The effect of experience, personality and learning style on health and safety performance and physiologic responses of miners training in a simulator

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Abstract

This study examined how learning style, personality type, and experience level influence the performance and heart rate variability (HRV) (quantified by LF:HF ratio and RMSSD) of individuals operating NORCAT's mining simulator. At Baseline, the twenty participants completed: Kolb's learning style questionnaire, the 44 item Big Five Inventory Index; and an Operator Experience Questionnaire. After which, participants were fitted with a Zephyr BioHarness to measure HRV. HRV data and performance scores (a computer-based evaluation generated from performance measures taken while the operator is using the simulator) were collected for three simulator trials: 1) first use of the simulator; 2) at the end of the operator training program; and 3) post training during a troubleshooting trial where emergency situations and faults are initiated by the trainer. During the troubleshooting run, reaction time to each fault was also recorded. Results indicated that the personality trait: conscientiousness; was associated with improved performance and increased Root Mean Square of Successive Differences (RMSSD). Moreover, experienced operators showed higher performance scores later in the training process.

Keywords:
Simulator, virtual reality, personality, learning style, experience, HRV, performance, mining training.

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Chapter 1

1.0 Background Information

Working in the mining industry exposes labourers to many, potential health and safety hazards that vary widely in severity; from minor injuries to fatalities. Trends indicate a decrease in injury and fatality rates involving mining equipment (Groves, Kecojevic, & Komljenovic, 2007). More specifically, in the United States, equipment-related fatalities in mining have decreased from 49 in 2000 to 15 in 2015 (Mine Safety and Health Administration, 2016). While this is promising, Schofield and colleagues have said that, in mining, there will always be the possibility that workers will continue to make skill- or rule-based errors (i.e.: failure to perceive a hazard) (Damian Schofield, 2001), which can lead to spikes in accident rates. This may be due, in part, to how individual differences in human factors among individuals impact a worker's training (Damian Schofield, 2001). For example, some individuals may respond differently to a specific training protocol. Researchers in other industries, such as aviation (Helmreich & Clayton, 1993) and rail (McInerney, 2005), agree that, because of individual differences, skill- and rule-based errors will continue to happen and may lead to spikes in injury rates. One strategy to mitigate accidents, and improve health and safety within the mining industry, involves ensuring that miners have adequate training in order to be able to perform their job, and understand corrective actions to take in the event of an unplanned incident (Tichon & Burgess-Limerick, 2011). Therefore, research on how and which individual factors may influence training in the mining industry needs to be conducted in order to develop strategies aimed at optimizing worker training protocols.

1.1 The Use of Virtual Reality and Simulation as a Training Method

For many years, virtual reality and simulations have been used alongside conventional real life training for high-risk industries such as medicine, military, aviation, and transportation fields. Ziv et al (2003) indicated that the use of simulation-based medical education is an "ethical imperative" (Ziv, Wolpe, Small, & Glick, 2003). Moreover, they explain that although medical training will require live patients at some point in the training process, the use of simulations can help medical professionals acquire knowledge and practice clinical skills while protecting patients from unnecessary risk. Similarly, the field of aviation uses simulation training to not only reduce the risk of potential injuries to trainees, but also to reduce the cost of training (Taylor et al., 1999). Taylor et al. (1999) found that new skills taught using a personal computer aviation-training device transferred substantially to real-world piloting. Further, the use of simulator training in aviation has become so widespread that the Federal Aviation Association (FAA) has developed the National Simulator Program in the United States, which oversees a set of National regulations for the use of simulators for training and skill maintenance. Simulators in other work and research domains have not yet attained this level of sophistication or regulation.

1.2 Simulator Training in the Mining Industry

In their review on the use of simulator training in the mining industry, Tichon and Burgess-Limerick (2011) identified four main themes for using simulator-training over (or complimentary to) conventional on-the-job methods: (i) cost and time restrictions in creating realistic hazardous environments; (ii) simulators provide the opportunity to produce a variety of hazard scenarios whereas real-world hazardous environments would be too specific and unable to adapt to different conditions; (iii) real-life scenarios could pose significant threat to the health and safety of trainees; (iv) virtual reality can

emulate scenarios that would be impossible to recreate in the real world (Tichon & Burgess-Limerick, 2011). For these reasons, virtual reality and simulation is desirable by both workers and workplaces, and is particularly well-suited to the mining industry. Additionally, it is believed that a simulator-trained operator has a better grasp of the perceptuo-motor skills required for the task, and better cognitive abilities that enhances decision making, problem solving, and hazard identification (Tichon & Burgess-Limerick, 2011). Additionally, simulation can improve situational awareness (Saus, Johnsen, Eid, & Thayer, 2012). This is achieved by giving trainees the opportunity to perform and practice regular, workplace tasks and skills using interfaces that would be similar (if not identical) to the ones they would use on the job. Therefore, since these skills and competencies can be acquired in a low-cost environment, it makes fiscal sense to pursue simulator-training options for operators of underground machinery. Further, since the virtual environment is also low-risk, the learner and in particular, the adult learner can acquire competencies in an environment with no extraneous stressors.

Anecdotally, there have been some attempts by companies utilizing f simulator training, or the simulator companies themselves, to validate the applicability of virtual reality and vehicle simulators for mining specific tasks. Technical reports from in-house simulator training conducted by individual mining or mining-related companies typically quantify errors that violate policy and procedure, rather than focus on health and safety measures (Bellehumeur & Marquis, 2016; Tichon & Burgess-Limerick, 2011). Most recently, Bellehumeur & Marquis (2016) performed an analysis of the Thoroughtec Cybermine simulator using the training program delivered by NORCAT (Northern Centre for Advanced Technologies) in Sudbury, Canada. Participants were asked to rank the training program based on their learning experience, the realism of the simulator, effect on their learning, and the transferability of skills learned. The result was an average of

3.71 out of 4 (Bellehumeur & Marquis, 2016). This indicates that trainees found that the use of the simulator was very realistic and that they believed the competencies developed during their training would be transferred to real-world environments. Although this subjective approach appears promising, a more objective analysis of the training program at NORCAT is required. The speculation by the industry is that simulator experience might lead to a reduced amount of required, real-world training. This speculation is based on results of simulator training in other industries such as aviation. In many cases, simulator sessions have replaced many training hours that had been previously completed in airplanes (Wynia, Phillips, Raisa, Arriaza, & Harley, 2017). With respect to the mining industry, Tichon and Burgess-Limerick determined that substituting simulator training for on the job instruction provided a safer and more cost-effective option for developing the skills required to perform underground mining tasks (Tichon & Burgess-Limerick, 2011). However, there has been no comprehensive, peer-reviewed study done to date, to understand the role of simulators in the mining industry, or how simulator training, and specifically health and safety learning with the simulators, transfers to real-world experience. Real-world transfer remains an elusive quantity to measure in a reproducible and reliable manner. Tichon & Burgess-Limerick (2011) suggested the following measures of real-world transfer: reaction time, situational awareness/hazard perception, and skill acquisition/performance scores as these measures may be related to safer actions underground. Hazard perception allows miners to determine the likelihood of a hazard (or if one has already occurred) by monitoring the dynamic environment. Similarly quick reaction times make it possible to avoid emergencies by taking action before a hazard occurs or before it becomes emergent. Monitoring skill acquisition through performance scores may reflect how miners will operate while on the job. High scores may be indicative of safer and more efficient

methods. It is important to note that the ability to collect unbiased, high-quality data in the field makes some of these variables difficult to measure in a meaningful way.

One of the leading, virtual reality models of high fidelity, mining simulation is the containerised, Cybermine simulator designed by Thoroughtec. The Cybermine simulator offers a variety of realistic mining machine machine options, including: loaders, bolters, and drill rigs from many well-known Original Equipment Manufacturer (OEM) companies such as Maclean, Sandvik and Atlas Copco. This simulator allows for interchangeable mining machine controls (i.e. machine- and company-specific consoles with unique hand/foot controls, dash information (dials, gauges, lights, etc.) sophisticated software that produces a projected and immersive virtual reality display, provides an advanced instructor station, as well as an external audience viewing station. On the ceiling over the console are four projectors that display images on the four walls, surrounding the seated operator. This creates an immersive, virtual reality without the constraints of a head-mounted set. Moreover, the advanced instructor station allows the trainer to set up and modify standard exercises, induce faults, cause emergencies and view performance/health and safety reports. Three reports are produced as a standard output: the performance enhancement score, the health and safety score and the machine use score. Overall, these reports give a score (out of 100%) based on many components included by the designer of the simulator. These scores will be referred to as the performance scores throughout this thesis and will be explained in greater detail in the methods section. Outside the simulator and out of sight from the trainee position, is an external viewing option that creates an opportunity for an audience to view what is occurring in the simulation. For example, an external reviewer or mine site trainer could watch from outside the container, so as not to distract the trainee. (ThoroughTec Simulation, 2015)

1.3 Measuring the User Response during Simulation

While simulators may be able to effectively replicate interactions with the worker and the equipment controls, they do not truly recreate the underground mine. For example, the lighting, the noise, the isolation of the worker and the smells that may co-occur with specific tasks or emergencies are poorly represented or excluded in the simulation training. For this reason, performance scores (which are used as a quantification of skill acquisition) from the simulator alone cannot indicate real-world competency, and other measures must be used to determine the effectiveness of the training. With this in mind, other variables need to be measured in order to determine whether or not the skills developed using simulator training can be transferred to the real world. Several measurement tools exist for determining how the skills learnt during simulator training can potentially be transferred to the real world environment. These include, but are not limited to eye tracking, functional magnetic resonance imaging (fMRI), electroencephalography (EEG), heart rate variability (HRV), and reaction time (Healey & Picard, 2005; Tichon & Burgess-Limerick, 2011).

Eye tracking involves comparing gaze patterns and eye behaviour between trainees and individuals considered experts at a task(Tichon & Burgess-Limerick, 2011). The stipulation is that the closer an individual's gaze pattern compared to the expert, the more likely they are to have a better performance (Tichon & Burgess-Limerick, 2011). Studies have found eye saccade movements to be useful measures of expertise and confidence (Jacob and Karn, 2005; Crundall et al. 2003) as well as an indicator of arousal (DiStasi et al. 2011) or mental workload (DiStasi et al. 2013).

Functional MRI allows investigators to examine which areas of the brain are most activated during specific tasks. The activated areas are then compared with known brain functions for that area (Goon et al., 2014), For example, if a trainee is completing a task

and the part of the brain the controls stressful responses is being activated, it is likely that the task is producing a stressful response. In contrast, if the area of the brain the represents long term memory and motor planning is activated, the trainee has potentially stored the motor plan and cognition required to complete the skill in their memory centers. This would be indicative of learning. Similarly, EEG involves measuring electrical activity of the brain using electrodes strategically placed on an individual's head (Berka et al., 2007). Research has shown that the EEG activity can be correlated to task engagement, mental workload, learning and memory (Berka et al., 2007). However, it should be noted that for both of these measurements significant and expensive technology is required, and are likely not feasible for real-world testing outside the lab environment.

The two measures that this research examined (reaction time, and HRV) were considered to be variables with potential for field-based measurements for future work that would gauge real-world transfer of skills and knowledge. These measurements were chosen based the availability of technology as well as their feasibility for both simulator and real-world testing.

1.3.1 Reaction Time:

In their review, Tichon and Burgess-Limerick (2011) identified response or reaction time as a relevant measure of training effect. Faster response times in real life leads to better situational awareness and more time to adjust a motor response in the face of uncertainty. This skill is key for mitigating risk of injury (Tichon & Burgess-Limerick, 2011) and therefore training-induced improvements in hazard identification and reaction time should help to improve the worker's health and safety while operating equipment. For the purpose of this research, reaction time had to be calculated using tasks already in place in the simulator training, due to the observational nature of the

study. Reaction time is represented by the time required for a hazard to be identified by the trainee (ie. the machine is on fire), plus the time needed for appropriate corrective actions to take place (ie. hit the fire suppression button), at which point the trainer "turned off" the hazard from the main computer. Hazard identification is a key component of situational awareness (Saus et al., 2012). This concept has been applied to drivers watching a series of traffic situation video clips. Participants were asked to press a button when they detected a potentially hazardous event (Horswill & Helman, 2003). The response times to hazards were calculated and they were able to distinguish differences between novice, intermediate, and advanced drivers in response times; with advanced drivers demonstrating a substantially faster response time to hazard identification (Horswill & Helman, 2003). Further, this measure has been applied in a safety training evaluation in the construction industry (Sokas, Jorgensen, Nickels, Gao, & Gittleman, 2009). Although this research was not directly based on time, it did consider the hazard perception portion of the measure. In this study, both apprentice and journeyman trainees were given a test to evaluate their knowledge of potential hazards in different environments. Following this, the trainees participated in a 10 hour health and safety training session and were re-evaluated. The results of this study showed that participants showed increased knowledge of hazard perception in fall safety and electrical safety (Sokas et al., 2009). This shows that training can increase the ability one's ability to anticipate a hazard therefore it will take less time for one to notice the initiation of a hazardous scenario and in turn allow the worker to react earlier.

1.3.1 Heart-Rate Variability (HRV)

Mental workload and stress can adversely impact a worker's response and performance in the real-world (Svensson, Angelborg-Thanderez, Sjöberg, & Olsson, 1997). Simulators have the potential to provide users with low-risk training time that can

reduce the level of mental workload associated with novice users, attempting a novel task in an open, changing environment. Other fields of study have used HRV as an indicator of stress levels or mental workload, (Healey & Picard, 2005; Hynynen, Konttinen, & Rusko, 2009). Since highly stressed states have been shown to impair decision making capabilities (Baddeley, 1972), decrease situational awareness (Vidulich, Stratton, Crabtree, & Wilson, 1994), and degrade performance (Helmreich & Clayton, 1993), HRV could be considered an important measure to determine the effectiveness of a training protocol. For this study, it is important to note that mental workload refers to the cognitive demands that a task places on an individual whereas stress indicates the sympathetic nervous system response to a task.

Functionally, HRV measures the variability in instantaneous heart rate. That is, it determines the time between consecutive, QRS complexes (caused by the depolarization of the sino-atrial node in the heart) (Malik et al., 1996). This data can be interpreted to determine information about stress and mental workload by using two types of methods (and both of these methods are usually applied together in published research): frequency domain methods, and time domain methods (Castaldo et al., 2015; Malik et al., 1996; Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2014). A frequency domain analysis involves identifying activity in three frequency intervals: very low frequency (VLF; ≤0.04Hz), low frequency (LF; 0.04Hz-0.15Hz), and high frequency (HF; 0.15-0.4Hz) (Malik et al., 1996). While an association between the VLF component has yet to be made with specific nervous system function, the HF and LF represent the activity of the two branches of the autonomic nervous system (Malik et al., 1996). That is, parasympathetic activity is represented by the HF component of HRV whereas the LF component indicates sympathetic activity (Malik et al., 1996). These values are usually expressed as a LF:HF ratio. Since the parasympathetic nervous system predominates for

physiologic activities at rest and the sympathetic branch predominates during states of excitement and stress (i.e.: fight or flight response), this ratio is interpreted as Stress:Rest. That is, when the ratio is high (high LF and low HF), interpretation of HRV data would indicate a stressful, internal state. In contrast, if the ratio were low, the individual would appear to be more relaxed (Table 1). Although strict cut off values for when the LF:HF ratio transitions from a non-stressed to a stressed state have not been agreed upon in the literature, it is clear that higher mental stress correlates with an increase in LF:HF ratio (Castaldo et al., 2015). Researchers can also compare the LF:HF ratio during a known stressful period to a period of quiet rest to determine whether a situation has caused a significant change to the mental state (Castaldo et al., 2015). Many manufacturers of HRV recording devices have designed their own proprietary filters using this basic understanding of the HRV signal, and provide software to partition a series of data points into different states: i.e. rest/recovery, stress, physical activity, other.

The time domain analysis involves looking at the time intervals between successive heartbeats and applying statistical algorithms to them. Specifically for this method, the root mean square of successive differences (RMSSD) is chosen as the most relevant and stable time domain variable, due to it's ability to analyze short-term HRV recordings (Malik et al., 1996). When an individual is exposed to a situation known to increase mental workload, the RMSSD value decreases. In contrast to the frequency domain methods, the RMSSD cannot differentiate between sympathetic vs parasympathetic activity. It strictly examines the time. When combining the two types of analyses (time-domain and frequency-domain), the HRV signal can be used to determine whether individuals can effectively handle increased mental workloads. In other words, if an individual experiences significant decreases in RMSSD in the absence of a significant

increase in LF:HF ratio, it would be demonstrative of a non-sympathetic modulation (therefore parasympathetic) of the heart rate (Saus et al., 2012). Note that these changes would not be due to physical activity, as these tasks are sedentary ones. In fact, the neural processes have modified HRV regulation so that increased workload has less adverse impact. For example, during a training scenario, a trainee is introduced to a scenario where they need to react to environmental stimuli. Due to the high, mental workload, the RMSSD would decrease however, if there is no increase in LF:HF ratio, the heart is being regulated by parasympathetic activation. This would indicate that this scenario is not perceived as a stressful one, despite the increased mental workload.

Proponents of simulator training would hope to demonstrate that stress-related HRV changes are lessened across the time spent on simulator. Further, researchers would expect that upon immersion into real-world training, the simulator-trained worker would have less significant stress-related changes to HRV due to the positive training benefits of the simulator. The research in this area is sufficiently sparse that these conclusions cannot yet be made.

Table 1: HRV frequency ratios and their corresponding nervous system activation patterns (adapted from Castaldo et al, 2015)

LF:HF Ratio	Nervous System Activation Patterns	Internal State
High	High sympathetic activity; low parasympathetic activity	Stressed State
Low	High parasympathetic activity; low sympathetic activity	Non-stressed State

Table 2: Root mean square of successive differences for heart rate variability and how it related to mental workload (adapted from Castaldo et al, 2015)

RMSSD	Mental workload
High	Decreased

Low	Increased

Table 3: the relationship between time and frequency domain analyses of heart rate variability and how they relate to one's internal state (adapted from Castaldo et al, 2015)

RMSSD	LF:HF	Internal state
High	High	A low mental workload regulated by primarily parasympathetic activation
Low	High	A high mental workload regulated by primarily parasympathetic activation
High	Low	A low mental workload regulated by primarily sympathetic activation
Low	Low	A high mental workload regulated by primarily sympathetic activation

1.4 Individual factors that can affect performance and learning

Individual factors that may play a role in how a person learns and performs in a simulator include: personality, learning style, and past experience. These will be discussed with reference to reaction time and HRV.

1.4.1 Personality

Extraversion, agreeableness, conscientiousness, neuroticism, and intellect (or openness) have been called the "Big Five" personality types by Goldberg (Goldberg, 1990). Different personality types have been shown to directly influence the trainability, job performance, and health and safety behaviours (Christian, Bradley, Wallace, & Burke, 2009). More specifically, some personality traits have been linked to increased motivation to adhere to occupational health and safety protocols while others indicate that some personalities may have difficulty coping with threatening or emergency situations (Christian et al., 2009)

In the realm of training and learning, research has shown that different personality types have different performance outputs (Flin, 2001). This is important because understanding how different personality types respond to training can allow

workplaces and training institutions to tailor or adjust their teaching methods to an individual's personality type or create a learning environment conducive for all personality types. For example, Flin (2001) found that extraversion and conscientiousness had a positive correlation with predicting the success of training amongst emergency service recruits. Conversely, the same study demonstrated a negative relationship between the effectiveness of training and the neuroticism personality type (Flin, 2001). Although the jobs of emergency service workers and miners are not the same, the combination of didactic and on the job training method is. Therefore, these findings may translate to training in the mining industry.

In a navy navigation simulator, Saus et al. (2012) found positive correlations between conscientiousness and extraversion and a measure of situational awareness as well as a negative relationship between neuroticism and situational awareness (Saus et al., 2012). This combination of high extraversion and conscientiousness traits with low neuroticism scores is representative of the resilient personality type (Saus et al., 2012). Individuals representing the resilient personality type are known to be able to effectively adapt to different environments as well as perform well under stress (Saus et al., 2012). Since hazard identification is a key component of situational awareness, and high situational awareness correlates with the resilient personality type there may be a relationship between the resilient personality and hazard identification. Due to its potential for improving health and safety performance, it is relevant to understand if hazard perception and the reaction times to such hazards have a relationship with the resilient personality type. In other words, the research team will be looking to determine whether the resilient personality is a positive factor in predicting performance and response times in a mining simulator. To date, there is no documentation of how prevalent the resilient personality is amongst mining workers and it remains unknown

how that personality might interact with skill learning on mining simulators, which varies considerably from navy navigation.

Although no research has combined specific personality types to HRV response in training or simulation environments, it is another relevant variable to investigate when evaluating how the learner reacts to the simulator experience. The previously mentioned study by Saus et al. also examined differences in HRV for individuals identified as having high situational awareness compared to a group with low situational awareness. They demonstrated significant suppression of HRV (lower RMSSD) in combination with an insignificant increase in LF:HF ratio for the high situational awareness group during navy navigation simulator training; compared to no differences for the low situational awareness group (Saus et al., 2012). Since the conscientiousness and extraversion were related to high situational awareness and high situational awareness individuals effectively supressed HRV during training, it may be that these personality types have superior abilities in managing physiological responses to simulator training. This thesis would look to document the same effect in a population of underground miners.

1.4.2 Learning Style

It is accepted in the education literature that different learning styles exist. The adult learning literature stresses that this must also be considered when attempting to evaluate adult learners, who may acquire knowledge in different ways or have existing knowledge and life skills to bring to the table. The Experiential Learning Theory (Kolb, 1984) identifies four styles of learning: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE). The theory suggests that everyone uses all of these styles, but to varying extents. Moreover, they develop preferences for two of the four styles, which allows researchers to define a 'learning type', which are:

1. Diverging – CE and RO;
2. Assimilating – RO and AC;
3. Converging – AC and AE; and
4. Accommodating – AE and CE.

Many researchers have found that individuals show improved learning when concepts are taught in *their* preferred learning style (Chwen Jen Chen, 2004). Additionally, performance of certain tasks has been shown to vary across different individuals with different learning types. More specifically, Lynch et al. found that third year medical students who were identified as convergers and assimilators, performed significantly better on the United States Medical Licence Examination Step 1. (Lynch, Woelfl, Steele, & Hanssen, 1998)

Chwen et al. examined differences between virtual reality and conventional methods for teaching road traffic regulations to learners identified as either assimilators or accommodators (Chwen Jen Chen, 2004). They found that simulation training, regardless of learning type was more beneficial than conventional lecture based learning. No other studies could be found that examined the other learning styles in a simulator environment. Moreover, no research has been done to date, comparing performance in a simulator-training program for mining equipment across the learning styles. This research will only include adults who have developed preferences in learning. Therefore learning may happen in different ways. Thus, understanding how learning style might interact with simulator learning performance in experienced and novice miners may be meaningful, in order to tailor future learning events to specific learning styles.

1.4.3 Level of Expertise

Differences in performance variables while receiving training are clearly evident when comparing novice to experienced individuals regardless of the field. In their review,

Tichon and Burgess-Limerick identified sensation and perception, action, and attention differences between novice and experienced miners as important considerations for designing virtual reality training programs (Tichon & Burgess-Limerick, 2011). More relevant to this research project: reaction time, in terms of hazard identification, as well as physiologic HRV adjustments have been shown to differ between novice and experts (Hynynen et al., 2009; Pojman et al., 2009; Sauvet et al., 2009; Wallis & Horswill, 2007).

Wallis and Horswill (2007) identified that experienced drivers react faster to hazards in simulated driving experiences. Further, they showed that experienced drivers have a lower threshold of danger before they react. In other words, novice drivers do not react until a threshold of danger has been reached (Wallis & Horswill, 2007).

Other fields of research, such as aviation (JORNA, 1993; Sauvet et al., 2009), marksmanship (Pojman et al., 2009), parachuting (Hynynen et al., 2009), and golfing (Neumann & Thomas, 2009) have identified differences in HRV patterns between novice and experienced individuals. Specifically, novice marksmen showed greater LF:HF HRV ratio (stressed state) while performing timed vigilance tasks with their eyes open and closed compared to experienced off-duty military (Pojman et al., 2009). It was hypothesized that this increased physiological response could indicate more sympathetic activation, and in turn higher anxiety and mental stress (Pojman et al., 2009). Research should assess whether these trends in 'level of expertise' remain true, for individuals training in a mining simulator.

Tichon and Burgess-Limerick (2011) have also explained perceptual differences between novice and experienced operators in a simulator. More specifically, differences have been shown in the perceptions or consequences in performing tasks. For example, if an individual makes a mistake in a simulator or experiences an emergency scenario, an experienced operator will be able to better understand the consequences of that mistake

or emergency, compared with novice operators (Tichon & Burgess-Limerick, 2011). This may lead to inappropriate physiological responses from novice operators that do not fit with the expected response documented earlier.

1.4.4 The Instructor

One other factor that will not be directly assessed in this research, but who's contribution to performance in a training environment should be acknowledged is the role of the instructor (Darling-Hammond, 2000). For example, it has been identified that if a student likes their teacher, motivation to learn, as well as the student's achievement will benefit positively (Montalvo, Mansfield, & Miller, 2007). Since adult learners are diverse (i.e.: life experiences, education, personalities…) they have different perspectives on future educational events (i.e. motivation to engage) (Lawler, 2003). With this in mind, the instructor should employ strategies to allow an adult learner to be self-directed and problem-centered (Conti, 1985). Moreover, the teacher should act as a facilitator rather than a repository of facts (Conti, 1985). When these strategies, are employed, adult learners appear to succeed (Conti, 1985).

1.5 Purpose

The purpose of this thesis was to understand how individual factors relate to performance (i.e. the three performance scores calculated by the simulator) and physiological responses while learning in a virtual, mining simulator environment. Secondarily, to describe HRV responses in a simulator environment for future comparison against real-world values obtained during similar mining tasks. The individual factors measured were: personality types based on the BFI; learning style, determined by the Kolb LSI; and level of expertise, based on the type of training that the participant was receiving at NORCAT outlined in the Experience Information Sheet (novice 2 day course vs refresher 1 day course). To determine performance, the

simulator software system produced three scores: health and safety, machine use, and performance enhancement. Physiological responses were quantified by monitoring HRV (time and frequency domains). Independent variables will be recorded at three points in time (start of training, ending of training and during a troubleshooting trial, also at the end of training) to evaluate how physiological responses may change throughout training.

1.6 Hypotheses

Based on the literature, several hypotheses can be made regarding the purpose of the study. We hypothesized the following:

1. The resilient personality type would correlate with improved performance scores, reduced RMSSD values as well as lower LF:HF ratios.
2. Learning style would have no impact on simulator score or physiologic response.
3. Novice miners would show greater absolute improvement than experienced miners from their first trial to the last, in terms of the three performance scores.
4. Experienced miners would exhibit effective suppression of HRV (i.e. less reduction in RMSSD) and a lower LH:HF ratio compared to novices across all types of trials (stressed or not stressed). Additionally, experienced miners will exhibit shorter reaction times compared to novice trainees.
5. Performance scores for the entire sample would improve from the early trial to the late trial while the troubleshooting trial would exhibit the lowest performance scores.
6. The mental workload would decrease over the course of training Additionally, there will be more sympathetic activation during the troubleshooting trial compared to either the early or late trial (higher LF:HF ratio).

Chapter 2

2.0 Methods

2.1 Participants

Participants were recruited from incoming sessions at NORCAT. Mining companies in the region sent these individuals for training. All workers attending training at NORCAT with the simulator were invited to participate; no trainee was excluded, unless they chose not to participate. This included: new or novice workers receiving training on a new machine, as well as experienced miners who were participating in refresher courses.

2.2 Study Design

Potential participants were recruited at the NORCAT facility, when they came for their scheduled training session. Researchers were invited to read the recruitment script with the participants, and if any individuals were interested in participating, they were provided with the consent form to read and sign. Once consent was received, the participants were asked to complete three questionnaires: the Kolb Learning Style Inventory – 10 minutes (Kolb, 1999), the BFI (John, Donahue, & Kentle, 1991), as well as the Experience Information sheet. One section of the questionnaire asked the participants to indicate if they were there as a new trainee on the selected equipment or if they were participating in a refresher course. With this in mind, level of experience was based on the type of training that were receiving as indicated in the Experience Information Sheet. Each of the questionnaires are described in General Methods below. Following this, the participant put on the Zephyr BioHarness3 HRV monitor (see Figure 1). Then, the participant entered the simulator and performed a training trial, which lasts

approximately one hour. Due to the nature of data collection in a field environment, there were some variations amongst the simulation trials and these will be detailed in the discussion section of this paper. However, in general, a one-hour training trial involved the trainee performing workplace tasks, specific to the machine that they were operating (i.e.: Roof Bolter or Jumbo Drill) underground. To simulate the operation of these machine, the trainee interacted with manufacturer specific user interfaces while observing their environment on four screens that surrounded them. In addition to HRV monitoring during each trial, the Cybermine's computer software program calculated health and safety, machine use, and performance enhancement scores, which were provided to the researchers, for the relevant trials. Trainee data (HRV; Health and safety, machine use and performance scores) was obtained at three different time points in the training period: at the start of training, at the end of training, and during a trouble-shooting trial, also at the end of training. The exact trial number varied between trainees due to the nature of the program and the access of the researchers to the facility. The trouble-shooting trial was a purposefully stressful trial where the trainer created machine malfunctions and emergency scenarios to which the trainee was expected to respond. As will be discussed later in this section, the total time required for the trainee to identify the hazard and apply corrective action was also recorded during this trial.

2.3 General Methods (GM)

2.3.1 GM1: Survey data collection:

Kolb Learning Style Inventory Version 3 (10 minutes) – Kolb's Learning Style Inventory (LSI) involves 12 lines with 4 statements about learning in each line. Participants were asked to rank the items on each line from 1 (least like them) to 4 (most like them) (Kolb, 1999). This data was then interpreted based on the procedure outlined

by Kolb and the participants were classified as one of 4 learning styles: diverging, converging, assimilating or accommodating (Kolb, 1999).

Big Five Index (10 minutes) – This study utilized the 44 item Big Five Index (BFI) to determine personality characteristics of the participants (John et al., 1991). The BFI includes 44 descriptive phrases for which the participant must assign a value of 1 (disagree strongly) to 5 (agree strongly). John and Srivastava (1999) recommend this tool when participant time is at a premium, and when participants may not be 'test savvy' (meaning that they may not be knowledgeable with what is being measured using the test). Further, they determined that alpha reliabilities with this tool range between 0.75-0.90 with an average of about 0.8 in the United States and Canada (John & Srivastava, 1999). These results indicate that the questionnaire demonstrates relatively high internal consistency. The output of this questionnaire results in a score for each of the Big Five personality type for each participant. These scores can then be used to perform correlations with other results.

The Experience Information Sheet (10 minutes) – This is a questionnaire developed by the research team. It included anthropometric measurements (i.e.: height, weight, age), work history (i.e.: number of years working in underground mining as well as the number of years working in other industries), equipment history (how many years the participant has been operating heavy equipment), the machine they are currently being trained on, how long the worker has been operating the machine in question, and the type of training protocol they are receiving (1 day refresher course [for experienced operators] or 2 day training course [for novice operators]) .

2.3.2 GM 2: HRV data collection and analysis

HRV monitoring was used to quantify physiologic responses to simulator training and determine the internal state (i.e.: stressed or not stressed/level of mental workload)

of the participant. The BioHarness3 from Zephyr Technologies was chosen for this task. Participants wore the BioHarness for each of their simulator training sessions (Figure 1).

Figure 1: Placement of the Zephyr BioHarness (Rawstorn et al., 2015)

Once the HRV data was collected, the raw HRV data (R-R interal) was extracted from the BioHarness3 and inputted into the Kubios HRV analysis software (Tarvainen et al., 2014). This software performs frequency-based analysis based on defined frequency domains for the HF (0.15-04.Hz) and LF (0.04-0.15Hz). Since long trials can compromise the validity of HRV data (Castaldo et al., 2015; Malik et al., 1996), 5 minute sections from the beginning of the early and late run were analyzed. Additionally, the 5 minute interval containing the most faults in the troubleshooting run was utilized in order to produce a sample representative of the most stressful situation. Kubios quantified the HRV data using the frequency domain expressed as the LF:HF ratio as well as the time domain expressed as RMSSD. Results were hand recorded to an Excel spreadsheet.

2.3.3 GM 3 – Cybermine Simulator H&S and performance scores

The health and safety score is composed of items such as: incorrect park brake test procedure, lights off while tramming, using horn incorrectly when moving, did not

activate the fire suppression system, enters a decline on a red light, moved off with doors still closing, etc. If the participant makes one of the mistakes monitored by the simulator, forgets to perform a certain task, or mixes up the sequence of tasks during a training scenario, the system deducts points from the trainee's Health and Safety Score. Similarly, the simulator measures two other performance scores: the machine use score, and the performance enhancement score. The machine use score examines several elements such as correct order of steps to perform a task and any other mistakes made by the trainee that may not be directly related to health and safety. Additionally, the performance enhancement score looks at timings and how efficient the trainee was during the trial (ThoroughTec Simulation, 2015).

Each of the simulator interfaces (Maclean Bolter, the Jumbo Drill or the Load-haul dump (LHD)) have different scenario requirements. For the bolter, participants were required to drive the machine, apply screens, drill holes, insert resin and bolts, secure the screen, etc. Similarly for the Jumbo Drill, participants had to drill several holes in the correct pattern while monitoring water pressure and hole depth. As for the LHD, trainees were required to drive the machine both above and below ground, fill their scoop underground with rocks that had been recently blasted and dump that material into a dump truck. They had to complete those tasks while avoiding interactions with the surrounding mine and other machinery.

Data was analyzed for the first and last simulation trials, which were fairly uniform in terms of required tasks and length of trial. Data was also collected for a third, "trouble-shooting" trial. In this trial, the trainer pre-programs problems such as oil leaks and engine fires to occur during the simulation scenario. The participant must identify these hazards and employ corrective actions. The simulator computer produced a report

identifying how long the participant took to resolve the problem, from which reaction time could be determined.

2.3.4 GM 4 – Reaction time

During the trouble-shooting simulation trial, the trainer caused simulated machine malfunctions (such as a bolt jam or failed parking break), and emergencies (such as an engine fire). Once the "fault" had occurred, the simulator recorded the time required for the trainee to react appropriately. The output for this reaction time was in graph format such that the x-axis indicated the time (from origin, i.e. initiation of the fault) and the y-axis was the state of the machine (e.g. if the fault was an engine fire, the state of the machine would report the status of the fire suppression: activated or deactivated). Therefore, the research team could accurately measure the time from initiation of the hazard to activation of correct protocol. To achieve this, ImageJ was used; this is a software program used to measure pixels and calibrate them to known measurements as described in Blanchard, Smith, & Grenier (2016). To ensure the accuracy of these results, inter-rater reliability was assessed. The results of this analysis can be found in Appendix A.

2.4 Statistical analysis

2.4.1 Correlations

Pearson correlations were used to identify trends between the following measures:

- Personality type scores and each of the three performance scores for the early, late, and troubleshooting trials.
- Personality type scores and reaction times for troubleshooting trials.

- Personality type scores and LF:HF ratio and RMSSD for each of the early, late and troubleshooting trials.

Significance was accepted at $p<0.05$.

2.4.2 Repeated measures ANOVAs

Repeated measures ANOVAs were used to identify mean differences in all three performance scores using time (early, late, and troubleshooting) as the within subject factor in order to determine absolute learning effect for the whole group as a function of those three time points. Moreover, this test was also run using the LF:HF ratio and the RMSSD as the within subject factor for all three trials to determine whether there were any significant physiologic changes across the time points in response to the training. "Mixed" models were also employed using the same within subject factor of time, and the level of experience (novice or experienced) as the between subject factor. Similarly, these tests were run again using the learning style (diverging, assimilating, or accommodating) as the between subject factor. Post hoc testing was performed to identify where these differences occurred. Significance was accepted at $p<0.05$. In all cases, except the personality descriptors, the normality assumption was tested and violated. However, research has shown that the analysis of variance is very robust to non-normal data (Glass, Peckham, & Sanders, 1972). Therefore, since this research requires a "mixed" model and there is no non-parametric version of a mixed repeated measures ANOVA and given that the ANOVA is robust, the research team went ahead with this statistical analysis.

2.4.3 One-Way ANOVA

A one-way ANOVA will be used to look for mean differences in reaction time between learning styles for the troubleshooting trial only.

2.4.4 Independent Sample t-test

An independent samples t-test will be used to determine if there is a statistically significant difference in mean reaction time between the novice and experienced groups.

Chapter 3

3.0 Results

A total of twenty (20) male participants were recruited (out of 21 subjects that were invited to participate) for the study with a mean age of 42.8 years. Sixteen (16) of these participants were training on the McLean Bolter, two (2) on the LHD, and two (2) on the Jumbo Drill. One participant, opted out of wearing the Zephyr BioHarness during testing, therefore, HRV was not recorded for that participant. Moreover this participant did not perform the troubleshooting trial due to time constraints. Additionally, due to technical difficulties, the HRV data was not collected for two other participants for their "late" trial.

3.1 Training Effect

3.1.1Performance Scores:

Repeated measures ANOVA identified significant differences in all of the performance scores. Table 4 shows the mean performance scores and HRV measures for each trial. Figure 2 illustrates the overall performance scores.

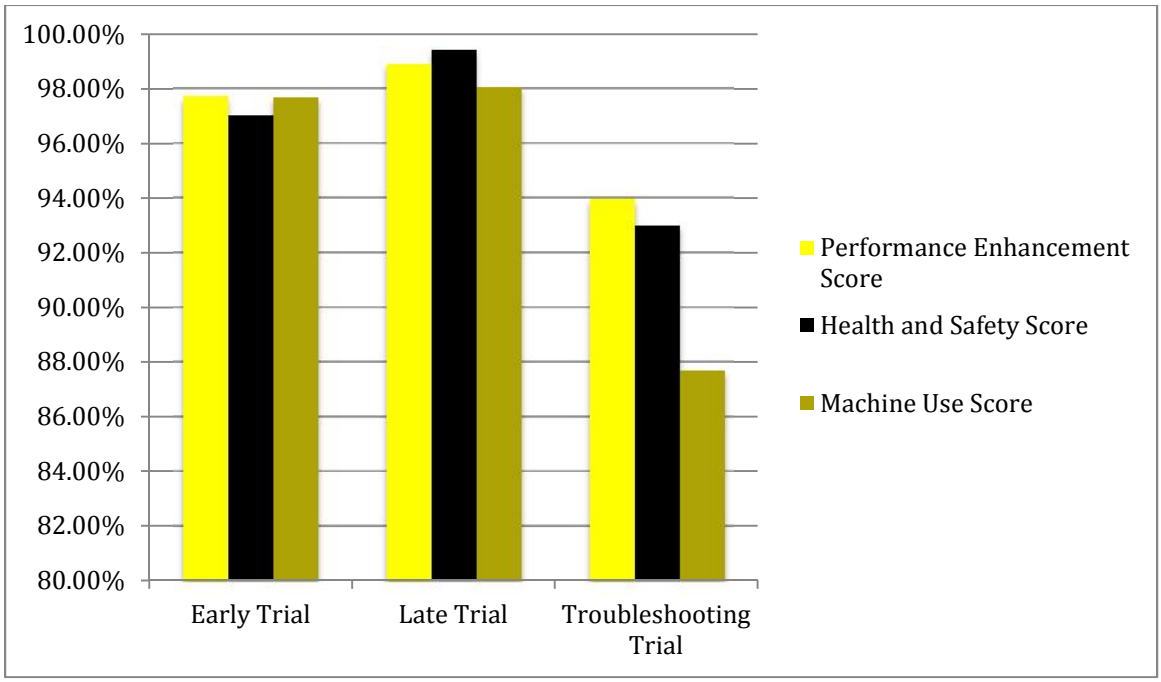
Table 4: Overall mean performance scores and HRV for each trial with standard deviations in brackets

	Early Trial	**Late Trial**	**Troubleshooting Trial**
Performance enhancement score	97.70% (1.30%)	97.00%*(2.27%)	97.68% (1.29%)
Health and Safety score	98.90% (3.06%)	99.40% (1.96%)	98.05%** (3.31%)

Machine use score	93.95% (4.33%)	93.00% (4.96%)	87.68%** (6.99%)
LF:HF ratio	2.875 (2.44)	3.465 (2.42)	4.66 (4.39)
RMSSD	94.61ms (89.06)	85.68ms (116.29ms)	118.40ms (197.93ms)

*statistically lower than the early trial;
**statistically lower from both the early and late trials

Figure 2: Overall Performance Scores



<u>Performance enhancement score:</u> Mauchly's test of Sphericity was violated (X^2= 13.209, p=0.001) therefore a Greenhouse-Geisser correction was used. This identified that there was a significant difference over the course of the training (F (2, 36)= 3.936, p=0.05). Post Hoc testing revealed that this difference occurred between the early (97.70%) and late score (97.00%).

<u>Health and safety score:</u> Mauchly's test of Sphericity was violated (X^2=19.347, p=0.00) therefore the Greenhouse-Geisser correction was used. This identified that there was a significant difference over the course of the training (F(2,36)=9.375, p=0.004). Post hoc testing showed that the troubleshooting trial score (98.05%) was statistically lower than both the early (98.90%) and late (99.40%) scores.

Machine use score: Mauchly's test of sphericity was violated (X^2=13.164, p=0.001) therefore the Greenhouse-Geisser correction was used. This identified that there was a significant difference over the course of the training (F(2,36)= 11.499, p=0.001). Post hoc testing showed: the troubleshooting trial (87.68%) score was significantly lower than the early (93.95%) and late (93.00%) trial scores.

3.1.2 Heart Rate Variability Data:

LF:HF: When analysing the 5-minute sections of HRV data for all participants together over the course of their respective training, repeated measures ANOVA showed no significant effect across the different time points of early, late and troubleshooting for the LF:HF ratio values (Sphericity was not violated; F=2.886, P=0.070).

RMSSD: When analysing the 5-minute sections of HRV data for all participants together Mauchly's test of sphericity was violated (X^2=12.043, P=0.002). Therefore the Greenhouse-Geisser correction was used and this showed no significant effect of early, late or troubleshooting time points (F (2,34)=0.6, P=0.49). Mean LF:HF and RMSSD results for each trial can be seen in Table 2.

3.2 Personality type

3.2.1Performance Scores:

Performance Enhancement Score: High scores in conscientiousness were directly related to improved scores in the performance enhancement score for the troubleshooting trial as well (p=0.05; r =0.469). No other significant correlations were detected.

Health and safety scores: No significant correlations were detected.

Machine use scores: High scores in conscientiousness were directly related to improved machine use scores during the troubleshooting trial (p=0.043; Pearson correlation value =0.452).

Table 5 shows the mean personality scores for the total sample as well as grouped means based on the different independent variables. There were no consistent trends between any performance scores and the personality types.

3.2.2 Heart Rate Variability Data:

LF:HF: Personality type scores did not have any significant correlation with LF:HF.

RMSSD: Personality type scores did have significant correlation with RMSSD. Agreeableness and conscientiousness were positively correlated to the RMSSD for the late trial (p=0.005; r=0.619 and 0.015; r=0.548, respectively) and for the troubleshooting trial (p=0.007 r=0.599, and 0.021 r=0.524,, respectively). All significant correlations and their respective values are reported in Table 6.

Table 5: Mean personality scores

	Personality Type Scores				
	Extraversion	Agreeableness	Conscientiousness	Neuroticism	Openness
Total (out of 5)	3.475	4.000	4.256	2.163	3.510
Learning Style					
➢ Diverging (n=9)	3.542	3.827	4.161	2.278	3.478
➢ Assimilating (n=9)	3.347	4.161	4.333	2.000	3.522
➢ Accommodating (n=2)	3.750	4.056	4.333	2.375	3.600
➢ Converging (n=0)	N/A	N/A	N/A	N/A	N/A
Experience Level					
➢ Novice (n= 12)	3.375	3.954	4.213	2.281	3.533
➢ Experienced (n=8)	3.625	4.069	4.319	1.984	3.474
Machine					
➢ Bolter (n=16)	3.492	3.958	4.250	2.188	3.488
➢ Jumbo Drill (n=2)	3.875	3.889	4.333	2.188	3.750
➢ LHD (n=2)	2.938	4.444	4.222	1.938	3.450

Table 6: Pearson correlations DVs with personality type scores

		Troubleshooting Performance enhancement score	Troubleshooting machine use score	Late RMSSD	Troubleshooting RMSSD
Extraversion Score	Pearson Correlation	-.100	-.022	.027	-.019

	Sig. (2-tailed)	.683	.928	.912	.938
	N	19	19	19	19
Agreeableness Score	Pearson Correlation	.420	.226	.619*	.599*
	Sig. (2-tailed)	.074	.353	.005	.007
	N	19	19	19	19
Conscientiousness Score	Pearson Correlation	.452*	.469*	.548*	.524*
	Sig. (2-tailed)	.050*	.043*	.015*	.021*
	N	19	19	19	19
Neuroticism Score	Pearson Correlation	-.040	.152	-.051	-.037
	Sig. (2-tailed)	.871	.535	.837	.879
	N	19	19	19	19
Openness Score	Pearson Correlation	-.007	-.321	.127	.059
	Sig. (2-tailed)	.977	.181	.603	.810
	N	19	19	19	19

*Indicates significant results

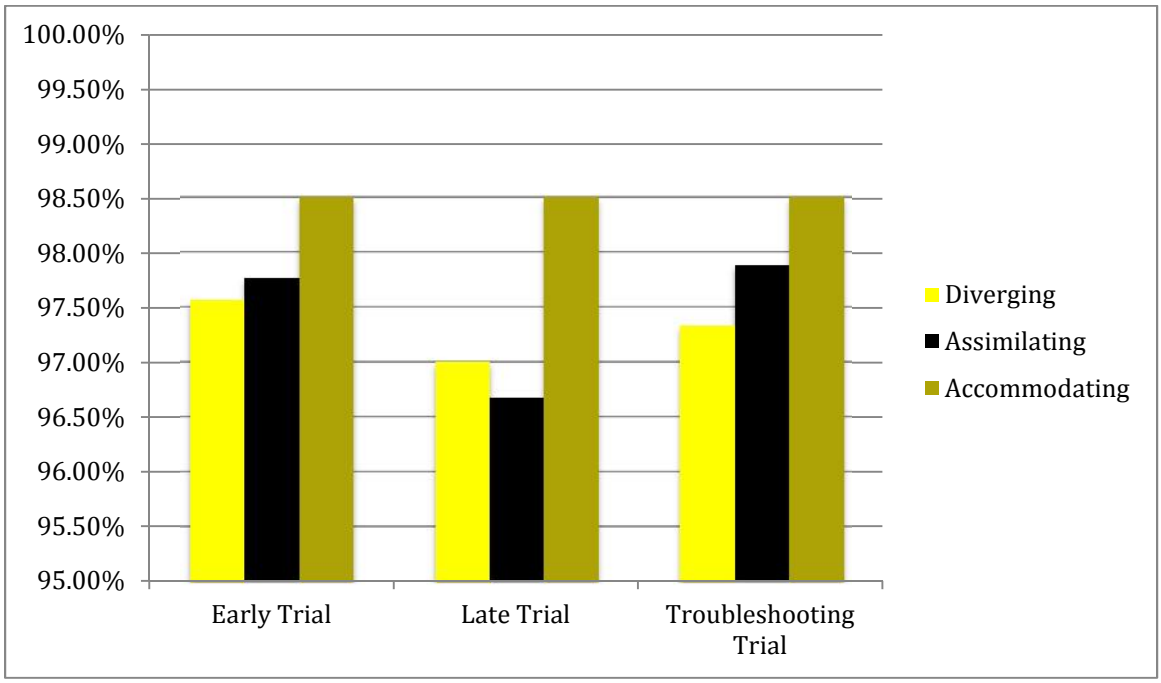
3.3 Learning Style

Based on this sample, only three learning styles were represented: Diverging (n=9), Assimilating (n=9) and Accommodating (n=2).

3.3.1 Performance Scores:

Performance enhancement score: Mauchly's Sphericity assumption was violated (X^2=10.566, p=0.005), therefore the Greenhouse Geisser correction was applied. There was no main effect of time (F (2,32)= 1.487, p=0.241) or learning style (F (4,32)= 0.954, p=0.446) for any of the simulator scoring metrics. Additionally, there was no interaction between time and learning style. The performance enhancement scores are illustrated in Figure 3.

Figure 3: Performance Enhancement Score by Learning Style

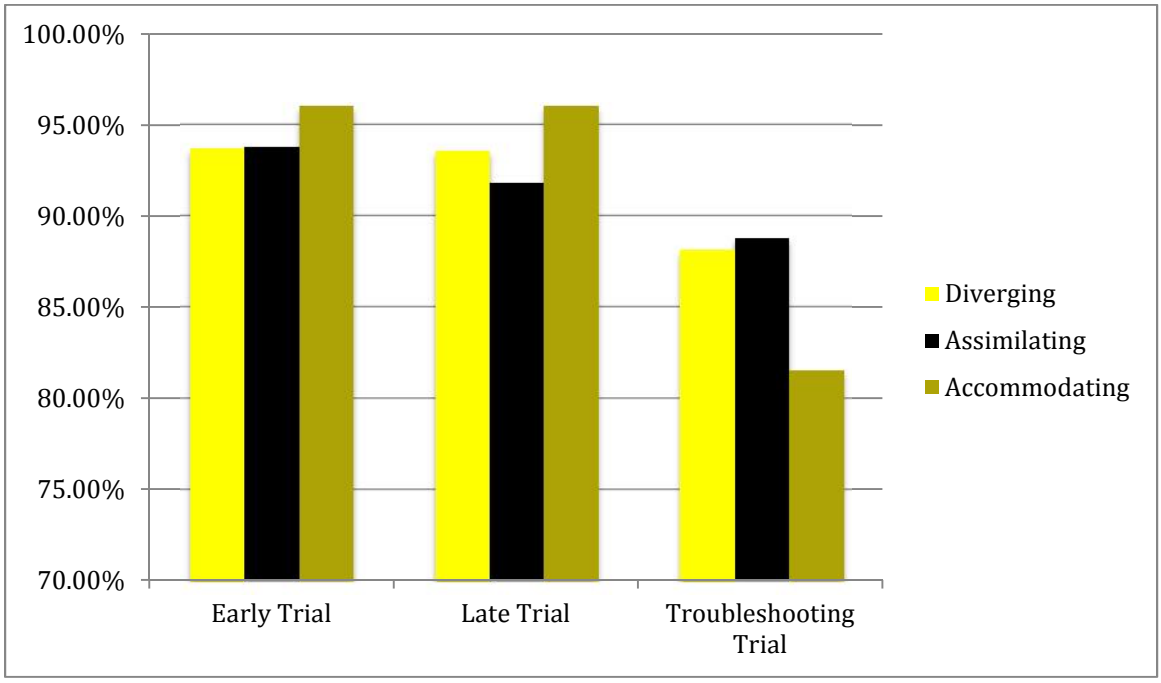


Health and safety score: Mauchly's Sphericity assumption was violated (X^2=16.780, p=0.000), therefore the Greenhouse Geisser correction was applied. There was no main effect of time (F (2,32)= 1.487, p=0.241) or learning style (F (4,32)= 0.954, p=0.446) for any of the simulator scoring metrics. Additionally, there was no interaction between time and learning style. The health and safety scores are illustrated in Figure 4.

Figure 4: Health and Safety Score by Learning Style

Machine use score: Mauchly's Sphericity assumption was violated (X^2=9.996, p=0.007) therefore the Greenhouse Geisser correction was applied. There was no main effect of time (F (2,32)= 1.487, p=0.241) or learning style (F (4,32)= 0.954, p=0.446) for any of the simulator scoring metrics. Additionally, there was no interaction between time and learning style. The machine use scores are illustrated in Figure 5.

Figure 5: Machine Use Score by Learning Style



Learning style specific performance scores are reported in Table 7.

Table 7: Performance scores by learning style with standard deviations in brackets.

	Performance (%)								
	Performance enhancement Score			Health and Safety Score			Machine Use Score		
	E*	L*	TB*	E*	L*	TB*	E*	L*	TB*
Learning Style									
➢ Diverging (n=9)	97.56 (1.59)	97.00 (1.66)	97.33 (1.32)	99.89 (0.33)	100.0 (0.00)	99.11 (0.93)	93.67 (5.43)	93.56 (4.72)	88.11 (8.36)
➢ Assimilating (n=9)	97.76 (1.12)	96.67 (2.96)	97.88 (1.36)	97.67 (4.36)	98.67 (2.83)	96.63 (4.81)	93.78 (3.73)	91.78 (5.65)	88.75 (4.17)
➢ Accommodating (n=2)	98.50 (0.71)	98.50 (0.71)	98.50 (0.71)	100.0 (0.00)	100.0 (0.00)	99.00 (0.00)	96.00 (0.00)	96.00 (0.00)	81.50 (10.61)
➢ Converging	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*E=Early trial; L=Late trial; TB=Troubleshooting trial

3.3.2 Heart Rate Variability Data:

LF:HF: Mauchley's Sphericity was violated (X^2=5.298, p=0.05), therefore the Greenhouse Geisser correction was used. There was no significant main effect for time (F (2,30)=02.475, p=0.119) or learning style (F (4,30)=1.023, p=0.401), and there was no interaction between the two factors.

RMSSD: Mauchley's Sphericity was violated (X^2=7.910, p=0.019), therefore the Greenhouse Geisser correction was used. There was no significant main effect for time (F (2,30)=0.799, p=0.459) or learning style (F (4,30)=2.494, p=0.091) and there was no interaction between the two factors.

Table 8 shows the mean HRV measures for all trials separated by learning style with associated standard deviations.

Table 8: Mean LF:HF ratios and RMSSD values by learning style with standard deviations in brackets

	HRV					
	LF:HF Ratio			RMSSD (ms)		
	Early	Late	Troubleshoot	Early	Late	Troubleshoot
Learning Style						
➢ Diverging	2.012 (1.47)	3.812 (2.76)	5.088 (4.55)	72.91 (51.83)	42.15 (25.71)	47.60 (49.08)
➢ Assimilating	3.339 (2.71)	3.358 (2.24)	4.088 (4.33)	87.21 (101.67)	122.45 (157.78)	183.23 (266.45)
➢ Accommodating	4.234 (4.64)	2.554 (2.92)	5.765 (6.87)	214.77 (90.14)	94.34 (110.35)	74.94 (82.19)
➢ Converging	N/A	N/A	N/A	N/A	N/A	N/A

3.3.3 Reaction Time

A one-way ANOVA showed no significant difference in mean reaction time between learning style (F(2, 19)=0.227, p=0.799). Table 7 shows the mean reaction times by learning style.

Table 9: Mean reaction time by learning style

	Reaction Time (s)
Total	10.958
Learning Style	
➢ Diverging	11.168
➢ Assimilating	10.224

➢ Accommodating ➢ Converging	13.315 N/A

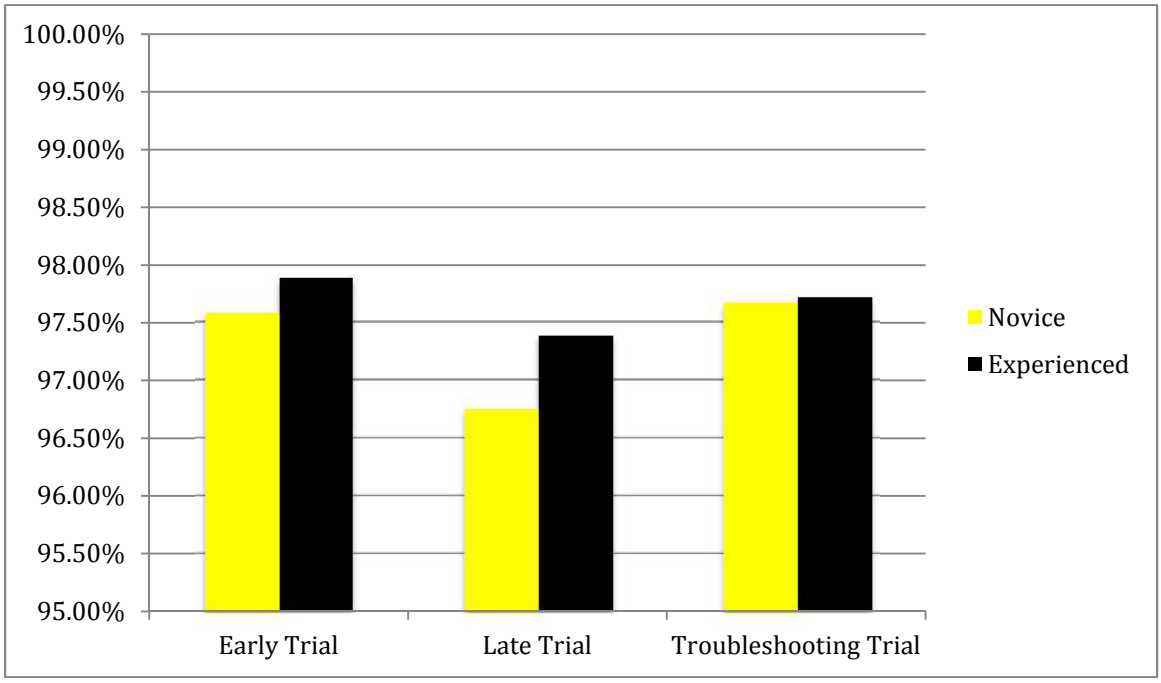
3.4 Level of experience

3.4.1 Performance Scores:

The mean performance scores for each trial split by level of experience is reported in Table 10.

Performance enhancement score: Mauchley's Sphericity was violated (X^2=12.419,), therefore Greenhouse Geisser correction was applied. The main effect of time and experience were not significant (F (1.299, 22.08)= 3.225, p=0.077 and F (1.299,22.08)=0.129, p=0.788, respectively). There was no interaction between the two factors. The performance enhancement scores are illustrated in Figure 6.

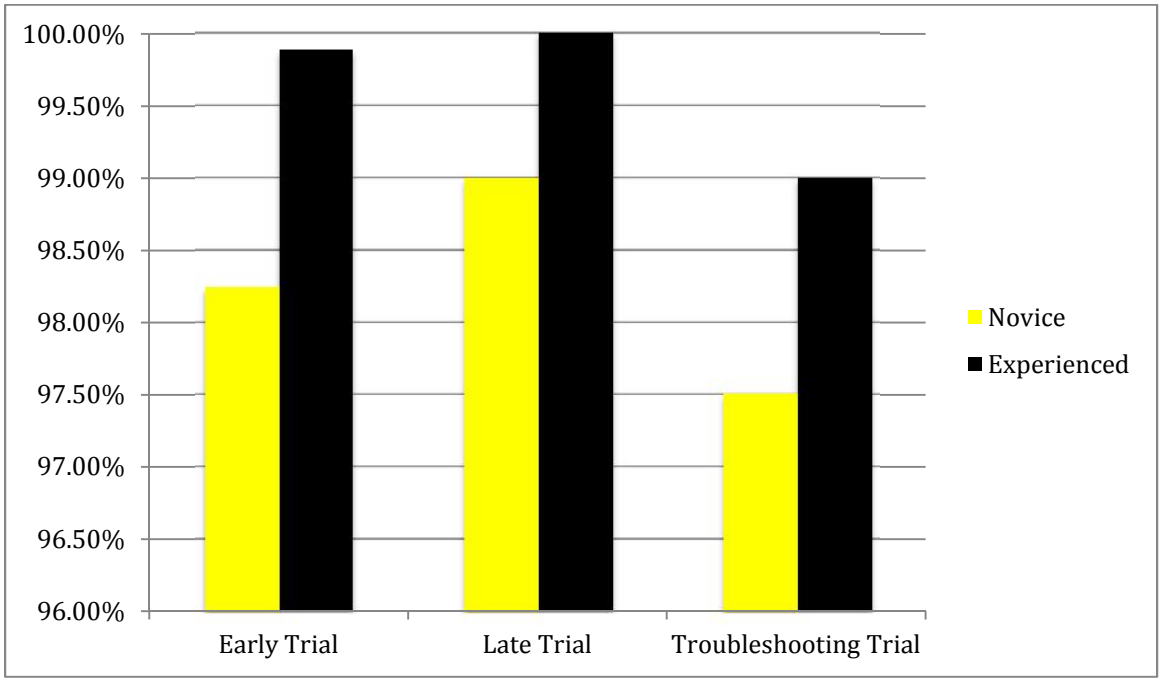
Figure 6: Performance Enhancement Scores by Level of Experience



The health and safety score: Mauchley' Sphericity was violated (X^2=18.334, p=0.000), therefore the Greenhouse Geisser correction was applied. A near- significant main effect of time was found (F (1.189, 20.213= 7.765, p=0.09). However, the main effect of

experience was not significant (F (1.189, 20.213= 508, p=0.515). No interaction was shown between level of experience and the time of the trial (i.e. early, late or troubleshooting). The health and safety scores are illustrated in Figure 7.

Figure 7: Health and Safety Scores by Level of Experience



<u>Machine use score:</u> Mauchley' Sphericity was violated (X^2=12.951, p=0.002) therefore the Greenhouse Geisser correction was applied. A significant main effect of time was found (F (1.286, 21.866= 7.765, p=0.04). A main effect of experience was not found (F (1.286, 21.866= 7.765, p=0.389). However, in this case there was an interaction between the two factors (F(1,17)=0.017). The level of experience only exhibited differences in the late and troubleshooting machine use scores. Higher scores were attained by experienced trainees in both of these trials (95.75% and 92% respectively) compared to the novice trainees (91.17% and 85.17% respectively). These differences were statistically significant at P=0.019 and 0.036 respectively. The health and safety scores are illustrated in Figure 8.

Figure 8: Machine Use Score by Level of Experience

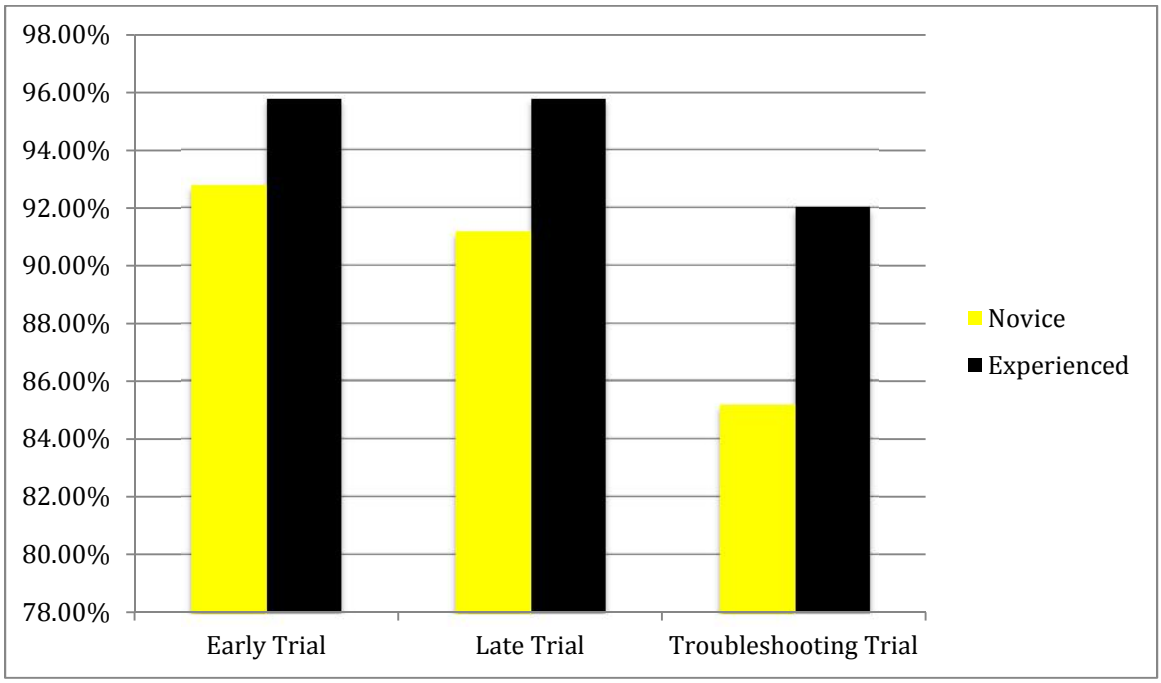


Table 10: Mean performance scores by level of experience with standard deviation in brackets

	Novice			Experienced		
	Early Trial (n=12)	Late Trial (n=12)	Troubleshooting Trial (n=12)	Early Trial (n=8)	Late Trial (n=8)	Troubleshooting trial (n=7)
Performance Enhancement score	97.58% (1.44%)	96.75% (2.01%)	97.67% (1.44%)	97.88% (1.13%)	97.38% (2.62%)	97.71% (1.11%)
Health and Safety score	98.24% (3.86%)	99.00% (2.49%)	97.50% (4.06%)	99.88% (0.35%)	100.0% (0.00%)	99.00% (1.00%)
Machine use score	92.75% (5.28%)	91.17% (5.62%)	85.17% (2.07%)	95.75% (1.04%)	95.75%* (1.67%)	92.00%* (4.28%)

*Indicates statistically significant differences between experienced and novice trainees

3.4.2 Heart Rate Variability Data:

LF:HF: Mauchly's Sphericity was not violated therefore no correction was applied. The result was a non significant main effect of time (F (2,32)= 2.015, p=0.150) and a non-significant main effect of experience (F (2,32)= 1.414, p=0.2.58). There was no interaction between the two factors.

RMSSD: Mauchly's Sphericity was violated when analyzing the RMSSD data (X^2=10.728, p=0.005), therefore the Greenhouse-Geisser was applied. This demonstrated non-

significant main effects of both time (F (1.324, 21.179= 0.775, p=0.469) and experience (F (1.324, 21.179= 0.783, p=0.421).

Table 11 shows the mean HRV measures by level of experience.

Table 11: Mean HRV measures by level of experience

	HRV					
	LF:HF Ratio			RMSSD (ms)		
	Early	Late	Troubleshoot	Early	Late	Troubleshoot
Experience Level						
➢ Novice	2.832 (3.05)	3.950 (2.27)	5.489 (4.07)	115.95 (91.27)	89.41 (139.53)	108.25 (217.12)
➢ Experienced	2.932 (1.41)	2.798 (2.60)	3.366 (4.89)	65.27 (82.44)	80.55 (83.15)	134.35 (178.74)

3.4.3 Reaction Time

An independent samples t-test revealed no significant difference in mean reaction time between the novice (10.45s) and experienced (11.72s) groups (p=0.642).

Chapter 4

4.0 Discussion

This research examined the effect of the NORCAT mining simulator training program on the overall learning and physiologic responses of its participants based on several outcome variables: performance scores (Performance Enhancement Scores, Health and Safety Score, and Machine Use Score), reaction time, and HRV (LF:HF ratio and RMSSD). Further it examined whether specific individual factors (personality type, learning style, and level of experience) influenced these outcome variables over the course of the training.

4.1 Overall Training Results

4.1.1 Performance Scores

It was hypothesized that over the course of the training (i.e. from the early to the late trial) there would be an improvement in performance scores. Additionally, that due to the presence of faults initiated by the trainer, the troubleshooting run would produce lower performance scores. It was anticipated that there would be differences between experienced and novice performers in how they reacted and responded to those faults.

With respect to the performance enhancement score, there was actually a significant decrease in the scoring from 97.7% in the early trial to 97.0% in the late trial, which contradicts the initial hypothesis. Although, statistically significant, clinically a reduction of 0.7% is not a meaningful change. In addition, there was no significant difference between the performance enhancement score acquired during the troubleshooting trial and that of the early and late trials. This indicates that the faults encountered during the troubleshooting run may not have had such a significant influence on the performance enhancement score compared to the two other performance scores.

The health and safety score as well as the machine use score showed no significant change from the early trial to the late trial and statistically, lower scores for the troubleshooting trial, as would be expected. However, the decrease in health and safety score during the troubleshooting run was 0.85% lower than the early trial and 1.35% lower than the late trial. Again this may not be a clinically meaningful change since scores were still above 90%. On the other hand, the machine use score obtained during the troubleshooting run was 6.27% and 5.32% lower than the early and late trial respectively. These values begin to be more substantial than the other differences presented. This suggests that the faults initiated in the troubleshooting run had a

negative effect on the user's ability to appropriately operate the machine, and less of an impact on health and safety or performance enhancement scores. Regardless, the ability to operate the machine appropriately in the face of adverse conditions, faults, etc. can have implications for the health and safety of the operator and those around him.

Currently, it is not possible to compare the results of the current study with other mining simulator research, as no such publication exists in the literature (based on the review of literature performed by the research team). Additionally, in other fields (such as medicine, driving and aviation) virtual reality based training performances have not been analyzed in the same manner as this study. In these fields, simulator-training performance is compared to a control group receiving the conventional training methods (Roenker, Cissell, Ball, Wadley, & Edwards, 2003; Seymour et al., 2002; Taylor et al., 1999; Tuggy, 1998). This project was not able to initiate a crossover design to thoroughly explore the impact of conventional vs simulator use. However, one study examined the change in performance of anaesthesiology residents from baseline to a final test following a 3-month simulator-training program on emergency cases. Baseline performance score was determined to be 58.7% compared to a follow-up test score of 70.3% (Chopra et al., 1994). Evaluations were made by independent, licensed anaesthesiologists watching video recordings of the tests (Chopra et al., 1994).

The hypothesized improvement in performance scores was not consistently observed in the present study. In fact, only the health and safety score showed a slight, non-significant improvement (0.5%) from the early trial to the late trial whereas the two other performance outcomes exhibited decreases in scores from the beginning to the end of the training session. The lack of improvement in performance over the course of the training raises concerns regarding the teaching program. In their review on the effectiveness of virtual reality as a medium for health and safety training in the mining

industry, Tichon and Burgess-Limerick indicate that trainees should have the opportunity to make mistakes and correct them (Tichon & Burgess-Limerick, 2011). If all of the scores are high from the beginning of the training, trainees are essentially not actually making any errors and are missing out on learning opportunities. In addition to this, Tichon and Burgess-Limerick also recommend that the trainees should develop a sense of mastery over the course of the training (Tichon & Burgess-Limerick, 2011). The results of this study do not give an impression that this is occurring. However, these performance scores will be further explored based on the individual factors evaluated by the research team later in this discussion.

4.1.2 HRV

The hypotheses for the HRV analysis for all participants were that the LF:HF would decrease and RMSSD would increase or remain unchanged over the course of the training. Additionally, the troubleshooting trial would cause the highest mean LF:HF ratio and the lowest RMSSD. This is because it was expected that the participants would become more comfortable with the simulator tasks and exhibit a less stressful (i.e.: sympathetically modulated) response and then be most stressed during the troubleshooting trial. Similarly, it was expected that the mental workload would decrease or at least remain the same from the early to the late trial, whereas the troubleshooting trial would produce the highest workload.

The results of the HRV analyses for the present study demonstrated no statistically significant changes over the course of the simulator training for either the LF:HF ratio or the RMSSD. This indicates that as a whole the group of trainees did not experience a change in the autonomic regulation of the heartbeat, including when the trainer attempted to purposefully create a stressful environment (i.e. troubleshooting trial).

The lack of a baseline measurement for this study does not allow the team to determine if there was a difference from the resting state to any of the trials. Therefore, the research team determined that the HRV data from the late trial would serve as a reference point. The assumption was made that the first five minutes of the last trial would be a time when the participants were most comfortable with the training process, and knew what to expect and therefore would in the most relaxed state. In the present study there was a non-significant decrease in LF:HF ratio from the late (baseline) trial (3.465) to the early trial (2.875). This decrease suggests that the late trial may have produced more sympathetic nervous system activity compared to the early trial. Moreover, as predicted, LF:HF ratio was highest in the troubleshooting trial (4.66) indicating the most sympathetically regulated heart-rate variability. The stressful conditions of the troubleshooting trial leading to higher LF:HF ratios appears to be in line with the literature on this topic. It is important to remember that the results of the HRV analyses were not statistically significant. This may be in part do to the small sample size. In their meta-review of acute mental stress assessment using HRV, Castaldo et al found that the LF:HF ratio during stress was lower compared to a resting condition in 6 out of 7 studies (however only one of these showed statistically significant results) (Castaldo et al., 2015). These publications had n values between 12 and 65 (Castaldo et al., 2015). Moreover the one study that produced an increase in LF:HF ratio showed that the ratio grew by only 0.01 (Castaldo et al., 2015). Therefore, the expectation is that LF:HF ratio would increase in response to a stressful situation or high workload was observed in the simulator results. This work provided some baseline data to which real-world measurement could be compared to in the future. For instance, one could compare levels of observed HRV during real-world operation, and make conclusions about the best place to learn new skills.

In contrast, the RMSSD values from this study appeared to show opposite trends compared to the literature. In the present study, the RMSSD increased from the late/baseline (85.68ms) to 94.61ms in the early trial then again to 118.4ms in the troubleshooting trial. This would indicate that as the conditions became more stressful and the mental workload increased, the RMSSD also increased. However it is important to note that these differences were not statistically significant. In contrast, Castaldo et al found that in 4 out of 4 studies reporting RMSSD, the values decreased from resting to stress (3 out of the 4 demonstrated statistically significant decreases) (Castaldo et al., 2015). Having a true baseline to compare the changes in each trial to would be useful. The HRV data will be further explored based on the individual factors evaluated in this study later in this discussion.

4.2 Personality type

It was hypothesized that the resilient personality type (that is, high scores in conscientiousness and extraversion in combination with low scores in neuroticism) would correlate with improved performance. However, the present study identified a potential link between conscientiousness and stressful scenarios. More specifically, statistically significant positive correlations were established between conscientiousness and 2 of the 3 performance scores (performance enhancement score, and machine use score), during the troubleshooting trial. John and Srivastava have indicated 6 facets to the conscientious personality: competence, order, dutifulness, achievement striving, self-discipline, and deliberation (John & Srivastava, 1999). Competence, refers to ones efficiency in performing the tasks given; order, pertains to one's ability to be organized; dutifulness, makes reference to an individual not being careless; achievement striving, speaks to a person being thorough; self discipline, applies to not being lazy; and deliberation, indicates non-impulsive behaviour (John & Srivastava, 1999). Based on

these facets it is clear that personality can improve performance. However, published research on personality types has yet to demonstrate a correlation to performance in a simulator. A study on surgeons found that there was no correlation between personality types and performance in a surgical simulation (Rosenthal et al., 2013). On the other hand, Saus et al found that high scores in extraversion and conscientiousness was related to increased situational awareness in a navigation simulator, but failed to report how navigation performance was quantified (Saus et al., 2012). In comparison to the research by Saus et al (2012), the current study did not determine any correlation between personality type and reaction time even though reaction time/hazard identification is an important factor in situational awareness. In addition, a meta-analysis of the Big-Five Personality traits found that conscientiousness had the highest validity of the five dimensions in terms of overall job performance (Hurtz & Donovan, 2000). Similarly, Flin found that individuals scoring high in extraversion and conscientiousness showed improved performance in an on-the-job paramedic training program (Flin, 2001). These results suggest that the relationship between conscientiousness and simulator performance may be transferable to on-the-job performance. In light of these results, in a practical sense it may be the individuals who do NOT score high on conscientiousness who require more attention in the simulator training schedule in order to attain the same levels of learning.

This research also examined the relationship between personality type scores and physiologic responses to simulator training. . It was hypothesized that the resilient personality type would relate to lower LF:HF ratios and reduced RMSSD values.A positive relationship between the late trail and a troubleshooting time domain measurement (RMSSD) of the HRV was found with both agreeableness and conscientiousness. That is, it appears that those who score high in these two personality traits experience higher

mental workloads during simulator training. The higher workload, while possibly taxing mentally, may translate to higher performance scores and more focus on tasks and processes that make one safe and efficient in the workplace. To our knowledge, one study has examined the link between HRV and personality traits (Saus et al., 2012). This study found that individuals with high situational awareness and the resilient personality (characterized by high scores in extraversion and conscientiousness and low scores in neuroticism) showed significant decreases in RMSSD during simulator training with no change in the LF:HF ratio. That work suggested that the resilient personality was well-suited to simulator learning (Saus et al., 2012). However it should be noted that Saus et al analyzed 1 hour of HRV data (Saus et al., 2012). This long length of data compromises the validity of time domain analysis of HRV (Castaldo et al., 2015; Malik et al., 1996). Again, from a practical perspective, it would be the "other" personalities that may require more or different training to achieve the same outcomes.

4.3 Learning Style

It was hypothesized that learning style would have no effect on the performance scores, nor the physiologic response to simulator training. Based on the results, these hypotheses cannot be completely accepted. Although analysis revealed no specific effect of learning style on performance scores, HRV, or reaction time; only three learning styles were present in the research. Among this cohort, the Diverging learning style had 9 participants, the Assimilating learning style had 9 participants and the Accommodating learning style only had 2 participants. No participants presented with the Converging learning style. Based on the sample sizes, one cannot report valid findings or make conclusions for the Accommodating and Converging learning styles. Running an independent t-test on the reduced dataset (eliminating two accommodating participants) revealed a trend to suggest that those with a diverging learning style scored significantly

higher on health and safety score across all three time points compared to individuals with an assimilating learning style. Kolb (1984) has broadly described people with divergent learning styles as those who like to learn a wide range of information, while people with assimilating learning styles are those who adhere to logical principles. In the context of performance scores, the latter would do well with learning the logics of machine use, and may not see the benefit of learning about health and safety procedures. Whereas the former may only distinguish themselves in the health and safety scoring due to the nature of their learning style; which is to find a wide variety of things interesting (Kolb, 1984). It may take extra effort on the part of the trainer to engage the other learning styles regarding the importance of health and safety items. Learning style also interacts with the teacher's personality; an area not explored in this thesis.

4.4 Level of Experience

It was hypothesized that experienced trainees would have higher initial performance scores, but show less absolute improvement over the course of the training. Additionally, it was speculated that the experienced group would perform better in the troubleshooting trial. The results of the study revealed that only one of these hypotheses was true. The experienced group performed significantly better in the troubleshooting trial (machine use score only) suggesting that experience plays an important role in dealing with stressful and emergency conditions. Additionally, it was found that the experienced group also out-performed the novice group in the late trial (machine use score only). We have postulated that the drop in certain performance scores from early to late trials may be related to fatigue, or disinterest in the training process as the trainee nears the end of the training session. However based on the results, the experienced group showed statistically higher scores later in the training. Therefore one can speculate that although fatigue may be affecting both groups, its effect is more substantial on the

novice group. In a study on simulated laparoscopic surgery, Uhrich et al found that experienced surgeons demonstrated less muscular fatigue than resident (less experienced) surgeons (Uhrich, Underwood, Standeven, Soper, & Engsberg, 2002). Although laparoscopic surgery and mining simulations are very different fields, the tasks completed are not that different. They both involve operating hand-held tools and staring at a screen while completing precise tasks. Therefore, it may be possible that the fatigue experienced by the surgical residents may manifest itself in the novice mining trainees.

In addition to the hypotheses regarding performance scores, the current study hypothesized that experienced trainees would exhibit lower LF:HF ratios and higher RMSSD at all time points, indicating less sympathetic nervous system activation that is associated with reduced mental workload. However the results of the HRV analysis indicated that the level of performance did not have an effect on the physiologic response to mining training in a virtual reality environment. This differs from the results in the literature. For example, Pojman et al showed that experienced marksmen exhibited lower LF:HF ratios compared to a novice group (Pojman et al., 2009). Although the results were not significant, the current study followed this trend. During the late/baseline trial, the LF:HF ratio for the experienced group was 2.798 compared to 3.950 in the novice group. The ratios were almost equal during the early trial (potentially due to equal anticipation for both groups) at 2.932 and 2.832 for the experienced and novice groups respectively. For the troubleshooting trial, the experienced group had a ratio of 3.366 whereas the novice group had a ratio of 5.489. This shows that the experienced group showed very little fluctuation in LF:HF ratio during a supposedly stressful situation, suggesting little impact on their perceived mental workload as might be expected. However, it is possible that the simulator exercise is not that stressful because trainees know that if they make a mistake they may be able to just try again. In contrast, the novice group demonstrated a

high LF:HF ratio during the troubleshooting run, indicative of stress or high perceived workload. Although these results were not found to be significant, the data demonstrated high levels of variability, skewness and non-normality. Future attempts to record HRV data should be done with smaller time periods and a true baseline condition for comparison. In order to determine a baseline, one should record the HRV while the participant is resting for a period of time with no stimulation. In terms of the time domain analysis, the experienced group showed lower RMSSD values for the early and late run however the novice group showed lower RMSSD values during the troubleshooting trial. These results do not coincide with previous literature, and furthermore, these values were not significantly different between time points. The potential difference between the experienced and the novice RMSSD values could potentially be attributed to the immersion in the experience. As discussed in the introduction, novice trainees may not be completely aware of the implications of the tasks they are completing, making it more difficult to be completely immersed in the simulator. They may not perceive the risk associated with their mistakes in a real-world context, and this may have skewed the observed HRV stress response observed in this study. In order to improve the immersion, NORCAT could attempt to teach what the implications are for some mistakes. Additionally, the simulator could attempt to stimulate other senses including smell and sound (Tichon & Burgess-Limerick, 2011). Simulation trainers might also borrow from the concept of gamification learning, in which performance is linked to tangible rewards, which might serve to cue the novice trainees about the importance of some of the tasks they are attempting, as well as the risks associated with incorrect performance.

4.5 Limitations

There were several limitations to this study including the variability in training process, the lack of a true resting HRV reference, the observational nature of the study, and the small sample size.

First off, this research was completed in the field, which impacted the quality of results that we were able to acquire. There was large variability in the delivery of the training program, between sessions and even, between participants of the same session. The trainer, at times, would change up the order of the trials (i.e. make the trouble shooting trial the last trial of the program or it could be somewhere in the middle of the program). Additionally, during the troubleshooting run, the faults initiated by the trainer were not always the same and were sometimes produced several times versus only once with other trainees. This variability in training delivery causes consistency issues with the research and can threaten the reliability of the results.

Secondly, this research failed to acquire resting HRV data. Therefore, it was not possible to determine if any of the trials varied from rest. For instance, it would be useful to compare whether there was more or less sympathetic/parasympathetic/mental workload during the simulator trials compared to resting conditions. This also made it difficult to compare our results with those reported in the literature. The initial goal of the project in terms of HRV was to measure changes throughout the training program, thus a resting baseline was overlooked.

Thirdly, this study was purely observational. The research team did not attempt to alter the delivery of the training in any way. Therefore, it was difficult to control for several variables. For instance, the trainer went over many of the operating procedures before the participants went into the simulator for their first trial. This could be the

reason for consistent high performance scores throughout. This study could have benefitted from a more controlled environment.

Lastly, the initial small sample size was further complicated by technical difficulties and time constraints during one of the training programs. This small sample size made it less probable to identify significant findings between small sub groups. However, due to timing of training sessions no more participants could be recruited during the timeline of this research.

4.6 Recommendations for future research

It would be beneficial to reproduce this research over a longer period of time in order to recruit more test participants. There are several outstanding questions that could be investigated with a crossover design that includes a group of trainees undergoing traditional training methods. Additionally, ensuring that a baseline measurement for HRV is acquired and adequate representation from all subgroups are present (i.e. learning styles). Furthermore, the troubleshooting trials should strive to be more consistent so that the trials between different participants can be more accurately compared. To do this, the trials could be programmed so that the same faults occur at the same times throughout all trials, which would also serve to remove the variable response of the trainer

This research presents some values to compare future mining simulation training research on. Moreover, future research should look to assess the transfer of skills and knowledge learned during the simulator training to real-world practices. A comparison between the simulator training program and an on-the-job training program may also reveal interesting results.

Chapter 5

5.0 Conclusion

The present study identified that the simulation training program at NORCAT is fairly robust in dealing with the different individual factors evaluated in this study (i.e. learning style, personality type, and level of experience). However, it is possible that the learners may not be appropriately immersed in the training or aware of the consequences of improper operation. Additionally, it appears that individuals are scoring very high at the beginning of the training and then the scores tend to decrease over the course of training regardless of the individual factor being evaluated. This decrease is slightly lower in the experienced group compared to the novice group. Therefore one may presume that the decline in performance scores could be a result of fatigue. Moreover, it appears that the training does not affect the HRV of trainees. This indicates that the autonomic regulation of the participant's heart rate is not affected by the training process nor the simulated "stressful" environments. More research should be completed with baseline testing to determine if the overall experience of simulation influences the sympathetic/parasympathetic nervous system activity.

Appendix A – Inter-rater reliability

Inter-rater reliability was assessed for the reaction time measurements. Two researchers independently measured the reaction time to 10 randomly chosen faults. The mean scores can be seen in table 1. The intra-class correlation was found to be 1.00 and this was significant at p=0.00. The results of this analysis can be seen in table 2.

Table 1: Mean reaction times in seconds for each researcher.

	Mean reaction time measurement (s)	Standard deviation	N
Researcher 1	9.54060	8.921707	10
Researcher 2	9.56020	8.869849	10

Table 2: Intraclass Correlation Coefficient

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	1.000[a]	1.000	1.000	25436.242	9	9	.000
Average Measures	1.000[c]	1.000	1.000	25436.242	9	9	.000

Appendix B – Experience Information Sheet

CROSH CRSST

Participant Code: _____

Experience Questionnaire

Please take the time to fill out this short questionnaire which aims to provide a summary of your experience in mining specific machine use, mining related activities and underground experience.

All of the information in this questionnaire will be kept confidential.

Name: _____ Date: _____

Date of birth (YY/MM/DD): _____

Sex: **M** or **F**

Height (circle – cm or inches): Weight (circle – kg or lbs):

Please answer the following questions as accurately as possible.

1. How many years have you been employed with your current company: _____
2. How many years of experience do you have with underground mining with any company: _____
3. Please list any other industries in which you may have been employed (i.e. forestry, construction) and how many years you spent in each:

Industry	Years
_____	_____
_____	_____
_____	_____

4. How many total years of experience do you have in operating heavy equipment of any kind:

_____

5. Do you have any past experience with simulator training: **Yes** or **No**
   If yes, what specific type of equipment were you trained on: _____
   _____
   If yes, how many days of training did you receive: _____
6. Do you have any past experience of video gaming: **Yes** or **No**
   If yes, at what age did you begin playing video games: _____

   If yes, what specific type of gaming system(s) did/do you use:
   _____
   _____
   _____

   If yes, what kinds of controller did/do you use:
   _____
   _____

7. What piece of mining machinery are you currently being trained on in the Cybermine Simulator at NORCAT: _____
   _____

8. Are you currently completing a 4-day session or 2-day session of simulator training?
   4-day _____ 2-day _____

9. Approximately how much time have you spent on this piece of machinery in an underground environment?
   _____ years or _____ months or _____ days

10. What type of training (if any) have you had on this specific piece of machinery?: _____
    _____

Appendix C – Kolb Learning Style Questionnaire

LEARNING-STYLE INVENTORY

The Learning-Style Inventory describes the way you learn and how you deal with ideas and day-to-day situations in your life. Below are 12 sentences with a choice of endings. Rank the endings for each sentence according to how well you think each one fits with how you would go about learning something. Try to recall some recent situations where you had to learn something new, perhaps in your job or at school. Then, using the spaces provided, rank a "4" for the sentence ending that describes how you learn *best*, down to a "1" for the sentence ending that seems least like the way you learn. Be sure to rank all the endings for each sentence unit. Please do not make ties.

Example of completed sentence set:

1. When I learn: 2 I am happy. 1 I am fast. 3 I am logical. 4 I am careful.

Remember: **4** = *most* like you **3** = *second most* like you **2** = *third most* like you **1** = *least* like you

	A		B		C		D	
1. When I learn:	___	I like to deal with my feelings.	___	I like to think about ideas.	___	I like to be doing things.	___	I like to watch and listen.
2. I learn best when:	___	I listen and watch carefully.	___	I rely on logical thinking.	___	I trust my hunches and feelings.	___	I work hard to get things done.
3. When I am learning:	___	I tend to reason things out.	___	I am responsible about things.	___	I am quiet and reserved.	___	I have strong feelings and reactions.
4. I learn by:	___	feeling.	___	doing.	___	watching.	___	thinking.
5. When I learn:	___	I am open to new experiences.	___	I look at all sides of issues.	___	I like to analyze things, break them down into their parts.	___	I like to try things out.
6. When I am learning:	___	I am an observing person.	___	I am an active person.	___	I am an intuitive person.	___	I am a logical person.
7. I learn best from:	___	observation.	___	personal relationships.	___	rational theories.	___	a chance to try out and practice.
8. When I learn:	___	I like to see results from my work.	___	I like ideas and theories.	___	I take my time before acting.	___	I feel personally involved in things.
9. I learn best when:	___	I rely on my observations.	___	I rely on my feelings.	___	I can try things out for myself.	___	I rely on my ideas.
10. When I am learning:	___	I am a reserved person.	___	I am an accepting person.	___	I am a responsible person.	___	I am a rational person.
11. When I learn:	___	I get involved.	___	I like to observe.	___	I evaluate things.	___	I like to be active.
12. I learn best when:	___	I analyze ideas.	___	I am receptive and open-minded.	___	I am careful.	___	I am practical.

MCB200C

Appendix D – Big Five Index

How I am in general

Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who *likes to spend time with others*? Please write a number next to each statement to indicate the extent to which **you agree or disagree with that statement.**

1	2	3	4	5
Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree strongly

I am someone who…

1. ____ Is talkative
2. ____ Tends to find fault with others
3. ____ Does a thorough job
4. ____ Is depressed, blue
5. ____ Is original, comes up with new ideas
6. ____ Is reserved
7. ____ Is helpful and unselfish with others
8. ____ Can be somewhat careless
9. ____ Is relaxed, handles stress well.
10. ____ Is curious about many different things
11. ____ Is full of energy
12. ____ Starts quarrels with others
13. ____ Is a reliable worker
14. ____ Can be tense
15. ____ Is ingenious, a deep thinker
16. ____ Generates a lot of enthusiasm
17. ____ Has a forgiving nature
18. ____ Tends to be disorganized
19. ____ Worries a lot
20. ____ Has an active imagination
21. ____ Tends to be quiet
22. ____ Is generally trusting
23. ____ Tends to be lazy
24. ____ Is emotionally stable, not easily upset
25. ____ Is inventive
26. ____ Has an assertive personality
27. ____ Can be cold and aloof
28. ____ Perseveres until the task is finished
29. ____ Can be moody
30. ____ Values artistic, aesthetic experiences
31. ____ Is sometimes shy, inhibited
32. ____ Is considerate and kind to almost everyone
33. ____ Does things efficiently
34. ____ Remains calm in tense situations
35. ____ Prefers work that is routine
36. ____ Is outgoing, sociable
37. ____ Is sometimes rude to others
38. ____ Makes plans and follows through with them
39. ____ Gets nervous easily
40. ____ Likes to reflect, play with ideas
41. ____ Has few artistic interests
42. ____ Likes to cooperate with others
43. ____ Is easily distracted
44. ____ Is sophisticated in art, music, or literature

Appendix E – Ethics Approval Form

LaurentianUniversity
UniversitéLaurentienne

APPROVAL FOR CONDUCTING RESEARCH INVOLVING HUMAN SUBJECTS
Research Ethics Board – Laurentian University

This letter confirms that the research project identified below has successfully passed the ethics review by the Laurentian University Research Ethics Board (REB). Your ethics approval date, other milestone dates, and any special conditions for your project are indicated below.

TYPE OF APPROVAL / New X / Modifications to project / Time extension	
Name of Principal Investigator and school/department	Alison Godwin, Human Kinetics
Title of Project	Evaluating the impact of simulator training for improving mining health and safety outcomes
REB file number	2015-04-07
Date of original approval of project	May 20, 2015
Date of approval of project modifications or extension *(if applicable)*	
Final/Interim report due on: *(You may request an extension)*	May, 2016
Conditions placed on project	

During the course of your research, no deviations from, or changes to, the protocol, recruitment or consent forms may be initiated without prior written approval from the REB. If you wish to modify your research project, please refer to the Research Ethics website to complete the appropriate REB form.

All projects must submit a report to REB at least once per year. If involvement with human participants continues for longer than one year (e.g. you have not completed the objectives of the study and have not yet terminated contact with the participants, except for feedback of final results to participants), you must request an extension using the appropriate LU REB form. In all cases, please ensure that your research complies with Tri-Council Policy Statement (TCPS). Also please quote your REB file number on all future correspondence with the REB office.

Congratulations and best wishes in conducting your research.

Rosanna Langer

Rosanna Langer, PHD, Chair, *Laurentian University Research Ethics Board*

Appendix E – Consent Form

Participant Code: _____

Consent Form

LaurentianUniversity
UniversitéLaurentienne

Evaluating the impact of simulator training for improving mining health and safety outcomes

I, _____, am interested in participating in the study by Alison Godwin from Laurentian University. The purpose of the study is to investigate how worker characteristics impact the efficacy of simulator training. This will be done by measuring things like personality, learning style, safety attitudes and work experience using questionnaires. In the long term, this research will help to improve simulator training programs.

If I agree to participate I will be asked to complete four questionnaires during my time at the NORCAT training centre. Each questionnaire will take between 10-30 minutes and I can complete them at my leisure during the two/four day simulator testing. During the two/four days of training, I will also be asked to wear a device attached to a chest harness that can monitor my heart rate. The researcher will instruct me on how to attach the harness, which is worn under my clothing. They will verbally confirm that the harness is not irritating my skin. I understand that the results of my training runs in the simulator will be printed and stored by the research team and that my name will be immediately blacked out on that document and replaced with a unique code. Individual results from the questionnaires and heart rate monitoring will not be reported in publications nor given to my employer. Results from this study will only be reported as averages. In the event that researchers notice something potentially abnormal in your heart rate data, they will ask you in a private session to consider speaking with your family doctor, or a local health care clinic about having a full evaluation by a qualified professional.

I have been informed that only members of the research team will have access to the questionnaire and heart rate data collected. NORCAT will keep records of the simulator data. **My participation is strictly voluntary** and I am free to withdraw from completing the study details at any moment. I am aware that I will continue to complete the NORCAT training as scheduled. I have received assurance from the researcher that all individual data collected will remain strictly confidential using a unique coded identifier. All collected data will be coded with a subject number and stored in a locked filing cabinet (in Professor Godwin's office) or a password secured laptop (only members of the research team will have access to the data). After a period of 5 years, all electronic and paper documents will be shredded.

I understand that I will receive no immediate benefit from my participation.

There are two copies of this consent form; one which the researcher keeps and one that I keep.

If I have any questions or concerns about the study or about being a participant, I may contact the lead researcher, Professor Alison Godwin via email agodwin@laurentian.ca and by phone at 705 675 1151 ext 1079 If I have any questions or concerns surrounding the ethical conduct of the study, I may contact the Laurentian University Research Office (ethics@laurentian.ca) or telephone # 705-675-1151 ext 3213 (toll free 1 800 461 4030. If I would like to receive a copy of the study results I can contact Professor Alison Godwin anytime after Sept. 1, 2016 using the contact information on this form.

I agree to participate in this study.

Participant's Signature: _____ Date: _____

Researcher Signature: _____ Date: _____

Please place a check mark in the box below if you agree to participate in the study but you would prefer NOT to have your heart rate variability data collected:

☐

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