relatively permanent" (2004, p. 134). Some skills can be learned implicitly, which is the unconscious learning of a skill (Wulf & Schmidt, 1997). However, typically to learn a skill, practice is required. Practice is the deliberate repetition of a skill, and it is generally the most important part of improving and mastering skills (Adams, 1964; Guadagnoli & Lee, 2004; Magill, 2001; Schmidt & Lee, 2018). Many factors influence the quality of motor learning; for example, feedback (e.g. Badets & Blandin, 2012), simulation environments (e.g. Walsh, Rose, Dubrowski, Ling, Grierson, Backstein & Carnahan, 2011), stress and anxiety (e.g. Young, St, Gibson, Partington, Partington, & Wetherell, 2013), the amount of practice (e.g. Guadagnoli & Lee, 2004), the type and difficulty of skill (e.g. Wulf & Shea, 2002), and the applicability of a practice skill to real life (e.g. Wrisberg & Liu,1991). Although many of these factors are well studied, some elements like anxiety and task complexity in motor learning require further study (e.g. Adams, 1964; Guadagnoli & Lee, 2004; Magill, 2001; Maran & Glavin, 2003; Mori, Carnahan, & Herold, 2015; Schmidt & Lee, 2018; Walsh et al., 2011; Wulf & Shea, 2002; Young et al., 2013). The properties and fundamental concepts of motor learning and performance are relevant to the life and work of many individuals.

To examine motor learning, researchers typically observe performance, but performance is not considered motor learning. Since motor learning is immeasurable, performance measures are used to indicate and reflect the learning of a skill. Performance is described as, "the behavioural act of executing a skill at a specific time and in a specific situation" (Magill, 2004, p.193). Typically, improvements in performance indicate skill learning (Luft & Buitrago, 2005). Performance can be measured in many ways; for example, reaction time (Henry & Rogers, 1964; Klapp, 1995; Magill, 2004, p.20), error measures (Magill, 2004, p.23; Schmidt, Zelaznik, Hawkins, Frank, & Quinn, 1979), and kinetics and kinematics (Magill, 2004, p.29). These dependent measures can be used to evaluate performance over multiple trials to create learning curves (Crossman, 1959). To measure performance and skill learning over a period of time researchers use retention and transfer testing to examine these effects. Retention tests are, "tests of a practiced skill that a learner performs following an interval of time after practice has ceased" (Magill, 2004, p.199). While transfer tests are, "tests in which a person performs a skill that is different from the skill he or she practiced or performs the practiced skill in a context or situation that is different from the practice context or situation" (Magill, 2004, p.201). Retention and transfer tests are a valid predictor of learning and many researchers have utilized these tests (e.g. Guadagnoli & Lee, 2004; Jarus & Gutman, 2001; Porte et al., 2007; Wrisberg & Lui, 1991; Wulf & Shea, 2002). While many factors influence the outcome of performance and motor learning, it is important to have an understanding of these factors to improve skills.

1.2 Practice

One of the most important factors that effectively demonstrates improvements in motor learning, is practice (Adams, 1964; Guadagnoli & Lee, 2004; Magill, 2001; Schmidt & Lee, 2018). Repetition of certain skills under a variety of conditions can allow an individual to learn a skill and develop into an expert. Although the amount of practice has generally been positively related to skill improvement, many factors also contribute to whether practice will be beneficial or not. Some of these factors include feedback (e.g. Badets & Blandin, 2012), the type and difficulty of skill (e.g. Wulf & Shea, 2002), and the generalizability (e.g. Wrisberg & Liu,1991) and environment of the practice setting. Practice can be performed in a controlled laboratory/classroom setting or in a real-world field setting. Collectively, these variables influence the rate and degree of skill learning.

Individuals can use both mental and physical practice to improve motor skill learning. One of the functions of mental practice is that it assists the performer in psychologically preparing to perform a skill (Feltz & Landers, 1983). Research has shown that mental practice can enhance teamwork and technical skills, especially in high fidelity simulations (Arora, Aggarwal, Hull, Miskovic, Kneebone, Darzi & Sevdalis, 2011). Mental practice has been proposed to be a time and cost-effective strategy to enhance training (Arora et al., 2011). Both mental and physical practice were found to be equally effective during acquisition of skill development (Stebbins, 1968). For example, Brouziyne and Molinaro (2005) observed that a combination of mental and physical practice can benefit beginners performance of golf shots. Therefore, to increase an individual's performance and learning, mental practice should be added so that the full benefit from physical practice can be realized.

The relationship between practice and skill learning is often referred to as a law of practice (Newell & Rosenbloom, 1981) and mathematical models have largely represented this statement (Crossman 1959; Guadagnoli & Lee, 2004). The National Institute of Health (NIH, 2009) describe five steps of a skill proficiency scale; fundamental awareness, novice, intermediate, advanced, and expert. Fundamental awareness is the first step in skill learning and where knowledge and understanding of the basic techniques or concepts is learned. Novices can discuss terminology, concepts, principles and issues then utilize all the resource materials in this competency; these individuals typically need assistance completing the skill. Individuals with intermediate and advanced proficiencies can independently perform the skills. Experts have the recognized authority and the ability to provide guidance, assistance with troubleshooting and answer questions related to this area (NIH, 2009). Experts achieve skill mastery after many years of practice, with researchers arguing that more than ten thousand hours of deliberate practice is needed to achieve mastery and expertise (Ericsson, Krampe & Tesch-Römer, 1993; Gladwell, 2008). Guadagnoli and Lee (2004) state that, "if skill level is related positively to the development of skill at the task, then larger amounts of practice will produce learners of higher skill" (p.219). In practice, many factors can have negative impacts on skill performance. During practice different types of praise (Baumeister, Hutton, & Cairns, 1990), training environments (Kozak, Hancock, Arthur & Chrysler, 1993), and psychological factors (Hordacre, Immink, Ridding & Hillier, 2016) can impact skill performance negatively. The task, environment, and individually specific properties of practice has very large impacts on the quality of motor learning and performance.

1.2.1 Specificity of Practice

To maximize learning and performance, it is best to provide specific training that reflects the real-world situation. The task, individual, and learning characteristics are factors that affect the specificity of training (Magill & Hall, 1990). Context specificity refers to the environmental factors that influence remembering and learning of information (Schmidt & Lee, 2018). These environmental factors can affect individuals physically and emotionally, thus affecting performance. For example, a cold environment (Parsons, 2014, p.396) can impair an individual physically; conditions that include an element of fear (Rodriguez, Craske, Mineka & Hladek, 1999) can impact an individual emotionally, thus impacting performance and learning. The greatest benefits from performance can be achieved if the practice that is prescribed is specific to the desired outcomes and context (Minett & Costello, 2015). A laboratory task has increased control but it can be less generalizable (Mook, 1983; Mori et al., 2015). In an occupation that has a certain element of anxiety, for example firefighting, the training should incorporate a certain level of anxiety while learning skills to fully maximize an individual's learning and performance. One approach that is used within training programs for anxious conditions is the concept of stress inoculation. Stress inoculation is described as training with effective coping skills prior to stress exposure to prepare the individual for future stressful events (Saunders, Driskell, Johnston & Salas, 1996). This approach was originally used to assist individuals with phobias, pain and anger but researchers demonstrated it's use in workplace training to minimize anxiety and maximize performance. Saunders and colleagues (1996) observed that stress inoculation training reduced state anxiety while enhacing performance under anxious conditions. This provides evidence for the specificity of learning principle and practicing with anxiety.

The specificity of learning principle is described by Henry (1968) as the "best learning experiences are those which approximates most closely the movement components and environmental conditions of the target skill and context" (Schmidt & Wrisberg, 2004, p.198). The two components of this principle have shown how context specificity (Smith, 1998) and task specificity (Linn & Burton, 1994) can negatively impact performance and learning. Context specificity can have a large impact on performance and learning domain but these results can also be impacted by task specificity. The task specificity refers to whether the task being practiced is similar to the task that is meant to be learned. These tasks can range from simple to complex skills. Task difficulty is explained further below. For learning to be optimized for the individual, training needs to be multisensory to allow for individual learning needs (Shams & Sietz, 2008). Some research pertaining to the specificity of training and learning focuses on how the source of afferent visual information needs to be specific for optimal performance and learning (Tremblay & Proteau, 1998). This principle has been shown in manual aiming and positioning tasks (Proteau, 1992), precision walking (Proteau, Tremblay & Dejaeger, 1998), and powerlifting (Tremblay & Proteau, 1998) and indicates that the specificity of learning hypothesis applies to various types of tasks. To maximize the benefits of learning through practice, environmental, individual and task specific factors all need to be involved in training development (Lewthwaite & Wulf, 2012).

1.3 Simulation Training

Motor skills can be learned in simulated environments and in applied settings. Simulation environments are important because they allow a degree of control and safety but they also allow the participant to practice in an environment that is more realistic than a classroom setting (Kneebone, 2009; Walsh et al., 2011). Simulation has been evolving for the last several centuries (Perkins, 2007) with evidence of the first involvement of medical field simulation developed by Abrahamson and Denson in the late 1960s (Bradley, 2006). Simulation training has many applications and is widely integrated into programs where skill learning is imperative, including healthcare, military, driving, air traffic control, first responder education, engineering, and public services contexts (e.g. Maran & Glavin, 2003; Mori et al., 2015; Walsh et al., 2011; Yeung, Dubrowski, & Carnahan, 2013; Young et al., 2013). Walsh and colleagues (2011) offer valid reasoning for integrating simulation training into procedural skill acquisition by explaining that students enhance, develop, and refine their skills through repetitive practice. Since simulations occur in a controlled environment, safety training can also be added as a benefit of simulation training (Kneebone, 2009). Another benefit includes the learner has multiple controlled practice attempts in a supportive and educational environment. In many cases, failure in simulation training is encouraged so students can review the experience and learn from their mistakes in a protected environment (Perkins, 2007). While simulation techniques are beginning to be used by many researchers as a factor in experimental design (e.g., Maran & Glavin, 2003; Mori et al., 2015;

Walsh et al., 2011; Yeung et al., 2013) further research needs to be performed to provide a better methodological base for simulation training (Bradley, 2006).

One concept that aligns with simulation training is simulation fidelity; which is, “the degree to which a model or simulation reproduces the state and behaviour of a real-world object, feature or condition” (Hays & Singer, 1989, p.49). Low fidelity simulations are typically lower cost and are less like the real-world conditions; for example, classroom-based training for a skill that is never used in a classroom. High fidelity simulations include environments very similar to the real-world condition; for example, simulated patients in the medical environment (Maran & Glavin, 2003). Norman, Dore and Grierson (2012) summarized how high-fidelity simulation provides gains in performance and transfer learning. McGaghie and colleagues (2006) discovered that there was a positive relationship between number of hours of high-fidelity simulation practice and standardized medical evaluations. Depending how representative the simulation is to the actual environment, the generalizability of the study can increase or decrease and this can be vital for research.

Simulation training can occur in both controlled environments as well as virtual spaces. In particular, firefighter training is often completed in virtual environments to minimize risk (Perdigau et al., 2003; St Julien, & Shaw, 2003; Tate, Sibert, & King, 1997). For example, Backlund and colleagues (2007) used a virtual-reality video game to enhance firefighter training. The authors discovered that virtual training complimented the traditional firefighter training by improving learning objectives while increasing self-motivation. Other work has used traditional firefighter training simulations to test training (Henderson, Berry, & Matic, 2007). These simulations involved real-life tasks that may have maximized the fidelity. Virtual reality environment training offers a cost-effective solution to training but it should be accompanied with real-life simulation training. Kozak and colleagues (1993), describe how their real-life training group performed significantly better than the virtual reality training group. Therefore, a combination of virtual reality training and real-life training is best to increase performance and learning.

Secondary factors found in simulation can have a large impact on performance and learning. These secondary factors include feedback, quality of instruction, simulation environments, stress levels, the amount of practice, and the type of skill and affect the motor learning of a skill. By combining the secondary factors to create a better outline for methodological procedures of simulation training, researchers can aim to improve training to ultimately improve performance and learning. Although considerable research exists with clinical and medical skill training, there is a lack of research in simulation training within other fields.

1.4 Challenge Point Framework

The challenge point framework introduced by Guadagnoli and Lee (2004) explains how learning is intimately related to the amount of information that is available and interpretable during performance, which, in turn, depends on the nominal and functional difficulty of the task (Guadagnoli & Lee, 2004). Nominal task difficulty refers only to the difficulty of the task and is impacted by both perceptual and motor performance requirements (Guadagnoli & Lee, 2004). Functional task difficulty refers to how challenging the task is relative to the skill level of the individual performing the task and to the performance conditions (Guadagnoli & Lee, 2004). This is important as it acknowledges that the characteristics of both the individual and the task difficulty must be considered. Characteristics within this framework and the motor learning field include task difficulty, experience levels, practice schedules/variables, feedback, and the optimal point to challenge a participant to increase learning (Guadagnoli & Lee, 2004). It is important to define and describe these characteristics to assist with future training. This framework provides a basis for task difficulty and performance to learning relationships which has been lacking from previous research. The framework states that a certain level of informational challenge is needed for leaners to benefit from training. This information can be from the environment, skills, internal (from the individual) and external feedback (from outside sources), and arousal levels of the individuals. Too little, too much, or the absence of information can hinder learning. A teacher must take into account the skill level of an individual and task difficulty and provide an optimal amount of information for learning to be enhanced. By increasing the informational demands through functional task difficulty, performance during practice may be impeded but learning may be enhanced (Guadagnoli & Lee, 2004). Other manipulations of practice and retention context, or the environment where the skill is performed, can help increase or decrease learning. Environmental manipulations can impact the external and internal feedback of individuals while performing skills (Badets & Blandin, 2012). By performing a skill in a controlled setting, a beginner may benefit from this because no external feedback from the environment is affecting performance or learning. An expert may benefit more from performing skills in an environment that causes certain levels of arousal. For example, an intermediate or advanced performer may practice skills in an environment that causes anxiety to benefit and develop their skill learning. Guadagnoli and Lee (2004) explain how an optimal challenge point is needed for different individual levels and tasks. When the amount of potential interpretable information from the task and environment is beneficial to the individual, this is described as the optimal challenge point (Guadagnoli & Lee, 2004). With this in mind, the current study will utilize nominal task difficulty through complexity variations and functional task difficulty will be manipulated through testing location.

1.4.1 Contextual Interference (CI)

There are many ways to arrange a practice session to improve the amount of learning that takes place. One of the more common approaches is called the Contextual Interference (CI) effect (Lee & Magill, 1983). It has been shown that random practice or unsystematic presentation of multiple and related versions of a skill leads to decrements in performance when compared to blocked or drill typed practice of a skill. However, when participants who engaged in random practice, perform a transfer test, they demonstrate improved learning compared to those who engaged in block practice (Magill & Hall, 1990). Random practice refers to several different skills practices in a random practice order; blocked practice refers to the same skills performed several times in a row. Through increasing the contextual interference of practice schedules, through random presentation, it is hypothesized that participants are required to engage in much deeper cognitive processing when practicing a skill which leads to enhanced learning (Wulf & Shea, 2002).

1.5 Task Complexity

Recent research highlights the impact that skill complexity has on motor learning (Wulf & Shea, 2002). Defining simple and complex skills and the differences between the two in terms of learning and performance is a developing area of research. Sanli and Lee (2015) used a method for categorizing skill complexity using the challenge point framework. The authors utilized and manipulated nominal and functional task difficulty to observe the effects on practice and transfer learning (Sanli & Lee, 2015). This study offered a basis for categorizing skill complextity. Results of their work exhibited that the challenge point framework did not predict the relationship between simple and complex skills but provided a starting point for describing complex skills (Sanli &Lee, 2015). Research throughout the years has focused on simple skill learning. It was previously thought that the principles that apply to simple skills could be generalized to all skills, including complex skill, but it is evident that simple and complex skill are learned differently (Wulf & Shea, 2002). Complex skills are much more difficult to define. The motor learning of simple skills and complex skills are typically not achieved the same way (Wulf & Shea, 2002). Complex skill learning is of interest in this thesis because the skills to be learned are thought to be complex in nature. Various practice variables, feedback, and instruction all affect the outcome of learning both simple and complex skills. However, Wulf and Shea (2002) proposed that complex skills may benefit more from blocked practice. Wulf and colleagues (2002) reviewed studies with complex skill learning and the pattern typically shown was that random practice was detrimental to learning complex skills. Wulf and Shea (2002) also explain how observational learning is best for complex skills. Observational learning is where an individual imitates a model and self-regulates their performance and learning (Ferrari, 1996; Pollock & Lee, 1992). Complex tasks require high memory demands that obscure the normally beneficial effects of CI (Wulf & Shea, 2002). It is evident that further research needs to be conducted on complex skill learning to fully understand the motor learning of complex skills.

A study completed by Ollis, Button, and Fairweather (2005), manipulated task complexity when learning novel knot tying tasks. The current thesis differs by focusing on the general population and configuration systems that utilize certain knots. Ollis and colleagues (2005), had 24 firefighters and 24 college students train to learn six knots with varying complexity, that are used within the firefighting profession (Ollis et al., 2005). They established a pre-test baseline and utilized two transfer tests to examine learning. The transfer tests, one occluded visual feedback, and the second transfer test consisted of a novel knot tying task. The first transfer test of tying knots blindfolded was selected to reflect that firefighters have to tie knots within confined and smoke-filled/dark locations (Ollis et al., 2005). Ollis and colleagues (2005) found that practice on complex knots led to poorer performance during retention, compared to the group that practiced on the simple knots. Thus, complexity during practice is an important variable to consider when developing skill training.

Psychological factors, specifically anxiety, can also accompany complex skill learning. Anxiety reduces the benefits of random practice schedules because participants become uncomfortable with variability and unpredicted contexts (Shewokis et al., 1995). A model called the inverted-U hypothesis (Yerkes & Dodson, 1908), explains that different complexities in tasks must have different and optimal levels of arousal and anxiety to be advantageous to performance (Eysenck, & Calvo, 1992; Martens & Landers, 1970). Therefore, for an individual to excel in performance the anxiety must be low for a difficult task and the anxiety must be high for easy tasks Yerkes & Dodson, 1908). Anxiety can have major impacts on the performance and motor learning of tasks with various complexities.

1.6 Anxiety

According to the The Mental Health Commission of Canada (2014), anxiety disorders are one the most common mental illness in Canada with 9% of men and 16% of women affected annually. Anxiety could be used as a tool to improve performance and learning. Two types of anxiety have been defined. Trait anxiety refers to personality characteristics rather than the temporary feeling of state anxiety. Whereas state anxiety is an unpleasant emotional arousal toward threatening demands or dangers (Spielberger, 1972). The mental appraisal of a threat is a prerequisite for the involvement of this emotion (Lazarus, 1991). State anxiety can be further classified into cognitive or somatic anxiety (Williams et al., 2016). Cognitive anxiety is described as the psychological or mental component of anxiety. (Martens et al., 1990, Spielberger, 1980). In contrast, somatic anxiety is observed through the physiological symptoms (Martens et al., 1990), often through an increase in heart rate, respiration and perspiration (Williams et al., 2016). Cognitive anxiety mostly hinders performance, while somatic anxiety does not have as much of an effect (Zeidner, 1998). Cognitive anxiety measures include the State-Trait Anxiety Inventory (STAI) test (Spielberger 1980, 1983) or response to a simple single question using a Likert scale or perceived anxiety measure (Davey, Barratt, Butow & Deeks, 2007). Somatic anxiety is typically measured using physiological devices like heart rate monitors (Martens et al., 1990; Zeidner, 1998).

Research surrounding anxiety and motor learning has demonstrated mixed findings. Research on task complexity and anxiety has observed detrimental and beneficial impacts on performance and learning (Calvo, Alamo, & Ramos, 1990; Lawrence et al., 2014; Morris, Davis, & Hutchings, 1981; Mueller, 1992; Mullen, Hardy, & Tattersall, 2005; Shewokis et al., 1995). As previously stated, task difficuty has been shown to impact anxiety levels during skill performance (Shewokis et al., 1995). Task complexity has been shown to have a similar effect on cognitive anxiety and feelings of worry (Morris, Davis, & Hutchings, 1981). Therefore, one might expect if participants would perform wore if they were told a task was difficult. One of the past research studies that observed the detrimental effects of task complexity on learning was completed by Calvo and colleagues (1990). They found that difficult tasks, fine tasks, trait anxiety, and cognitive state anxiety were associated with minor performance impairments (Calvo, Alamo, & Ramos, 1990). Another study where anxiety was manipulated through the instructions given in golf putting tasks (Mullen, Hardy, & Tattersall, 2005). Mullen and colleagues (2005) discovered that with high anxiety, performance was impaired. Anxiety and stress affect the learning and performance of motor skills (Mueller, 1992). While many studies have demonstrated anxiety and stress have a detrimental effect on performance (Mueller, 1992), recent research has found that practicing with anxiety can be beneficial to performance. Work by Lawrence, Cassell, Beattie, Woodman, Khan, Hardy and Gottwald (2014) discovered that when participants were already anxious in golf-putting tasks, they performed under conditions generating anxiety better than participants who were not previously introduced to anxiety. This study shows the importance of specificity of practice and how it can improve motor skill performance (Lawrence et al., 2014). Further, when researchers elicited anxiety and stress prior to training they found that after intervention self-reported stress and anxiety were higher than the control group (Hordacre et al., 2016). These results suggest that from that anxious testing conditions may effect performance but are likely not to impair learning (Calvo, Alamo, & Ramos, 1990; Mullen, Hardy, & Tattersall, 2005). However, these studies have not determined what type of conditions have detrimental or benefical effects on performance and learning. Future studies may benefit from the implementation of the challenge point framework (Guadagnoli & Lee, 2004); whereby anxiety could be modified through task difficulty, environment, or expertise. Anxiety typically has a negative stigma surrounding it, but adding anxiety to a training regime could actually help performance and learning.

1.6.1 Anxiety and Fear of Heights

One explanation for increases in anxiety and stress during performance is a phobia. A phobia is a response to a perceived threat that is consciously recognized as dangerous (Spielberger, 2013). A phobia results in an unpleasant emotional state consisting of both psychological and physiological responses such as agitation, dread, tension, and increases in heart rate, perspiration and respiration. Fear and anxiety have many overlapping states that focus on threats, but are considered separate (Öhman, 2008). While the response to phobias have an identifiable stimulus, the responses to anxiety are less identifiable. Anxiety is typically a response to a phobia and is considered an emotion (Öhman, 2008). One study that describes anxiety and phobias examined the sensory and cognitive anxiety variables of acrophobia (Coelho & Wallis, 2010). Acrophobia, is defined as the abnormal dread of being in a high place or a fear of heights, and is one of the most prevalent phobias (Coelho & Wallis, 2010). Results show that a fear of heights can produce strong feelings of discomfort and fear in otherwise calm individuals (Coelho & Wallis, 2010). Therefore, a fear of heights may have an impact on the motor learning of tasks. While this phobia is often observed in the general population (Coelho & Wallis, 2010) there is a growing area of research observing the impacts of fear and anxiety on working professionals' performance and learning. Many professionals are exposed to a complex combination of stressors; including fear of death and injury and uncertainty which can accompany acrophobia (Coelho & Wallis, 2010; Lieberman et al., 2006; Young et al., 2013). For example, while working at heights, firefighters must be calm and focused; although a fear of heights may be detrimental to their performance and endanger others (Young et al., 2013). Further research is needed to distinguish the role of anxiety on performance and learning in professionals.

1.6.2 Anxiety in the Workplace

Professionals can be vulnerable to anxiety and stress in a workplace environment. In particular, research from first responders shows high levels of stress and anxiety in the occupation (Brown et al., 2002; LeBlanc et al., 2005 Roy & Steptoe, 1994; Young et al., 2013). First responders work in dangerous settings and must be able to perform under stress (Young et al., 2013). These environments can be life threatening, to both the people these professionals are assisting and to themselves. LeBlanc and colleagues (2005) observed stress in first responder paramedics and found high levels of stress in clinical settings can increase human errors. The profession of firefighting is very diverse and firefighters must perform a variety of skills, often in extreme environments. Some firefighting job descriptions require these professionals to work at heights, on the ground, with fires, with hazardous materials, provide medical aid, and perform rescue/recovery operations (Ollis et al., 2005). Brown and colleagues (2002) outline the stressors that firefighters experience and suggested that as a profession they are not coping effectively. Young and colleagues (2013) examined different stressors and anxiety in the fire fighting profession and observed that stress levels and percieved workload are dependent on the role of the firefighter (Young et al., 2013). A strategy that may assist with diminishing the ocupational stress is more task specific training. Given the workplace demands on firefighters it is important to ensure that training is designed to reduce anxiety while maximizing performance (Alexander et al., 1993; Young et al., 2013).

1.7 Conclusions

The literature surrounding motor learning describes many of the secondary factors that affect the performance and learning of skills. The current review focused on the factors related to the current research. The type, amount, and specificity of practice all have major impacts on an individual’s ability to perform and learn skills. Simulation training was observed to be a strong aid in motor learning and performance. The benefits and disadvantages of training with anxiety have conflicting evidence. It is clear how anxiety impacts skill performance, although it is unclear about how anxiety affects the learning process. Skill training and professional training should incorporate a certain level of challenge; manipulation through anxieties, task difficulties, and environmental factors could lead to better skill training, better performance on the job, and better learning.

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Chapter 2: Co-Authorship Statement

The following specifies my role in the preparation of the manuscript.

Research Design

The methodological procedures were developed based on previous research in the field of motor learning and anxiety and the need of research in this area. Discussions with Drs. Elizabeth Sanli, Linda Rohr and Heather Carnahan assisted in the refinement of the project details and aided in obtaining the ethics approval by the Memorial University Interdisciplinary Committee on Ethics in Human Research (ICEHR) board under protocol 20180703-HK.

Data Collection

The collection of the data was completed by myself, with assistance from Dr. Elizabeth Sanli and instructor, Dan LaCour.

Data Analysis

Myself with the assistance and direction from Drs. Elizabeth Sanli, Linda Rohr, and Heather Carnahan completed data analysis.

Manuscript Preparation

The manuscript was written by myself, with the editing and feedback assistance from Drs. Elizabeth Sanli, Linda Rohr and Heather Carnahan.

Chapter 3: Manuscript

Learning to Prepare Hauling Systems for Rope Rescue

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3.1 Introduction

3.1.1 Background

Rope rescue techniques can provide lifesaving safe and rapid extraction from hostile environments for victims and rescue crews (Brennan, 1998). A wide variety of environmental emergency situations require the use of rope rescue techniques including water, ice, confined spaces, and high-angles like towers, bridges, and tall structures. Many emergency personnel personnel, such as search and rescue and firefighters, undergo rope rescue training. From 2012 to 2015, eleven fatalities occurred, in the United States, during rope rescue training and in the line of duty (Feder, 2016). Clearly these tasks have risks that can be anxiety provoking for trainees. Our work will address the role of anxiety during the learning of these rope rescue skills.

The study of real life skills, like rope rescue, can provide insight into our understanding of motor learning. In turn, the theoretical study of motor learning can also inform industrial and emergency training protocols. Over the past half century, motor learning research has progressed substantially through elucidating the variables that affect practice and retention. Skill retention after practice is a reflection of how much learning has taken place, whereas learning is defined as a relatively permanent change in behaviour (Schmidt & Lee, 2018 p178).

Practice is one of the most important factors that has been effectively shown to lead to improvements in motor learning, where greater amounts of practice have generally been positively related to skill improvement (Guadagnoli & Lee, 2004; Magill, 2001; Schmidt & Lee, 2018). Whether the learner benefits from the practice is influenced by factors such as the task, the environment, and practice characteristics.

Motor skills can be learned in applied settings as well as in simulated environments. Benefits from simulation include safety and targeted training to the learners’ needs. Also, simulation allows for multiple controlled practice attempts, and provides a supportive and educational environment. To maximize practice and learning, it is best to provide specific training that reflects the real-world situation (Tremblay & Proteau, 1998). Task specificity involves whether the task being practiced is similar to the task that is meant to be learned. To maximize the benefits of learning, environmental, individual, and task specific factors should be considered during practice (Lewthwaite & Wulf, 2012).

One consideration when making practice realistic is that for certain industrial skills, a more realistic training scenario may cause anxiety, such as a firefighter training with real fire and smoke, marine safety training performed in open water, or rope rescue training taking place at height. We know very little about how practice with anxiety affects learning, but depending on certain factors, anxiety may be beneficial or detrimental. Therefore, more work is needed to better understand the role of anxiety in order to optimize the benefits and minimize any negative effects (Calvo, Alamo, & Ramos, 1990; Lawrence et al., 2014; Morris, Davis, & Hutchings, 1981; Mueller, 1992; Mullen, Hardy, & Tattersall, 2005; Shewokis et al., 1995). Performance impairments have been shown when instruction and task difficulty were manipulated to increase anxiety (Calvo, Alamo, & Ramos, 1990; Mullen, Hardy, & Tattersall, 2005; Young et al., 2013). It was observed that anxious testing conditions may affect practice but are likely not to impair learning (Calvo, Alamo, & Ramos, 1990). Contrasting research shows that individuals may improve practice and learning from the arousal associated with anxiety (Lawrence et al., 2014; Alexander et al., 1993; Tischler, Biberman, & McKeage, 2002). It is evident that further research needs to be completed focusing on complex skill learning to fully understand learning in realistic settings such as industry, health care, and safety training (Brydges, Dubrowski & Carnahan, 2007).

There are two classifications of state anxiety; cognitive and somatic (Williams et al., 2016). Cognitive, also known as worry anxiety, is described as the mental component of anxiety that includes feelings of worry and negative thoughts (Martens et al., 1990, Spielberger, 1980). Somatic or emotionality anxiety, is reflected by physiological symptoms (Martens et al., 1990) such as, an increase in heart rate, respiration and perspiration (Williams et al., 2016). It was observed that cognitive anxiety typically hinders performance, while somatic anxiety does not have as much of an effect on performance (Zeidner, 1998). Fear and anxiety have many overlapping states that focus on threats, but are considered to be separate (Öhman, 2008). Acrophobia, which is defined as the abnormal dread of being in a high place or a fear of heights, is one of the most prevalent phobias associated with cognitive anxiety (Coelho & Wallis, 2010).

To measure anixety, Spielberger (1980, 1983) pioneered the state-trait anxiety inventory (STAI) test. However, this has since been improved on by Davey and colleagues (Barratt, Butow & Deeks, 2007) who proposed that a Likert scale or visual-analogue scale was quicker, easier, and a suitable replacement for the STAI (Davey et al., 2007).

3.1.2 Purpose

This study aims to address the role of anxiety during practice on learning to configure hauling systems. Cognitive anxiety was induced by manipulating task complexity and somatic anxiety was induced by requiring participants to practice at heights. Thus, the research questions were as follows:

a) How does practice on hauling systems of various complexities affect skill performance during practice and retention?

b) How does practice on hauling system preparation at low and high heights affect skill performance during practice and retention?

c) Is anxiety during practice and retention affected when task complexity is increased?

d) Is anxiety during practice and retention affected when exposed to heights?

3.2 Methodology

3.2.1 Participants

Participants were volunteers from the general population of St. John's, Newfoundland and were considered beginners in knot-tying and hauling system preparation. Based on research conducted by Ollis and colleagues (2005), a statistical power analysis calculated in G*Power 3.1.9.2, indicated that a minimum sample of ten per group was required. During the recruitment process, participants were asked if they, "had any experience with rock climbing or rope system configuration?". If they responded yes, they were considered to have more experience than the general population and were excluded from the study. Exclusion criteria also included any neurological or physical limitations preventing the participant from climbing three flights of stairs, an extreme fear of heights, and/or if the participants was younger than 18 or older than 55 years. This reflects the typical age that a firefighter would complete this type of training. Twenty participants (N = 20) volunteered ranging from 19 to 48 years and were randomly assigned to one of the two practice groups. Participants verbally provided self-reported demographics and inclusion criteria. Participants received a twenty dollar coffee shop gift card as incentive for their participation. All procedures were approved by the Memorial University Interdisciplinary Committee on Ethics in Human Research (ICEHR)- 20180703.

3.2.2 Apparatus and Materials

Training and testing took place at the Marine Intitute's Offshore Safety and Survival Centre in Foxtrap, Newfoundland. The environment for the training and testing included a classroom and an elevated location. The elevated location consisted of a three story (~ 14 m) firefighting training structure with grated stairs and flooring that was surrounded by railings.

Hauling Systems

Hauling and lowering systems are comprised of a series of knots, pulleys and devices assisting in high-angle rope rescue (Frank, 2010; Jackovics, 2019). Firefighters and rescue personnel are typically the individuals that would utilize these systems. These systems could be used for both hauling an individual up or lowering them to the ground (Frank, 2010). Our hauling systems includes single and double pulleys, carabiners, a multi-purpose device, double figure eight and prusik knots. The double figure eight knots are a very stable knot that are easy to take apart if needed. The triple-wrap prusik is bi-directional and can easily slide along the line and can be hauled on. The multi-purpose device is a high-efficiency pulley, with an integral rope-grab mechanism. This device allows it to be used as a lowering device on the main line and belay line systems and can be quickly changed over to a hauling system without reconfiguring the entire system (Frank, 2010). The complexities used were 3:1 and 5:1 (Figure 1). The 3:1 hauling system is considerd a simple system and the 5:1 is considered a complex system (Frank, 2010). The 3:1 system creates a Z shape with the lines and also known as a z-rig. To configure the systems, one must begin with a double figure-eight knot at the load. Then a prusik with a carabiner is attached to a pulley and the multi-purpose device is attached to the anchor. The pulleys in the hauling systems utilize mechanical advantage, ultimately allowing a person to lift much more than they are physically capable of lifting. For example, within the 5:1 system pulling the rope 5 m will raise the load 1 m or, in other terms, pulling 1 unit of tension creates 5 units of tension at the load. Many more complexities exist, although only two different complexities were incorporated in the present study due to time constraints.

3.2.3 Dependent Variables

Hauling system performance was evaluated by error scores and movement time (MT). To measure cognitive anxiety, a self-reported perceived anxiety visual-analogue scale (range 1 -10) was used, where higher anxiety is expressed as higher numbers (i.e. 10). Somatic anxiety was measured by heart rate (HR) in beats per minute (bpm) and heart rate variability (HRV) in milliseconds (ms) between heart beats. Increased somatic anxiety is typically expressed through increased HR and decreased HRV (Hoehn-Saric, 1998).

Configuration Performance Scores

The number of correct responses that each participant made during the testing protocols was counted and identified by one of two trained evaluators, each checklist was verified by the expert instructor. A checklist (Figure 2) was developed by the research team to determine the corrects actions and errors made by the participants during practice and retention. The participant could perform the task either correctly, with non-critical errors (e.g. the hauling system could still be used but the aesthetics were not perfect), or critical errors (e.g. the hauling system could not be used). An example of a non-critical error in the configuration would be if the knot in the prusik was not offset correctly and was in the way of the carabiner. In this scenario the hauling system will still work, but the configuration is not optimal. An example of a critical error would be if the rope was not put through the multi-purpose device correctly, this could drastically interfere with the rescue operations and could result in the rescuer and victim falling. If a participant completed each component correctly, they would receive a score of eleven. Deductions from a perfect score of eleven were made for non-critical errors (- 0.5 point) and critical errors (-1 point). MT was used to measure performance (Keele, 1968; Sanli & Lee, 2015).

Cognitive Anxiety

Cognitive anxiety was examined through verbal questionning and a scoring sheet. A sheet of paper weighted with antonyms at each end, e.g. low and high was used to measure perceived anxiety (Davey et al., 2007; Young et al., 2013). The perceived anxiety measure contained a ten number Likert scale where ten indicated that the participants felt very anxious and one indicated that the participants did not feel any anxiety at all. The investigators used the perceived anxiety measure after every trial, and participants stated how they felt after each condition. Researchers used the following script while administering the perceived anxiety measure, "How do you feel after completing this trial? Please state or point to a number on the perceived anxiety scale. Ten indicates that you feel very anxious and one indicates that you do not feel any anxiety at all." The perceived anxiety measure was used as a quick and easy instrument to acquire the participants self-reported anxiety (Davey et al., 2007).

Somatic anxiety

Physiological/somatic anxiety was evaluated using a Zephyr Bioharness heart rate monitor that assessed the participants heart rate (HR) in beats per minute and heart rate variability (HRV) in milliseconds. HR and HRV have been shown to reflect anxiety (Williams et al., 2016). The BioHarness (Zephyr Technology Corporation, Annapolis, MD, US) is a wireless, physiological monitoring device that consists of an adjustable chest strap (50 g, 50 mm width; weight 35 g, 80x40x15 mm) and detachable transmitter unit (Johnstone et al., 2012; Kim et al., 2015). Kim and colleagues found the Zephyr Bioharness be an accurate method of heart rate data collection. Each participant wore the Zephyr Bioharness during practice and retention. The HR and HRV was further analyzed at two time points; at the beginning of the trial and at one minute and thirty seconds into the trial. The overall average MT (*M* = 3.23 min ± 0.15 *SD*) was divided in half, which gave an approximate time point of one minute and thirty seconds to analyze responses after the trial was half complete. To remain consistent, the same half way time point was used for both task complexities. A ten second average was used as a sampling window for calculations of each time point as a summary for the first and halfway responses to the trial. These sampling windows were used with the objective of observing changes in the somatic anxiety from the beginning of the trial to half way through the movement.

3.2.4 Procedure

Participants were randomly divided into two practice groups; a High practice group and a Low practice group. The Low practice group underwent training in a classroom setting and the High practice group trained at the elevated location (~ 14 m) (Figure 3). The practice training was performed within a group of one to four participants and retention testing was performed individually. The instruction during practice was completed by a trained expert (12 years) from the Offshore Safety and Survival Centre. The instructor utilized verbal, visual, and kinesthetic demonstrations of the hauling systems and its components. The instructor began by teaching each single component of the system to the participants and allowed them to get acquainted with the materials. The theory behind hauling systems, such as mechanical advantage, was taught to the participants and then the entire system was prepared. The first day of the study consisted of the practice of the hauling systems, which was completed at the respective locations that each participant was assigned to. Participants were given five practice attempts with feedback from the instructor after each attempt. During typical rope rescue training, students are only given one to two practice attempts of the hauling systems, and through pilot testing individuals typically achieved competence of the skill after three to four practice attempts. Given this, five practice attempts was deemed suitable. The participants first practiced the 3:1, followed by the 5:1 because 5:1 includes the 3:1 in the configuration. The first session took approximately three hours. The second session, completed five to seven days later, consisted of the retention test. For both training groups the retention tests were completed at the elevated location first and then in the classroom. For retention, participants were asked to complete each complexity of the hauling systems once in each environments (i.e. classroom and elevated location). The retention session took approximately one hour. After each trial the configuration performance scores and the MT was evaluated. During all trials the participants HR and HRV were continuously measured. After the completion of each trial (practice/retention testing) the primary investigator administered the perceived anxiety measure. A photograph of each hauling system configuration was taken after each trial to record and reviewed later as needed.

3.2.5 Analyses

Statistical significance was assessed at $p < .05$ throughout, and all analyses were conducted using SPSS Statistics for Windows, Version 23.0. Armonk, NY (IBM Corp, 2015). All dependent variables for practice were analyzed in separate 2 (Group; High, Low) x 2 (Complexity; 3:1, 5:1) x 5 (practice trial) mixed-design analyses of variance (ANOVA's) with repeated measures on the last two factors. The retention data for each dependant variable were analyzed in separate 2 (Group; High, Low) x 2 (Complexity; 3:1, 5:1) x 2 (testing location; Elevated, Classroom) mixed-design ANOVA's with repeated measures on the last two factors. Statistically significant ANOVA effects were further analyzed using the Tukeys Post-hoc method for comparing means. Sphericity calculations and Greenhouse-Geiser corrections were completed when necessary.

During practice and retention, less than 5% of the HR and HRV data collected from the Zephyr Bioharness was missing due to technological error. When this issue was observed, we checked to ensure the monitor was positioned correctly, all settings were correct and continued with collection.

3.3 Results

Participants, whose ages ranged from 19 to 48 years (*M* = 25.95 ± 6.47*SD*), were primarily students from Memorial University and 20% of the sample from the general population of St. John's, Newfoundland. This sample represents the typical age of a trainee that would undergo rope rescue training. While the majority of the rope rescue trainees in real life are males, an equal sample of ten males and ten females were included.

3.3.1 Practice Results

Performance Scores

Configuration

Configuration performance was rated out of eleven, with a score of eleven being considered 100%. There were statistically significant main effects for group ($F_{(1, 18)} = 8.72$, $p = .009$) and complexity ($F_{(1, 18)} = 5.96$, $p = .025$). As well as a significant interaction between group and complexity ($F_{(1, 18)} = 5.01$, $p = .038$). Tukey HSD post hoc tests revealed significant differences between the 3:1 system performed by the High practice group, and all other trials (Figure 5). Also, significant differences between each group and both complexities were observed. Participants in the Low practice group performed superiorly to the High practice group.

There were statistically significant main effects for practice trial ($F_{(2.47, 44.58)} = 7.38$, $p < .001$) when configuration performance was analyzed. Tukeys HSD test revealed significant differences between trial one had greater errors than practice trials two, three, four and five; indicating that the participants' configuration performance scores improved (Figure 4a).

Movement Time (sec)

There was no statistically significant effect of group ($F_{(1,18)}$ = .03, p = .85) or task complexity ($F_{(1, 18)}$ = 1.34, p = .26) in the analysis of MT. As well, no significant interactions were found for group, complexity, or practice trial. However, there was a statistically significant main effect for practice trial ($F_{(2.7, 48.61)}$ = 8.83, $p < .001$). Mauchly's test of sphericity revealed that the assumption of sphericity had been violated, (x^2 (9) = 20.52, p = .01), and degrees of freedom were corrected to Greenhouse- Geiser estimates (ε = .67). Movement time decreased from practice trial one to practice trial five (Figure 4b).

Anxiety Scores

Cognitive Anxiety: Self-reported Perceived Anxiety

Higher values on the ten point perceived anxiety measure reflected greater perceived anxiety. There were no statistically significant main effects for group ($F_{(1, 18)}$ = 1.15, p = .29), or complexity ($F_{(1, 18)}$ = 2.8, p = .11). There was a significant main effect for practice trial ($F_{(2.24, 40.23)}$ = 23.42, $p < .001$), as well as a significant interaction between skill complexity and practice trial ($F_{(4, 72)}$ = 3.13, p = .02). Tukey post hoc comparison revealed that for the 3:1 system, practice trials three, four and five were significantly less anxious than practice trials one and two. For the 5:1 system, practice trials two, three, four and five had significantly less percieved anxiety than practice trial one (Figure 6).

Somatic Anxiety: Heart Rate (HR - bpm)

When HR was analyzed, there were no statistically significant main effects for group ($F_{(1, 18)}$ = .68, p = .42) or complexity ($F_{(1, 18)}$ = .032, p = .86). However, there was a significant main effect of practice trial ($F_{(4, 15)}$ = 5.82, p < .001) as well as a significant interaction for complexity and practice trial ($F_{(4, 72)}$ = 2.72, p = .03). Mauchly's test indicated that the assumption of sphericity had not been violated for practice trial (x^2 (9) = 5.034, p = .83) and complexity by practice trial (x^2 (9) = 11.25, p = .26). Therefore, sphericity assumption values were used. Tukey post hoc comparisons revealed that the HR was higher for the 3:1 system between practice trial one and the remaining trials (Figure 7). For the 5:1, practice trial four was significantly lower than all the others.

Half way through the completion of the skill, at one minute and thirty seconds, an average of the 10 second heart rate data was analyzed. There was no statistically significant main effect of group ($F_{(1, 18)}$ = .97, p = .34). However there was significant main effect of complexity ($F_{(1, 18)}$ = 5.64, p = .03) and a main effect for practice trial ($F_{(4, 72)}$ = 3.44, p = .012) when HR was analyzed. Mauchly's test indicated that the assumption of sphericity had not been violated for practice trial (x^2 (9) = 2.69, p = .97). Therefore, sphericity assumption ANOVA values were used. For the 3:1 system (*M* = 99.15, *SE* = 4.39) participants had significantly higher HR's than when practicing the 5:1 system (*M* = 96.26, *SE* = 4.05). Post hoc comparisons revealed the HR for practice trial one (*M* = 100.82 bpm, *SE* = 4.18) was higher than practice trial two (*M* = 96.93 bpm, *SE* = 4.62), three (*M* = 96. 65 bpm, *SE* = 4.14), four (*M* = 96.59 bpm, *SE* = 4.33), and five (*M* = 97.53 bpm, *SE* = 4.03). No significant interactions were observed for HR.

Somatic Anxiety: Heart Rate Variability (HRV - ms)

Due to technological error, HRV (ms) data was missing for one participant in the Low practice group (N = 9). Therefore, HRV data reflected only a part of the sample. During the first

10 seconds of the skill HRV was analyzed. There was no statistically significant main effect for group ($F_{(1, 17)} = .004$, $p = .95$) or complexity ($F_{(1, 17)} < .00$, $p = .99$). There was a statistically significant main effect for practice trial ($F_{(2.34, 39.76)} = 3.18$, $p = .045$). Mauchly's test indicated that the assumption of sphericity had been violated for practice trial (x^2 (9) = 20.72, $p = .014$) therefore, degrees of freedom were corrected for using Greenhouse-Geiser estimates of sphericity ($\varepsilon = .58$). Participants HRV in practice trial one (M = 59.87 ms, SE = 5.49) was higher than practice trials three (M = 71.59 ms, SE = 6.65), four (M = 69.02 ms, SE = 6.337), and five (M = 67.71 ms, SE = 7.21). No statistically significant interactions were observed.

At one minute and thirty seconds into the skill, an average of 10 second HRV data was analyzed. Due to the technological error, HRV (ms) data was missing for one participant from each of the two groups (High practice group (N = 9) and the Low practice group (N = 9)). There were no statistically significant main effects for group ($F_{(1, 16)} = .32$, $p = .58$), complexity ($F_{(1, 16)} = .56$, $p = .46$) or practice trial ($F_{(4, 64)} = 1.40$, $p = .24$), and no significant interactions were observed.

3.3.2 Retention Results

Performance Scores

Configuration

There were no statistically significant main effects for group ($F_{(1, 18)} = .72$ $p = .40$), complexity ($F_{(1, 18)} = .17$, $p = .68$) or testing location ($F_{(1, 18)} = 3.61$, $p = .07$) and no significant interactions were found when configuration score was analyzed.

Movement Time (MT)

There was no main effect of group ($F_{(1, 18)} = .12$, $p = .73$), but we observed a main effect of complexity ($F_{(1, 18)} = 15.49$, $p = .001$), testing location ($F_{(1, 18)} = 6.82$, $p = .018$), and an interaction between complexity and testing location ($F_{(1, 18)} = 9.727$, $p = .006$). As seen in Figure 8c, the 3:1 complexity MT was the same for both the elevated and classroom environments. However, for the 5:1 complexity, MT was higher for the elevated location compared to the classroom environment.

Anxiety scores

Cognitive Anxiety: Self-reported Perceived Anxiety

There were no statistically significant main effects of perceived anxiety for group ($F_{(1, 18)} = .67$, $p = .42$) or complexity ($F_{(1, 18)} = .09$, $p = .77$). There was a significant main effect for testing location ($F_{(1, 18)} = 33.18$, $p < .001$, Figure 8a). Perceived anxiety was higher for both practice groups at the elevated location during retention. A significant interaction was observed between group and complexity ($F_{(1, 18)} = 9.04$, $p = .008$). For the 3:1 complexity there was no difference between the practice groups. However, the Low practice group had higher perceived anxiety than the High practice group during the 5:1 complexity (refer to Figure 8b)

Somatic Anxiety: Heart Rate (HR)

During the first 10 seconds of the skill, analyses showed no statistically significant main effects for group ($F_{(1, 18)} = .89$, $p = .36$), complexity ($F_{(1, 18)} = 1.07$, $p = .31$) or testing location ($F_{(1, 18)} = 1.18$, $p = .29$) for HR. However, there was a significant interaction for complexity and testing location ($F_{(1, 18)} = 5.18$, $p = .03$). For the 3:1 complexity, HR was significantly higher during the elevated condition ($M = 99.62$, $SE = 4.53$) compared to the classroom condition ($M =$

93.14, *SE* = 5.42). For the 5:1 complexity (which was performed after the 3:1 complexity) there was no difference between the retention testing locations.

The average of 10 seconds of HR data was analyzed at one minute and thirty seconds. There were no statistically significant main effects for group ($F_{(1, 18)}$ = 3.48, *p* = .08), complexity ($F_{(1, 18)}$ = 2.22, *p* = .15) or testing location ($F_{(1, 18)}$ = .83, *p* = .37). No significant interactions were observed in the variables, half way through the skill.

Somatic Anxiety: Heart Rate Variability (HRV)

Due to technological error, HRV (ms) data from four participants from each group was missing (the High practice group (N = 6) and the Low practice group (N = 6)). During the first 10 seconds of the skill HRV was analyzed. There were no significant main effects for group ($F_{(1, 10)}$ = 1.16, *p* = .31), complexity ($F_{(1, 10)}$ = 3.58, *p* = .08) and testing location ($F_{(1, 10)}$ = 4.61, *p* = 0.57). No significant interactions were observed.

Half way through the completion of the skill, at one minute and thirty seconds, an average of 10 seconds of HRV data was analyzed. Due to technological error, HRV (ms) data was missing and the group sizes are different from the other variables (where the High practice group (N = 5) and the Low practice group (N = 8)). There were no statistically significant main effects for group ($F_{(1, 11)}$ = 1.31, *p* = .27), complexity ($F_{(1, 11)}$ = 1.86, *p* = .20) or testing location ($F_{(1, 11)}$ = .10, *p* = .75). No significant interactions were observed half way through the skill.

3.4 Discussion

In summary, participant’s configuration performance during practice and retention was not affected by the complexity of the hauling system. However, performance speed was affected by hauling system complexity during retention (Figure 8). During practice, the configuration performance score was affected by practice trials and the practice group, but not during retention. However, MT was not affected by practice group during practice but MT was longer during retention tests, particularly during elevated retention. During practice, it was observed that complexity did not have an effect on cognitive or somatic anxiety during practice (Figure 6), but complexity had an impact on perceived anxiety during retention. When exposed to heights during practice, participants did not show significant effects on cognitive or somatic anxiety. During retention, perceived (cognitive) anxiety was highest during the elevated retention testing.

Practice trial effects

Performance (MT and configuration performance scores) and anxiety (cognitive and somatic) improved as a function of practice. This is important because it validates our dependent variables by showing that they were sensitive to practice effects (Schmidt & Lee, 2018, p234). For example, MT decreased as a function of practice and configuration performance scores increased as a function of practice. This finding also supports the notion that participants received adequate amount of practice on the skills that led to motor learning. There were learning curve effects for configuration performance, MT and perceived anxiety during the practice trials. Significant changes from practice trial one to the final practice trial were observed, theses changes followed a typical learning curve trajectory (Crossman, 1959) and explain for increases in performance and decreases in anxiety. The improvements in performance support the notion that deliberate practice increases the performance of tasks (Ericsson, Krampe & Tesch-Römer, 1993; Guadagnoli & Lee, 2004). Note that HR and HRV for the first practice trial was different from the other remaining trials, which generally did not differentiate from each other. This is likely caused by greater anxiety on the first exposure but once participants had adapted to the skill, physiological responses of anxiety quickly plateaued (Brouwer, Hogervorst, Holewijn & van Erp, 2014).

As stated before, real-world training only requires for one to two practice attempts of each complexity and in the current study the five practice trials completed show continuous improvements in performance from practice trial one to five. Therefore, hauling system training should incorporate a minimum of five practice trials to benefit performance and learning. Further research may investigate a larger number of practice to observe whether hauling system performance and learning benefits from more than five practice trials.

Height effects

During practice an important finding was that configuration performance scores of the Low practice group were significantly better than those of the High practice group. According to the challenge point framework (Guadagnoli & Lee, 2004), an individuals performance will suffer if the task difficulty is too high. We interpret that exposure to height increase task difficulty and reduced configuration performance.

We expected to observe influences of height on practice performance and learning (Camm, Malik, Bigger, Breithardt, Cerutti, Cohen... & Lombardi, 1996; Cinaz, Arnrich, Marca & Tröster, 2013). However, the only statistically significant effect of height on MT performance was during retention. It is interesting to note that practice and retention at height did not result in cognitive or somatic anxiety as expected. It is possible that while participants were performing at height (~ 14m) there were enough safeguards (railings) that they may not have experienced the expected anxiety. Also, a self-declared fear of heights was an exclusion criterion for participation for this study. We chose this as an exclusion criterion because we were attempting to create a sample involving personnel criteria that would be typical search and rescue recruitment. Future work could replicate this study with individuals who have a self-declared fear of heights or personnel who are involved with search and rescue. In retention, there was an increase in MT at height but this was independent to the type of practice environment. Its hypothesized that the added anxiety of being in a testing situation contributed to this effect (Eysenck, 1979). In other words, there may be a sub-threshold anxiety caused by working at heights, this was brought to threshold (as evidence by the significant effect of elevated perceived anxiety during retention) when performing at heights in a testing environment. Our results do not support a training specificity perspective (Tremblay & Proteau, 1998).

Task complexity effects

During practice, there was increased perceived anxiety and decreased configuration performance scores for the simple 3:1 hauling system in comparison to the 5:1 hauling system. While this was unexpected it should be noted that the 3:1 hauling system was always practiced prior to the 5:1 hauling system. As a result, the participants may have become comfortable with the task, materials and environment by the time they performed the 5:1 (Alexander et al., 1993; Tischler, Biberman, & McKeage, 2002; Taylor & Asmundson, 2008). Perceived anxiety likely decreased for the 5:1 configuration because participants had increased familiarity with the practice environment and the task. This pattern was replicated with HR results during practice. Participants may have gotten more comfortable with each trial and complexity and felt more competent with their abilities (Tischler, Biberman & McKeage, 2002), which could explain the decrease in anxiety and increase in performance scores. During retention, as expected, MT was longer for the complex 5:1 hauling system. This difference was magnified when performing the 5:1 system in an elevated environment. An increase in anxiety in the elevated location with the more complex hauling system may have led to the longer MT performance observed (Eysenck, & Calvo, 1992). These MT results are not consistent with measures of somatic anxiety but are consistent with cognitive anxiety measures (Morris, Davis, & Hutchings, 1981). Task complexity can negatively affect cognitive anxiety, which would explain why the Low practice group perceived the difficult 5:1 hauling system as producing the most anxiety (Morris, Davis, & Hutchings, 1981).

3.5 Perspectives

There were limitations to our study. We did not demonstrate any direct impacts from heights on performance or anxiety. The railings and safety barriers at the elevated location may have provided the participants with enough comfort that they did not experience realistic anxiety from that setting. Self-reported perceived anxiety was administered after every trial and it is possible that this measure may have lost its sensitivity over repeated exposure. Instrumentation issues may be apparent due to daily fluctuations in technology and self-reported scores can affect the internal validity (Taylor & Asmundson, 2008). The reliability of the Zephyr Bioharness was an issue due to the data missing for a few of the trials. The checklist utilized for the configuration performance scores has not yet been validated by experts and had a maximum of eleven items. During practice, the 3:1 complexity was practiced before the 5:1 complexity this means that some of the effects observed were from order rather than task complexity. The complexities were not counterbalance because the 3:1 must be learnt prior to the 5:1 since it is an addition onto the 3:1 system. As well in retention, all of the elevated trials were completed before the classroom trials. While this was purposeful to maximize the negative effects of performing at height it did create a potential order effect compound. Another limitation of the current study is the limited scope of our samples demographics and sample size. The participants in this study were primarily students, with only 20% from the general population. It was assumed that this sample would be similar to the real rope rescue population but perhaps a wider age range and primarily males. Suggestions for future research include creating a high testing and training environment that appears less safe, testing people who have self-declared phobias of height, and testing rope-rescue trainees so the results are more directly applicable to training firefighters and search and rescue.

3.6 Conclusion

To our knowledge, this is first studies to assess this type of firefighting (rope rescue) skills and anxiety induced by different complexities and environments. In the present study there was a relatively small sample size and the limited population demographics. Keeping this in mind, based on these results, training at height does not appear necessary for transfer to performing at height conditions and trainees need to practice the entire range of complexity. However, it is important that trainees get training on complex hauling systems because it has been shown that practicing and performing more complex hauling systems, contributes to cognitive anxiety related to performing at height. It is anticipated that these findings could benefit rope rescue training standards. The results do not support the specificity of training hypothesis in terms of height but do support the notion of practice for motor learning.

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3.8 Tables

Table 1*. *A.* *Significant main effects and interactions for practice.* *B.* *Significant main effects and interactions for retention.

A.

	F	*dF*	*p*
		Configuration Score	
Group	8.72	1, 18	.009
Complexity	5.96	1, 18	.025
Group & Complexity	5.01	1, 18	.038
Practice trial	7.39	4, 72	< .001
		Perceived Anxiety	
Practice trial	23.42	2.24, 40.23	< .001
Complexity & Practice trial	3.19	3.05, 54.82	0.032
		Movement time	
Practice trial	8.83	2.7, 48.61	< .001
		Heart rate (10sec)	
Practice trial	5.80	4, 15	< .001
Complexity & Practice trial	2.71	4, 72	0.036
		Heart rate (1:30)	
Practice trial	3.44	4, 72	0.012
Complexity	5.64	1, 18	0.029
		Heart rate variability (10 sec)	
Practice trial	3.18	2.34, 39.76	0.045

B.

	F	*df*	*p*
		Perceived Anxiety	
Location	33.18	1, 18	< .001
Group & Complexity	9.04	1, 18	0.008
		Movement time	
Complexity	15.46	1, 18	0.001
Location	6.82	1, 18	0.018
Complexity & Location	9.72	1, 18	0.006
		Heart Rate (10sec)	
Complexity & Location	5.18	1, 18	0.035

Table 2. A. *Absolute data of mean and standard error values of non-significant variables during practice.* ***B****. Absolute data of mean and standard error values of non-significant variables during retention.*

A.

Dependant Variable	**Independent Variable**	**Condition**	**Mean**	**Standard error**
Perceived anxiety	Group	High	3.73	.43
		Low	3.07	.43
	Complexity	3:1	3.60	.38
		5:1	3.20	.27
Movement time (sec)	Group	High	196.62	13.23
		Low	193.21	13.23
	Complexity	3:1	189.46	10.45
		5:1	200.37	10.50
Heart Rate -10 sec avg (bpm)	Group	High	92.05	5.87
		Low	98.89	5.87
	Complexity	3:1	95.60	4.40
		5:1	95.34	4.03
Heart Rate - 1:30 min avg (bpm)	Group	High	93.60	5.90
		Low	101.82	5.90
Heart Rate Variability – 10 sec avg (ms)	Group	High	66.25	8.12
		Low	67.04	8.56
	Complexity	3:1	66.64	6.11
		5:1	66.65	5.89
Heart Rate Variability – 1:30 min avg (ms)	Group	High	76.93	10.38
		Low	68.62	10.38
	Complexity	3:1	71.97	7.31
		5:1	73.58	7.53
	Practice Trial	1	68.36	6.50
		2	72.64	7.13
		3	72.64	7.95
		4	74.04	8.31
		5	72.93	8.11

B.

Dependant Variable	**Independent Variable**	**Condition**	**Mean**	**Standard error**
Configuration Score	Group	High	10.65	.08
		Low	10.75	.08
	Complexity	3:1	10.67	.09
		5:1	10.72	.06
	Location	Elevated	10.58	.09
		Classroom	10.81	.07
Perceived anxiety	Group	High	3.27	.43
		Low	3.77	.43
	Complexity	3:1	3.50	.31
		5:1	3.55	.32
Movement time (sec)	Group	High	180.80	13.14
		Low	174.35	13.14
Heart Rate -10 sec avg (bpm)	Group	High	91.21	6.36
		Low	99.69	6.36
	Complexity	3:1	96.38	4.67
		5:1	94.53	4.49
	Location	Elevated	96.91	4.14
		Classroom	94.01	5.18
Heart Rate - 1:30 min avg (bpm)	Group	High	89.16	6.06
		Low	105.15	6.06
	Complexity	3:1	99.62	4.50
		5:1	94.69	4.68
	Location	Elevated	98.43	4.50
		Classroom	95.88	4.50
Heart Rate Variability – 10 sec avg (ms)	Group	High	85.13	11.47
		Low	67.63	11.47
	Complexity	3:1	81.22	9.96
		5:1	71.53	6.74
	Location	Elevated	82.22	9.43
		Classroom	70.54	7.57
Heart Rate Variability – 1:30 min avg (ms)	Group	High	81.67	13.44
		Low	62.05	10.63
	Complexity	3:1	75.09	9.79
		5:1	68.63	7.88
	Location	Elevated	70.83	8.88
		Classroom	72.89	9.38

3.9 Figures

Figure 1. *Pictures of 3:1 and 5:1 hauling systems.*

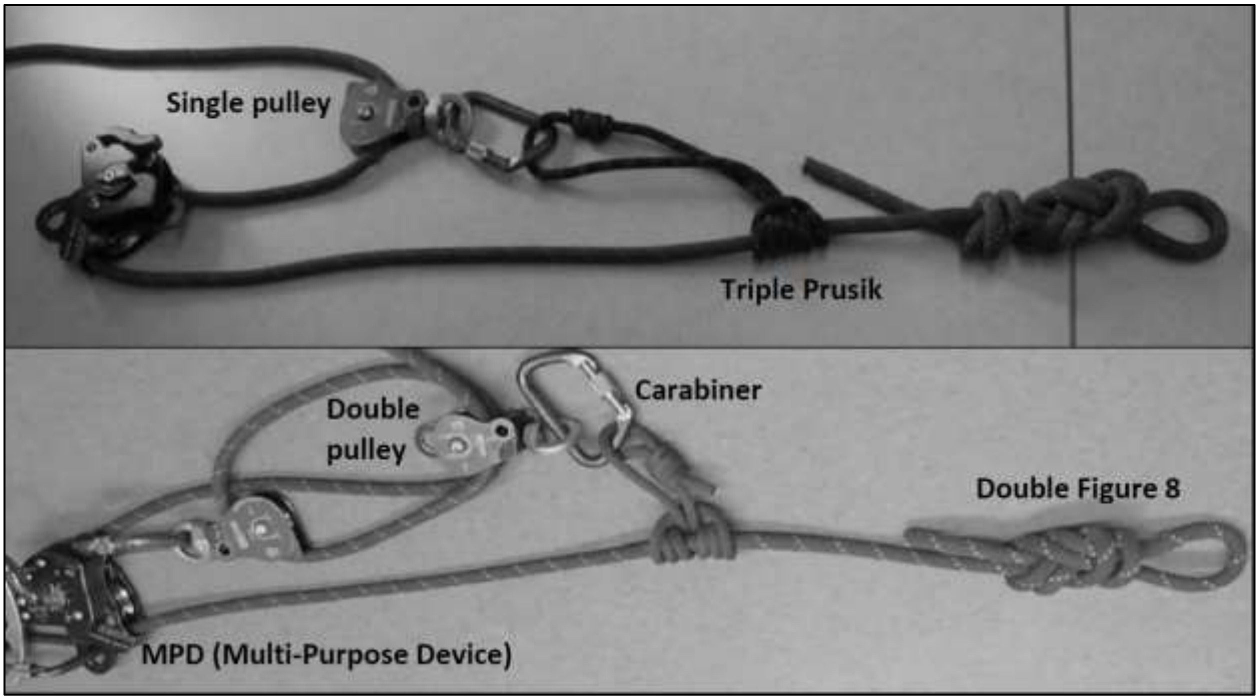
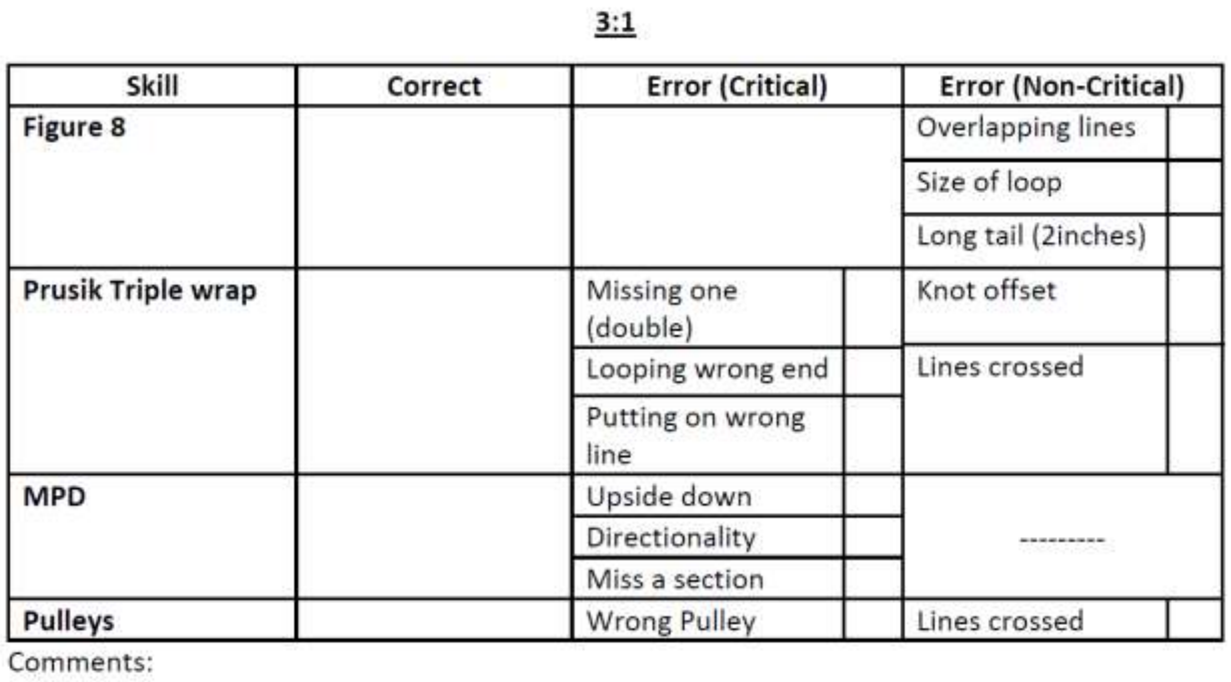


***Figure 2**. Example of the configuration performance score checklist for the 3:1 condition.*



3:1

Skill	Correct	Error (Critical)		Error (Non-Critical)	
Figure 8				Overlapping lines	
				Size of loop	
				Long tail (2inches)	
Prusik Triple wrap		Missing one (double)		Knot offset	
		Looping wrong end		Lines crossed	
		Putting on wrong line			
MPD		Upside down		---------	
		Directionality			
		Miss a section			
Pulleys		Wrong Pulley		Lines crossed	

Comments:

Figure 3. *Illustration of the procedures based on the day. Day 1 represents practice and Day 2 is the retention testing.*

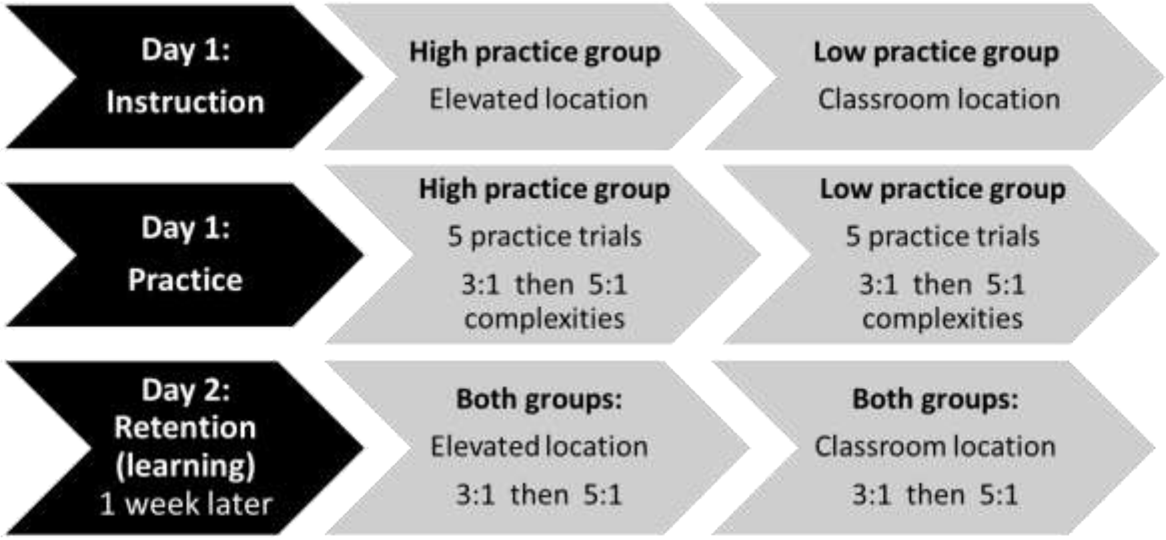
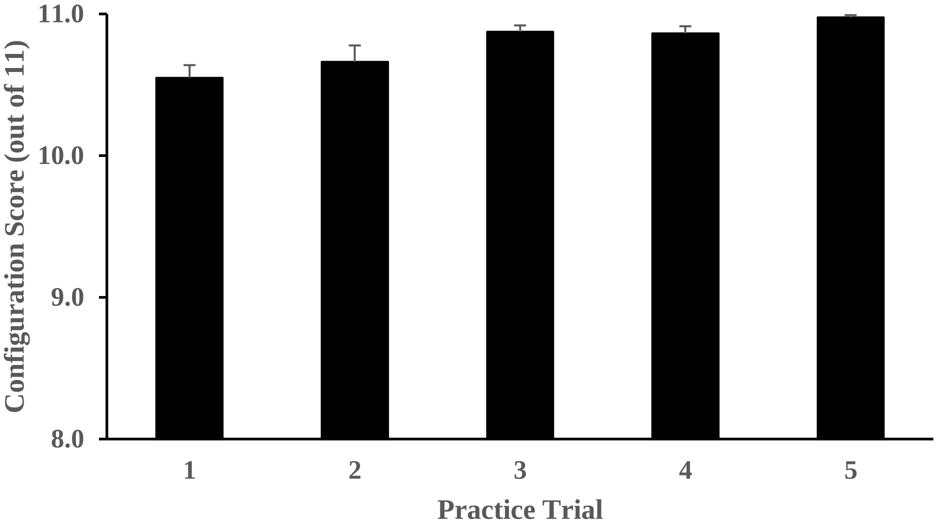
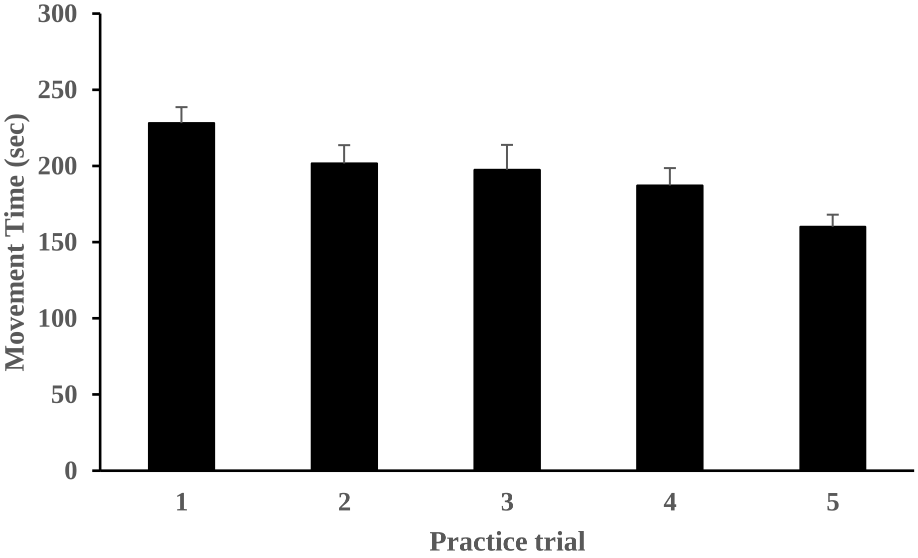


Figure 4**. Significant main effects during practice.* ***A. *The average and standard errors for configuration scores of each practice trial.* ***B.*** *The average and standard errors for Movement Time (MT) in seconds based on practice trial.*



A.



B.

Figure 5. *The significant interaction for configuration score (out of 11) between practice group and task complexity, during practice.*

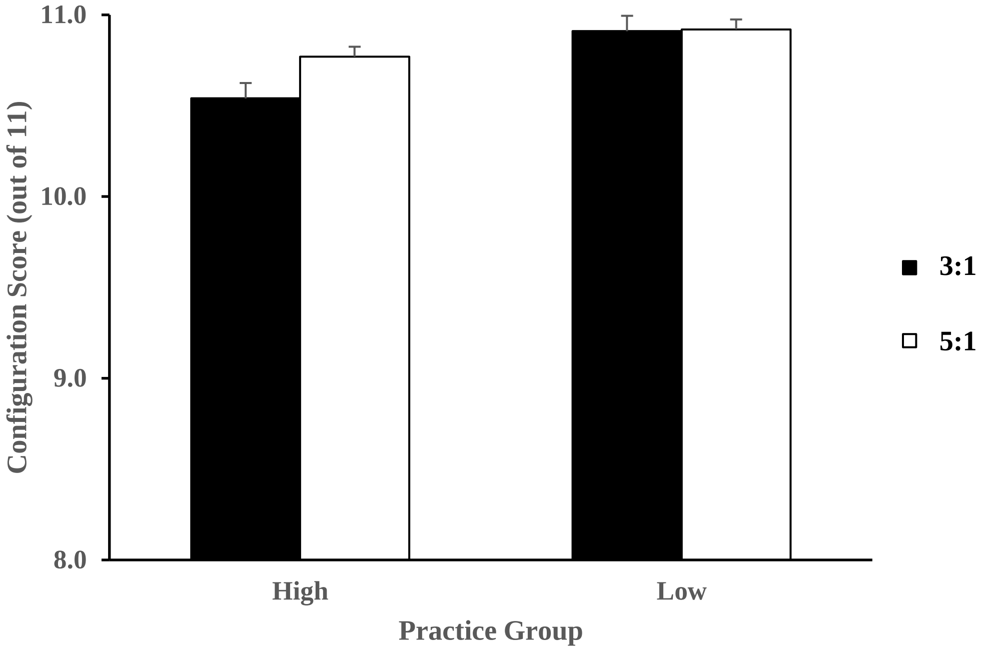


Figure 6. *The perceived anxiety scores (10 = very anxious, 1 = no anxiety) during each hauling system complexity and each practice trial.*

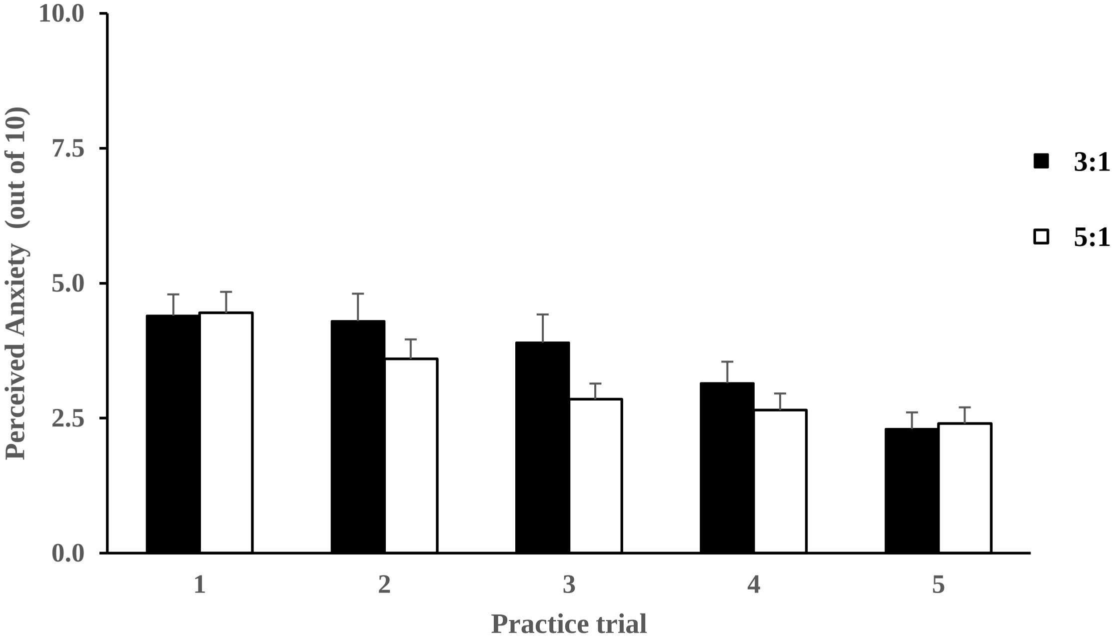


Figure 7. *The average HR (at first 10sec of movement) during each hauling system complexity and each practice trial.*

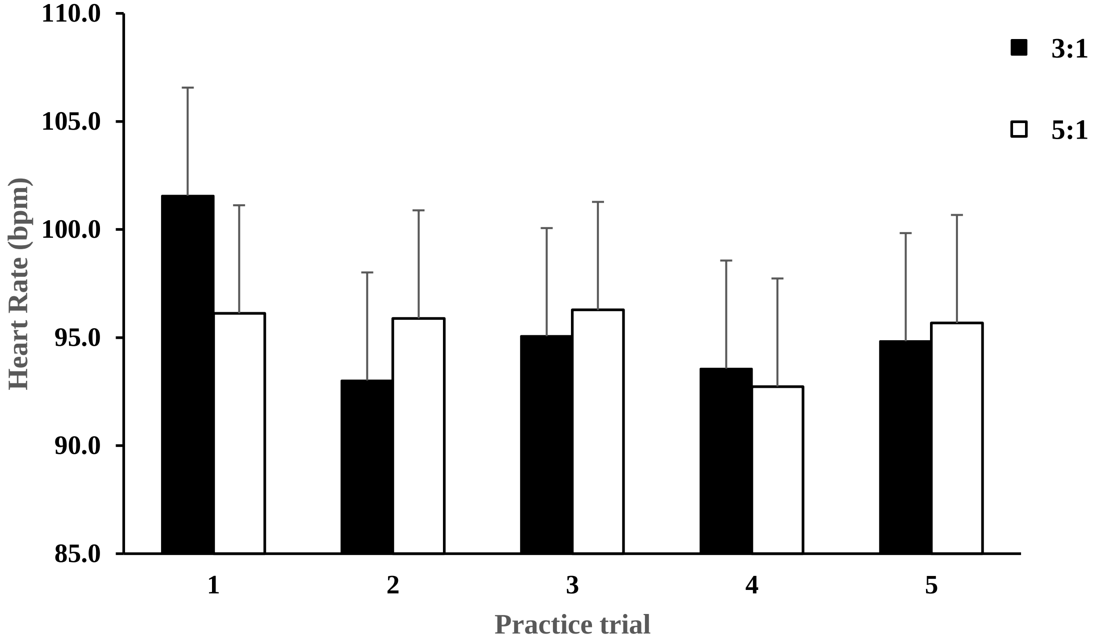


Figure 8. *Significant dependant variables during retention testing.* ***A.*** *The average perceived anxiety levels of each retention testing location.* ***B.*** *The perceived anxiety of each group while completing both complexities.* ***C.*** *The Movement time (MT) (seconds) based on task complexity and location.*