The Mediating Role of Mindfulness, Attention and Situational Awareness on Driving Performance in a Virtual Reality Underground Mine

by

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A thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Human Kinetics (MHK)

The Faculty of Graduate Studies
Laurentian University
Sudbury, Ontario, Canada

THESIS DEFENCE COMMITTEE/COMITÉ DE SOUTENANCE DE THÈSE
Laurentian Université/Université Laurentienne
Faculty of Graduate Studies/Faculté des études supérieures

Title of Thesis Titre de la thèse	The Mediating Role of Mindfulness, Attention and Situational Awareness on Driving Performance in a Virtual Reality Underground Mine	
Name of Candidate Nom du candidat	Knight, Carolyn Elizabeth Janelle	
Degree Diplôme	Master of	
Department/Program Département/Programme	Human Kinetics	Date of Defence Date de la soutenance June 20, 2018

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Abstract

Load-haul-dumps (LHDs) are used to transport materials in underground mining. Due to the design of LHDs and the design of the mine drifts, these vehicles are implicated in accidents involving other mining equipment, the mining environment and pedestrians. In 2015, the Ontario Ministry of Labour published the Mining Health, Safety and Prevention Review, which recommended that mobile equipment operators need to have a strong situational awareness.

Mindfulness training can be used to improve an individual's situational awareness and attention. Mindfulness is a trait that naturally varies amongst individuals. However, it is a technique that can be taught and with training and practice, a person's mindfulness levels can improve over time. There has been limited research conducted in the area of mindfulness and workplace health and safety; however, there is evidence to suggest that mindfulness training may be a method to improve workplace safety.

This study measured a person's inherent mindfulness, attention and situational awareness and correlated them against driver's performance measured from within a computer-based virtual reality underground mine simulator. The simulator, or the Situational Awareness Mining Simulator (SAMS), provided the virtual reality experience of operating an LHD in an underground mine. Perception-response time and collisions frequency were measured within the simulator and used as the measures of driver performance. Situational awareness was measured within the simulator by questioning the participants about physical aspects of the virtual mine, such as signage and colour of various objects. Mindfulness was measured using the Mindfulness Attention Awareness Scale (MAAS) and attention was measured using the Attention-Related Driving Errors Scale (ARDES-US).

Participants (n = 21) operated a load-haul-dump in the simulator for two trials, each approximately 15-20 minutes in length. Spearman's correlations showed a relationship between frequency of collisions and perception-response time (r = .449, p = .05); situational awareness and collision frequency (r = .507, p < .05); and situational awareness and mindfulness (r = .434, p < .05). These correlations were present in either Trial 1 or Trial 2, not both trials and thus, should be interpreted with caution. There was also a significant negative correlation between MAAS and ARDES-US scores (r = -.516, p = <.05). There were no other correlations present between ARDES-US scores and any other variables.

This study provides evidence that by cueing individuals to aspects of their surroundings, Level 1 situational awareness (SA) can be increased and further, the relationship between SA and mindfulness becomes more apparent. No evidence was able to suggest a relationship between attention levels, as measured by ARDES-US and driving performance, or situational awareness. The learning curve of adapting to the simulator was substantial, and clouded some of the results, especially pertaining to collision frequency, and situational awareness.

Keywords

Attention; Human Factors; Load-Haul-Dumps (LHDs); Mindfulness; Mining; Mobile Mining Equipment; Simulators; Situational Awareness; Virtual Reality

Acknowledgments

There are many people I would like to thank for their help, guidance and support while completing this degree. First, I would like to thank the individuals that participated in this study. Without the time they gave to be participants, this project would not have gone far!

Thank you to Stefan Klassen and Joshua Morandin who both worked to update and modify ITMo to become the SAMS. I am still amazed with the final product!

Thank you to the undergraduate research assistants that helped me these past two years. Nicholas Schwabe: Thank you for helping make my posters "esthetically pleasing", for analyzing data and for always being ready to be a guinea for the SAMS. Courtney Nickel: Thank you for being another willing guinea pig, for reviewing hours of video data and putting up with the countless photos that I regularly send you.

Thank you to the students of CROSH that I have been privileged to know and become friends with. I know that the laughs and fun we have in the lab have helped me with the stresses and pressures of graduate school.

Thank you to my thesis supervisor – Dr. Alison Godwin. I have thoroughly enjoyed working with you over the course of this degree and I cannot express how grateful I am to have had this opportunity. I am also thankful for all the abstracts and posters you have reviewed and for being supportive whenever I found yet another conference that I wanted to attend.

Thank you to my committee members – Dr. Tammy Eger and Dr. Aaron Langille. I am grateful for your expertise and time spent helping with my project. I am appreciative of you answering all of my questions, however random they may be.

Thank you to the Goodman School of Mines for their financial support, which helped me travel to my first international conference. Thank you to MegaComfort for their financial support through the MegaComfort Scholarship.

The biggest thank you goes to my family. Words cannot express how grateful I am to them for their support. Kath, ever since high school calculus, I have been awed by your grit, work ethic and perseverance (and stubbornness). Thank you for inspiring me and allowing me to raid your cupboards and have weekly kitten dates. Dad – Thank you for always being there, for always being proud of me and for always having an awful dad joke. Mom – Thank you for gently asking about deadlines, for the years (decades, really) of coming home to warm, freshly baked muffins and for being my loudest cheerleader.

And finally to the Rockstar. Thank you.

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Glossary

Attention-Related Driving Errors Scale-US (ARDES-US): American version of the ARDES; used to measure the likelihood of a driver experiencing a driver error due to an attentional failure.

Drift: A horizontal tunnel within an underground mine.

Level: The specific depth of a horizontal tunnel within a mine.

Line-of-Sight (LOS): A measure of visibility (or obstruction) around a vehicle. It is measured by drawing a theoretical line from the eye-line of the vehicle operator to the ground to determine any part of the vehicle that obstructs line-of-sight.

Load-Haul-Dump (LHD): Large bi-directional machine used in underground mining to transport ore or haul machinery.

Mindfulness: The practice of being open to new experiences and self-regulating attention, which may allow practitioners to be better aware of their thoughts, feelings and surroundings.

Mindfulness Attention Awareness Scale (MAAS): used to measure trait mindfulness within this study.

Mobile Mining Equipment: Electric or diesel powered vehicles that are often implicated in accidents or fatalities. Examples include load-haul-dumps, continuous mining machines, front-end loaders, roof bolters, etc.

Muck Pile: A collection of ore that has been broken apart from blasting. Large pieces of the ore are transported from here to another location.

Non-Playable Character: A character within a video game that is not controlled by the gamer.

Ore: Raw material that is mined and transported within a mine and from which minerals or metals are extracted.

Ore Pass: A vertical passage where ore is delivered and falls to a lower level within the mine.

Refuge Station: A location within the mine that workers gather in the event of a disaster or emergency.

Shaft: Vertical or near-vertical tunnel that extends below the ground into an underground mine.

Situational Awareness: The knowledge of knowing what is occurring in one's surroundings.

Situational Awareness Mining Simulator (SAMS): A virtual reality simulator of operating a load-haul-dump in an underground mine. Driver performance can be measured within the simulator, as well as situational awareness.

Situational Awareness Question (SAQ): Questions asked to measure Level 1 of an individual's situational awareness within the SAMS.

Virtual Reality: Computer-generated simulation of an environment that the user can interact with.

Chapter 1

1.1 Underground Mining and Load-Haul-Dumps

Underground mining is the extraction of mined or recovered materials from below the earth's surface (de la Vergne, 2008). Depending on the type of material being extracted, mines are considered either metal/nonmetal mines or coal mines (de la Vergne, 2008; Kecojevic, Komljenovic, Groves, & Radomsky, 2007). The raw material is transported through the underground drifts (horizontal tunnels within the mine) to the surface, and it is there that processing occurs (de la Vergne, 2008; Sawina, 2017). The raw material is transported through the mine through hoisting (i.e. vertical conveyor system, vertical shaft hoist) or haulage (i.e. vehicles, pipes) (de la Vergne, 2008; Sawina, 2017).

Powered haulage vehicles are used to transport raw materials within an underground mine (Sawina, 2017). Examples include but are not limited to, load-haul-dumps, front-end loaders, conveyors, forklifts, cherry pickers and bucket elevators (Mine Safety and Health Administration, 2011). Load-haul-dumps (LHDs) are large, electric- or diesel-powered vehicles that are used to transport ore and rock through the drifts of a mine (Eger et al., 2010; Sawina, 2017; Tyson, 1997). The design of these vehicles is dependent on the dimensions of a mine's drift, which usually results in LHDs being very long and wide (Eger et al., 2010; Tyson, 1997). To maximize their load-carrying capacity, large buckets are located on the front of the vehicles. These buckets have a carrying capacity of three to 11.6 cubic meters (Sawina, 2017). Within the operator cab, drivers sit perpendicular to the direction of travel. This allows for them to easily rotate, facing the direction of travel depending whether the vehicle is in a forward or reverse gear (Eger et al., 2010; Godwin, Eger, Salmoni, Grenier, & Dunn, 2007).

1.2 Review of Mobile Mining Equipment Accidents

Various design aspects of LHDs lead to visibility issues for the operators of these vehicles (Eger et al., 2010; Tyson, 1997). An operator's visibility is further reduced while driving an LHD due to environmental factors such as dust, fog, glare, poor lighting and underground terrain (Eger, Salmoni, & Whissell, 2004; Tyson, 1997). As a result of the design of LHDs and underground mining conditions, LHD operators have difficulty detecting hazards or obstacles within the mine, which increases the risk for accidents related to poor line-of-sight. These hazards and obstacles include pedestrians (both standing and kneeling), open holes in the ground, other vehicles, and the walls of the mine tunnel (Eger et al., 2004). Accidents involving LHDs result in equipment damage, lost work time for injured workers, and fatalities (Tyson, 1997).

Load-haul-dumps are not the only vehicles in underground mining that are implicated in accidents. Powered haulage, a category into which LHDs fall, is a type of mobile mining equipment that was involved in 21 deaths between 2012 and 2016 in underground mining in the USA (MSHA, 2017). In Ontario, there were 12 fatal injuries and 56 critical injuries reported between 2000 and 2014 that fell into the classification of powered haulage (Ministry of Labour (MOL), 2015a). The Ontario Ministry of Labour (2015b) recognizes that the large size of the mobile equipment used in underground mining puts pedestrians and other vehicles at risk of injury due to the equipment's reduced visibility.

Over a ten-year period between 1986 and 1996 there were 1559 accidents involving LHDs in Ontario mines that resulted in five fatalities due to poor operator visibility (Tyson, 1997). Between 1997 and 2002, an additional 324 accidents occurred, including two deaths (Eger, Kociolek, Grenier, & Pegoraro, 2007). Furthermore, in the USA alone, there were eight fatalities involving LHDs between 2001 and 2013 (MSHA, 2015).

1.3 Line of Sight

As a result of several coroner's reports as well as the Ontario Ministry of Labour's Mining Health, Safety and Prevention Review (2015a), recommendations were made to support more research into the development of line-of-sight (LOS) proximity detection devices, as well as collision avoidance systems suitable for underground mobile mining equipment. LOS is used to quantify what is theoretically available to be seen by the operator from within the vehicle (Eger et al., 2007). To measure LOS, an imaginary line is drawn from the level of the operator's eyes to a point on the ground, or other reference height. A clear LOS occurs if the point on the ground is not obstructed by part of the vehicle (Eger et al., 2007) and thus, researchers conclude that the operator of the vehicle should be able to observe that specific point. LOS is impeded if part of the vehicle obstructs the point on the ground (Eger et al., 2007).

1.4 Proximity Detection Devices

Research has been conducted to develop proximity detection devices to improve LOS (MOL, 2015a; Ruff, 2004). In addition to developing proximity detection devices, LHD vehicle modification has been explored (Godwin, Eger, Salmoni, & Dunn, 2008). Godwin and colleagues (2008) concluded that despite the ability to improve LOS through vehicle modification, there were still critical areas around the LHD that would restrict LOS. Various technologies have been evaluated for use in proximity detection systems for mining. Examples of these technologies include radar, sonar, tag-based detection systems (i.e. RFID), cameras (i.e. CCTV), and infrared cameras (Godwin & Eger, 2014; Ruff, 2004). In addition to developing effective technologies to work underground and properly detect hazards, the user interfaces of these devices need to be researched and developed with principles of human factors applied to their design. Potential interfaces are video feed, text, symbols, audio and visual alerts (Godwin &

Eger, 2014). Unfortunately, the current technology has been implemented in industry with insufficient research completed to make it either effective or relevant to underground mining (Godwin & Eger, 2014; MOL, 2015a).

1.5 Cognitive Factors and Accidents

An available LOS does not necessarily mean that the operator would see that location at any given point in time during operation, since attentional behavior and cognitive task demands also play a role in what operators choose to, or are able to, focus on while driving. Environmental variables including fog, glare, and background contrast can also impair an operator's ability to observe and respond to something around the machine. Moreover, many cognitive factors, such as fatigue, distraction and perception, might lead to an operator missing information that was theoretically available to be viewed.

1.5.1 Fatigue

Fatigue and sleepiness can lead to deficits such as periods of delayed responding or non-responding, slowed processing of information and increased reaction times, all of which can affect an individual's performance (Dinges, 1995). Operator inattention is often a symptom of fatigue, which can significantly contribute to performance errors and increase the risk of an accident (Dinges, 1995). Serious accidents have been shown to be the result of fatigue in industrial settings, nuclear power plants and in many types of transportation (Dinges, 1995).

1.5.2 Distraction

Driver distraction, combined with driver inattention, is a major contributor to motor vehicle accidents and near-accidents (Regan, Hallett, & Gordon, 2011). One estimate suggests that driver distraction is a contributing factor in over 20% of motor vehicle accidents (Harbluk, Noy, &

Eizenman, 2002). Whether or not a distraction is internal or external to a vehicle, it is assumed that attention is diverted away from the task of driving and safe driving is affected (Regan et al., 2011). Harbluk and colleagues (2002) investigated the use of in-vehicle technology (e.g. in-vehicle guidance systems, cell phones) and found the drivers' visual behaviour patterns changed; they had delayed braking responses and an increased subjective rating of workload. They concluded that distracting tasks negatively impact driver control and visual behaviour through delayed detection and decreased situational awareness (Harbluk et al., 2002).

1.5.3 Perception

A failure of perception can lead to accidents or near misses for drivers (Koustanaï, Boloix, Van Elslande, & Bastien, 2008). Drivers state that in these "looked-but-failed-to-see" accidents they did not see the other vehicle (or obstacle) or if they did, they did not see it until it was too late (Koustanaï et al., 2008; Martens & Fox, 2007). These accidents occur because the visual search strategy of the driver is inadequate for the situation, or the driver has an inappropriate assumption of the physical layout of the environment (Koustanaï et al., 2008). Furthermore, when the obstacles are unexpected or encountered less frequently than other types, "looked-but-failed-to-see" accidents may occur (Koustanaï et al., 2008; Martens & Fox, 2007). Often these types of accidents occur even when drivers are familiar with the road travelled on (Martens & Fox, 2007). It is possible that "looked-but-failed-to-see" accidents could occur for LHD operators because the operators would fully know the layout, and the usual movements of both vehicles and pedestrians within a mine.

1.6 Situational Awareness

The Ontario Ministry of Labour's Mining Health, Safety and Prevention Review stressed that regardless of what type of proximity detection device is developed and implemented to reduce vehicular collisions, the mobile equipment operators need to have a strong situational awareness (SA) (MOL, 2015a). Situational awareness is the knowledge of what is occurring in one's surroundings at a specific location and moment in time (Endsley & Garland, 2000). There are three hierarchical levels of situational awareness: perception, comprehension and projection (Endsley, 1995b; Endsley & Garland, 2000). Level 1 of situational awareness is perception, which is the lowest level of situational awareness and it is the discernment of the elements in one's current environment (Endsley, 1995b; Endsley & Garland, 2000). Level 2 is comprehension and it involves understanding the perceived elements of situations and combining them to form a complete picture of the surrounding environment (Endsley, 1995b; Endsley & Garland, 2000). Level 3, projection, requires that both perception and comprehension of the environment has occurred (Endsley, 1995b; Endsley & Garland, 2000). Based on the knowledge from Levels 1 and 2, individuals can predict what events may occur in the future and react accordingly (Endsley, 1995b; Endsley & Garland, 2000).

The maintenance of SA requires concentration, attention to detail and constant vigilance (Sneddon, Mearns, & Flin, 2006). However, SA can be negatively impacted through both stress and workload (Sneddon et al., 2006). Endsley (1995b) reported that stress can specifically impede a person's perception of a situation. Environmental stressors, such as vibration, temperature, noise, pollution and both high and low levels of light can negatively affect an individual's concentration or alertness (Sneddon et al., 2006). These stressors are especially common for operators of underground mobile mining equipment (Eger et al., 2004; McPhee, 2004; Tyson, 1997). When a person's workload is too low, boredom can result leading to reductions in attention and motivation (Sneddon et al., 2006). Conversely, if a workload is too high due to a complicated task, a person may not be able to perceive a potential incident or have enough time to appropriately respond (Sneddon et al., 2006).

Situational awareness research originated in the aviation industry (Endsley, 1995b) but has since gone on to include other occupations, such as shipping, driving, military, anesthesia (medicine), nuclear power and offshore oil drilling (Sneddon et al., 2006). Sneddon et al. (2006) analyzed 332 incidents that occurred on an offshore oil and gas rig; 135 of these incidents were related to SA failures. Specifically, 66.7% of the incidents were attributed to Level 1 SA errors, with more than half of the Level 1 errors classified as occurring as a result of poor vigilance, attention or distraction, or poor LOS (Sneddon et al., 2006). The percentage of incidents attributed to Level 2 and Level 3 of SA were 20% and 13.3%, respectively (Sneddon et al., 2006). The division of SA errors by level was similar to other industries, which suggests that the error classifications may be applicable to other high-risk industries (Sneddon et al., 2006), such as mining.

Sneddon and colleagues (2006) suggested that because the majority of the incidents analyzed occurred due to failure of Level 1 SA, training programs should be implemented in workplaces to improve SA. Specifically, training programs should include improving cognitive skills (Sneddon et al., 2006). It has been theorized that individuals with higher levels of SA should be better able to avoid collisions and other hazards (Kass, VanWormer, Mikulas, Legan, & Bumgarner, 2011).

Furthermore, improving situational awareness is of great importance because, currently, effective and appropriate interfaces for proximity detection devices has yet to be established (Burgess-Limerick, 2011; Godwin & Eger, 2009). Research from Burgess-Limerick (2011) suggested that accidents can still occur even with proximity detection devices installed on mobile-mining equipment. Specifically, if warnings issued by proximity detection devices are not understood or identified fast enough to avoid an accident, then these devices are not able to prevent accidents from occurring (Burgess-Limerick, 2011). Thus, it is possible that warnings issued by proximity detection devices are not sufficient to prevent some accidents from occurring (Burgess-Limerick, 2011).

1.7 Attention

There are many definitions of attention but a simple definition is “the concentration of the mind upon an object” (p. 147, Macquarie Dictionary, 1988, as cited in Regan et al., 2011). Thus, inattention can be defined as the failure of paying attention. However, this definition implies that individuals have control over their attention, and further, that inattention is negligent behaviour (Regan et al., 2011). Driver inattention, which has its own specific definition related to the task of driving, is a leading factor in vehicular accidents (Regan et al., 2011). There is concern that as more technology is installed in vehicles, there may be increased numbers of accidents due to the distraction of this technology (Regan et al., 2011). With an absence of research in industrial workplaces, this may hold true for the introduction of proximity detection devices in underground mining vehicles but there is sparse evidence to support this at this time.

Regan et al. (2011) defined driver inattention as either reduced attention or no attention to the activities required for safe driving. They stated that the attention a driver should be using to focus on the task of driving, is instead given to an activity, object or person (Regan et al., 2011). When drivers are in control of their distraction (a self-imposed distraction, such as adjusting the radio), they have a certain amount of leeway to regulate their driving behaviours (Regan et al., 2011). It is these drivers that are able to maintain situational awareness (Regan et al., 2011) despite a distracting environment. However, a driver may not have the same ability to selfregulate their attention if a distraction is particularly captivating and thus, situational awareness may be negatively affected (Regan et al., 2011). Endsley (1995a,b) states than in order to achieve situational awareness, attention must be maintained.

Attentional failure or attentional lapses can be measured using different scales. The Attention-Related Cognitive Errors Scale (ARCES) measures the likelihood of an individual having a performance error due to a lapse of attention, while the Cognitive Failures Questionnaire (CFQ) measures cognitive failures relating to perception, memory and action failures (Broadbent, Cooper, FitzGerald, & Parkes, 1982; Cheyne, Carriere, & Smilek, 2006). Specifically, the CFQ measures both attentional lapses and the errors that occur due to these lapses (Cheyne et al., 2006). Research by Larson and Merritt (1991, as cited in Cheyne et al., 2006) demonstrated that individuals that scored higher on the CFQ (and thus had a higher cognitive failure rate), were more likely to cause a vehicular accident compared to those that scored lower on the CFQ. Recognizing that attentional failures are a concern for road safety, Ledesma, Montes, Poó, and López-Ramón (2010) developed the Attention-Related Driving Errors Scale (ARDES) to measure the likelihood of a driver experiencing an error due to an attentional failure.

1.8 Mindfulness

The practice of mindfulness is not a new concept; it has its foundations in Buddhism dating back centuries (Bishop et al., 2004; Brown & Ryan, 2003). More recently, mindfulness has gained popularity through the use of Mindfulness-Based Stress Reduction developed by Jon Kabat-Zinn to manage chronic pain (Bishop et al., 2004; Brown & Ryan, 2003; Drew de Paz, Gomez, & Young, 2014). Additionally, mindfulness training has been used to treat individuals with generalized anxiety disorders, post-traumatic stress disorder, substance abuse, behavioural and eating disorders, psoriasis, type 2 diabetes and rheumatoid arthritis (Bishop et al., 2004; Drew de

Paz et al., 2014). Mindfulness training has been shown to be effective in the reduction of symptoms associated with various disorders and diseases. Individuals that practiced mindfulness during the treatment of their disease had an increased quality of life and a decrease in the distress often coupled with having the disease (Drew de Paz et al., 2014).

Those who partake in mindfulness training are better at maintaining attention (Kass et al., 2011) and controlling poor habits, automatic thoughts and unhealthy behaviours (Brown & Ryan, 2003).

Simple definitions of mindfulness is “paying attention on purpose” (Kass et al., 2011) and the “process of bringing a certain quality of attention to moment-by-moment experience” (Bishop et al., 2004). However, this study will adopt the operational definition of mindfulness as proposed by Bishop et al. (2004). They use the following as an example of meditation (Bishop et al., 2004):

> The client maintains an upright sitting posture, either in a chair or cross-legged on the floor and attempts to maintain attention on a particular focus, most commonly the somatic sensations of his or her own breathing. Whenever attention wanders from the breath to inevitable thoughts and feelings that arise, the client will simply take notice of them and then let them go as attention is returned to the breath. This process is repeated each time that attention wanders away from the breath. As sitting meditation is practiced, there is an emphasis on simply taking notice of whatever the mind happens to wander to and accepting each object without making judgments about it or elaborating on its implications, additional meanings, or need for action. (p. 232)

According to Bishop and colleagues (2004), through the regular practice of meditation, a state of mindfulness can be obtained and then be drawn upon during the day. Bishop and colleagues (2004) propose two main components to their model of mindfulness: self-regulation of attention and orientation to new experiences. The first component, regulation of attention, allows an individual to begin the practice of mindfulness by focusing his or her attention on their own surroundings and experiences (Bishop et al., 2004). With regular practice, one may gain the ability to maintain attention for longer periods of time (Bishop et al., 2004). Bishop and colleagues (2004) propose that mindfulness training will allow practitioners to have an awareness of things that may otherwise go unnoticed.

The second component of this mindfulness model is orientation to new experiences. Simply put, this is the acceptance of where the mind wanders during mindfulness practice and during each moment of a new experience (Bishop et al., 2004). They suggest that mindfulness practice allows for individuals to be more observant of both one's thoughts and feelings as well as being nonjudgmental of current experiences (Bishop et al., 2004).

1.9 Improving Situational Awareness and Attention through Mindfulness

Mindfulness may be a potential method to improve both an individual's situational awareness and attention. Mindfulness has been characterized as a trait but it has been also theorized to be a state (Brown & Ryan, 2003). This is because mindfulness levels vary among people (Brown & Ryan, 2003) and with training and practice, they can improve over time (Bishop et al., 2004; Brown & Ryan, 2003; Schofield, Creswell, & Denson, 2015; Valero-Mora et al., 2015; Zhang & Wu, 2014).

Endsley (1995b) hypothesized that situational awareness ability varies among individuals due to “an individual’s information-processing mechanisms, influenced by innate abilities, experience and training” (p. 35). Later work by Endsley and Garland (2000) showed that people are limited by attention, and that attention is necessary to develop and maintain situational awareness. However, through mindfulness training a person can improve his or her abilities of situational awareness (Zhang & Wu, 2014). Mindfulness training can also be used to improve an individual’s attention (Kass et al., 2011; Schofield et al., 2015).

1.10 Mindfulness and Occupational Health and Safety

Most of the research of mindfulness and occupational health and safety surrounds how mindfulness affects the health and well-being of workers. Mindfulness studies and interventions conducted in the workplace have included teachers, police officers, nurses, midwives, physicians, office workers and various branches of the military (Jamieson & Tuckey, 2017; Lomas et al., 2017). From the reviews conducted by Jamieson and Tuckey (2017) and Lomas et al. (2017), there was evidence to suggest that mindfulness reduces stress and absenteeism, and improves productivity, job satisfaction and job performance.

Compared to mindfulness interventions and its effect on occupational health and well-being, there is a dearth of evidence of mindfulness and workplace safety. The application of mindfulness research to workplace safety is a relatively new topic with limited findings (Drew de Paz et al., 2014). Currently, the University of California’s “Mindful Health & Safety” Center of Excellence is conducting research to determine the effect of a mindfulness intervention on workplace-related injuries and errors, stress, productivity and attention levels (Drew de Paz et al., 2014). Like many of the mindfulness workplace interventions conducted thus far, this project of Drew de Paz and colleagues (2014) will also evaluate mindfulness in nurses.

There have been no known studies of mindfulness and workplace safety in the mining industry but there has been research conducted in both construction (Leung, Liang, & Yu, 2016) and nuclear power plants (Zhang & Wu, 2014). Zhang and Wu (2014) evaluated dispositional mindfulness on nuclear power plant operators and found that individuals with higher levels of dispositional mindfulness were more likely to have better safety performances. In dynamic, complex and error-intolerant workplaces (such as aviation and nuclear power), Zhang and Wu stated that there was a clear benefit to being mindful compared to workplaces where a certain number of errors can be tolerated (2014). Furthermore, they suggested mindfulness training as a method to improve workplace safety (Zhang & Wu, 2014). Leung and colleagues (2016) measured mindfulness characteristics amongst construction workers to determine its effect on stress and safety performance. Their results showed that workers with higher levels of mindfulness were able to improve safety performance through reducing physical stress (Leung et al., 2016). Mindfulness allows individuals to be more aware of safety procedures and regulations, as well as aware of any potential hazards (Leung et al., 2016).

1.11 Mindfulness and Driving Performance

There is limited research on mindfulness and driving performance (Kass et al., 2011; Valero-Mora et al., 2015). Kass and colleagues (2011) questioned whether individuals receiving mindfulness training had increased levels of situational awareness (SA) in a simulated driving environment, compared to individuals that received no such training. Because higher levels of situational awareness should allow drivers to avoid collisions and other hazards in their surroundings, Kass and colleagues (2011) hypothesized that the individuals who completed mindfulness training would have greater SA and thus, better driving performances. The measures of driving performance included speeding, vehicular and pedestrian collisions and stopping violations. It was found that the treatment group (the group that received mindfulness training) had significantly higher concentration scores (*p* = .05) and situational awareness scores (*p* < .01) but not higher mindfulness scores compared to the control group (the group that received no intervention). Furthermore, there was no significant difference between the number of vehicular and pedestrian collisions nor the number of speeding violations between the two different groups While there were three times as many stopping violations within the control group, compared to the treatment group, it was not a significant difference (Kass et al., 2011).

The results suggested that the increased SA scores was due to increased concentration skills and not increased mindfulness skills (Kass et al., 2011). The control and treatment groups were combined and correlational analyses were conducted to determine if mindfulness had any effect on SA. It was revealed that SA was positively correlated with mindfulness ($r = .80$, $p < .01$) and concentration ($r = .61$, $p < .05$). Further analysis revealed a negative correlation between mindfulness and the number of pedestrian collisions ($r = -.61$, $p < .05$). Correlation analysis between stopping violations and mindfulness were not found to be significant ($p = .09$). However, there was a significant negative correlation between stopping violations and SA ($r = -.65$, $p < .01$). There were no other significant relationships between the other measures of driving performance. Kass and colleagues (2011) stated the results of their study indicated that improved levels of both mindfulness and concentration are associated with increased situational awareness, which in turn, should be associated with fewer traffic violations.

Valero-Mora et al. (2015) evaluated the relationships between mindfulness, inattention and driving performance in the context of a driving simulator. Participants used a driving simulator, as well as completed questionnaires measuring mindfulness and inattention. Driving performance was measured in terms of longitudinal control and lateral control. Mean speed was used to measure longitudinal control. Minimum time to line crossing, which indicates the risk of driving off of a road, was used to measure lateral control. The Mindfulness Attention Awareness Scale (MAAS), which is used to measure mindfulness, and the Attention-Related Driving Errors Scale (ARDES), which is used to measure the likelihood of having an attention-related accident while driving, were shown to be positively correlated with each other ($r = .523$, $p < .01$) (The MAAS was reverse scored when used in this study). The correlation between both lateral and longitudinal controls, and mindfulness were not found to be significant. However, there was a moderate correlation between driver inattention (as measured by the ARDES) and both lateral and longitudinal controls ($r = -.320$, $p < .01$; $r = .253$, $p < .05$, respectively). Regression analysis revealed that lateral control could be predicted using the ARDES (Standardized Beta = -.42; $t = -2.51$, $p < .05$) but not the MAAS. Results from this study did not support the relationship between mindfulness and driving performance but it did provide evidence of a relationship between attention and driving performance. Despite their results, Valero-Mora and colleagues (2015) suggested that additional research needs to be conducted to further evaluate the relationship between mindfulness and driving.

1.12 Measuring Performance in Driving Simulators

Driving performance within a simulator can be measured using numerous variables. Valero-Mora and colleagues (2015) used mean speed and mean time to line crossing as measures of driver performance within a driving simulator. Mean time to line crossing is used as a measure of driver’s lateral control of the vehicle (Valero-Mora et al., 2015) or their quality of steering (Gawron, 2008). Other measurements include collisions (with pedestrians or other simulated vehicles), speeding violations and stopping violations, such as at traffic lights or stop signs (Kass et al., 2011). Gawron (2008) reviewed measures used in evaluating driving performance. The number of brake responses can be evaluated to determine the effect of conducting a task secondary to the task driving (Gawron, 2008). The length of time to complete a driving task, such as completing lane changes or collision avoidance, can also be measured (Gawron, 2008). Finally, perception-response time can be measured. Perception-response time is the length of time from when an obstacle is perceived until the driver releases his or her foot from the gas pedal and applies the brake (Gawron, 2008).

1.13 Measuring Situational Awareness

There are various ways that situational awareness can be measured, such as physiological measures (electroencephalograms and P300), questionnaires and self-rating methods (Endsley, 1995a). However, one of the more widely used methods is the Situation Awareness Global Assessment Technique (SAGAT) (Endsley, 1995a). The SAGAT utilizes the freeze technique and is capable of measuring all three levels of SA (Endsley, 1995a). This method involves pausing the simulator at random, preselected times and quizzing the test subject on his or her perceptions of the current situation (Endsley, 1995a; Scholtz, Antonishek, & Young, 2004) When using the SAGAT method, test subjects are aware that the simulation may be paused at any time and that they will be quizzed on their surroundings (Endsley, 1995a). However, the researcher has predetermined a time to pause the simulator that is approximately the same for each individual (Endsley, 1995a; Scholtz et al., 2004). Furthermore, the SAGAT method requires that there is no display or visual aid visible to the test subject when being questioned (Endsley, 1995a). The test subject’s responses are recorded on the computer, which can later be compared to the correct observations provided from the simulator’s data-log (Endsley, 1995a).

1.14 Mindfulness Attention Awareness Scale (MAAS)

The Mindfulness Attention Awareness Scale (MAAS) was developed by Brown and Ryan (2003) to measure an individual's levels of awareness and attention to their current surroundings and experiences. The MAAS (trait version) consists of 15 questions about everyday experiences that are answered on a 6-point Likert scale (Brown & Ryan, 2003). The MAAS is scored such that individuals who have higher scores have higher dispositional mindfulness (Brown & Ryan, 2003).

This scale has been validated in both undergraduate college students and adults outside of the post-secondary environment (Brown, n.d.; Brown & Ryan, 2003). In 14 independent samples taken amongst college students, MAAS scores averaged 3.8 with a standard deviation of .70 (Brown, n.d.). The MAAS has been found to have high test-retest reliability, criterion validity and discriminant and convergent validity. Internal consistency has been found to range between .80 and .90.

1.15 Attention-Related Driving Errors Scale (ARDES-US)

The Attention-Related Driving Errors Scale (ARDES) was developed as a method of measuring driving errors that occur due to attentional failures (Ledesma et al., 2010). The ARDES looks at personal factors that may influence a person losing attention while driving and the errors or accidents relating to these attentional lapses (Ledesma, Montes, Poó, & López-Ramón, 2015). The ARDES assumes that all drivers will eventually make attention-related errors when driving, but some are more likely to commit them compared to others (Ledesma et al., 2015). Ledesma and colleagues (2015) suggest that this likelihood of committing attention-related driving errors is a trait-like variable that should be consistent and stable for an individual.

The ARDES was originally developed for a Spanish speaking population in Argentina (Ledesma et al., 2010) but has since been validated for Spanish speakers in Spain (Roca, Padilla, López-Ramón, & Castro, 2013), Chinese (Qu, Ge, Zhang, Zhao, & Zhang, 2015) and English speakers (Barragán, Roberts, & Baldwin, 2016; Peña-Suárez et al., 2016). The scale was validated for use in an American-English speaking population, the ARDES-US (Barragán et al., 2016). The ARDES-US consists of 18 questions answered on a 5-point Likert scale (Barragán et al., 2016). The scale asks questions relating to everyday attentional lapses that occur while driving a car (Barragán et al., 2016). The scale is scored such that individuals with higher scores are more likely to make attention-related driving errors (Barragán et al., 2016). Barragán et al. (2016) reported the average ARDES-US score to be 1.58 with a standard deviation of .42. The ARDES-US has shown to have both good construct validity and reliability, as well as good convergent validity (Barragán et al., 2016).

1.16 Gaps in Literature

Despite the accidents that have occurred involving LHDs as well as the visibility issues surrounding these vehicles, there has yet to be an effective solution put forth. Specifically, methods to improve situational awareness within the mining industry have not been developed. There has been some research with mindfulness and worker safety in similar industries (Leung et al., 2016; Zhang & Wu, 2014), but it is unknown if it is applicable to the operations of mobile mining equipment and mining. While the studies by Kass et al. (2011) and Valero-Mora et al. (2015) evaluated mindfulness and driver performance, they were not conducted for occupational health and safety applications. Furthermore, neither of these studies was definitive in saying that mindfulness training improves driving performance (Kass et al., 2011; Valero-Mora et al., 2015).

However, Kass et al.(2011) did conclude that there was improved situational awareness in those that completed mindfulness training.

1.17 Research Outline

This study aims to determine if mindfulness, attention and situational awareness have any role in explaining driving performance. Driver performance in this context was defined as the "safe" operation of mobile mining equipment in a virtual reality underground mine as measured by number of collisions and reaction time to stimuli.

1.18 Hypotheses

Based on the reviewed literature, several hypotheses were formed. (Recall, that lower attention scores, as measured by ARDES-US, reflects an individual with better attention).

1. Individuals with higher mindfulness scores (as measured by MAAS) will have lower attention scores.

2. Individuals with higher mindfulness scores will have fewer collisions within the underground mining simulator, compared to individuals with lower mindfulness scores.

3. Individuals with lower attention scores will have fewer collisions within the simulator, compared to individuals with higher attention scores.

4. Individuals with higher mindfulness scores will have shorter perception-response times (as measured within the underground mining simulator) compared to individuals with lower mindfulness scores.

5. Individuals with lower attention scores will have shorter perception-response times compared (as measured within the underground mining simulator) to individuals with higher attention scores.

6. Individuals with higher mindfulness scores will answer more situational awareness questions correctly compared to individuals with lower mindfulness scores.

7. Individuals with lower attention scores will answer more situational awareness questions correctly compared to individuals with higher attention scores.

Chapter 2

2 Methodology

The primary objective of this study was to determine if individuals with higher levels of dispositional mindfulness had increased situational awareness (compared to those with lower levels of dispositional mindfulness) and how those measurements related to driving performance when operating a load-haul-dump (LHD) vehicle in a simulated underground mine. Data were collected using the Situational Awareness Mining Simulator (SAMS), the Mindfulness Attention Awareness Scale (MAAS) and the Attention-Related Driving Errors Scale (ARDES-US). The SAMS is an underground mining simulator developed at Laurentian University; it evolved from the Line of Sight Interactive Training Module (LOS-ITMo) (Eger et al., 2007).

For the purpose of this study a general overview of LHD operation in an underground mine is defined as follows:

Drift: A horizontal tunnel within an underground mine.

Load-Haul-Dump (LHD): A large bi-directional machine used in underground mining to transport ore or haul machinery.

Ore: Raw material that is mined and transported within a mine and from which minerals or metals are extracted.

Ore Pass: A vertical passage where ore is delivered and falls to a lower level within the mine.

Muck Pile: A collection of ore that has been broken apart from blasting. Large pieces of the ore are transported from here to another location.

Underground Mine: Mine consisting of drifts and shafts, below the earth’s surface, from which raw materials are extracted.

2.1 Situational Awareness Mining Simulator (SAMS)

SAMS is an underground mining simulator operated on a desktop computer. It was designed using the Unity 3D Game Engine and is operated while wearing the Oculus Rift Developer Kit 2 (DK2) headset. Wearing the Oculus Rift DK2 headset allows for the user to have a fully immersive experience. Anywhere the user turns his or her head, they will view an alternate reality; in this simulator, that reality is an underground mine. The user inputs include both foot pedals and joystick, which allow the user to navigate a typical underground machine in the simulated mine (Figure 1).

Figure 1. The Situational Awareness Mining Simulator (SAMS) operated on a desktop computer with Oculus Rift headset, joystick and foot pedals. The image on the computer monitor shows what the participant sees in the Oculus Rift headset. The virtual LHD is operated with the driver sitting perpendicular to the direction of travel; therefore, the participant has to turn his or her head to the left to see a forward driving image and to the right to see a backward driving image.

The virtual reality experience while using the SAMS is that of operating a LHD vehicle within an underground mine. The user is virtually positioned in the seat of the LHD cab and is able to see both the interior of the LHD and outside to the drifts of the mine. The purpose of the simulation is to drive the LHD from the ore pass, through the drifts of the mine to one of two muck piles to collect ore. Then the user must return the LHD to the ore pass to deliver the ore. While doing this, the operator is encouraged to avoid potential hazards within the mining environment. These hazards include Virtual Industrial Pedestrians (VIPs), Non-Playable Character Load-Haul-Dumps (NPC-LHDs) and the walls and ceilings of the mine’s drifts. During this task, the user is asked to record their earliest perception of the presence of a VIP through the use of a specific button on the joystick.

There are three different sizes of LHD vehicles that can be driven within the SAMS (Figure 2). In this study, the dimensions of the LHD used were 18.9m long, 4.7m wide and 4.2m tall. Each of these vehicle models has been designed such that it articulates along its midpoint, providing a more realistic experience of operating an LHD bi-directionally. To control the bucket of the LHD, the operator uses the joystick. The operator is required to raise, lower and adjust the angle of the bucket to successfully gather and deposit ore. Additionally, the joystick is used to steer and change the gears of the LHD. The gears include 1, 2, neutral, reverse 1 and reverse 2. The foot pedals are used for “accelerating” and “braking” within the gaming environment. While this particular aspect may not be representative of driving an actual LHD, it is consistent with passenger-vehicle driving, which allows for a university population to be used as study participants.

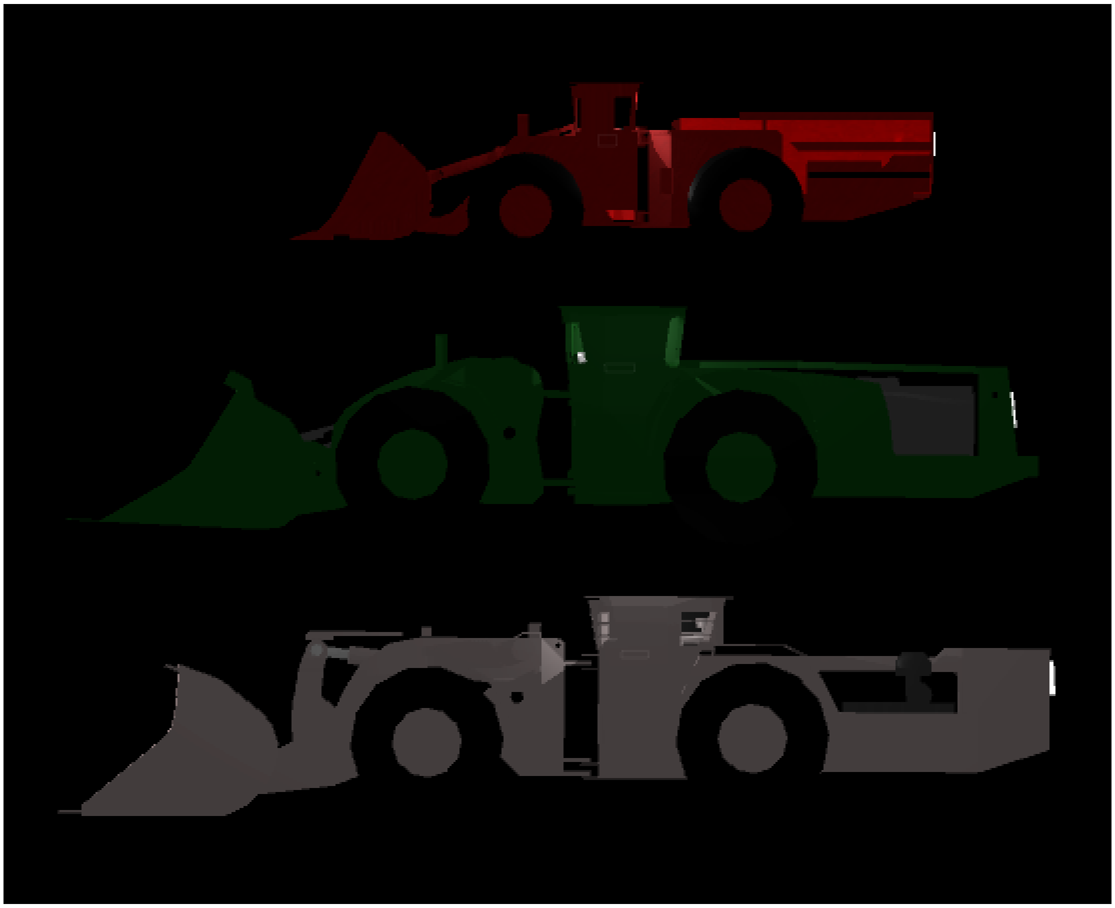


Figure 2. Load-Haul-Dump (LHD) models used within the SAMS. The top LHD is 8.3 m long, 2.7m wide and 3.3m tall. The centre LHD is 19.9m long, 5.3m wide and 4.9m tall. The bottom LHD is 18.9m long, 4.7m wide and 4.2m tall, and was the LHD used within this study.

The SAMS has been designed such that there are components within the mining environment that can be varied or controlled to create different simulation experiences. Audio of the LHD's engine could either be audible or muted. The virtual LHD has a monitor for both external rear-view and front-view cameras within the cab. When the LHD is in a forward gear, the front-view camera is enabled; while the LHD is in a reverse gear, the rear-view camera is enabled. For the duration of this study, the monitor was removed from the cab (Figure 3). When the monitor is present, it can be positioned in one of two locations: central or the left side of the cab (Figures 4 and 5). On the dashboard of the virtual LHD, the operator can see which gear the vehicle is currently in as well as the total number of collisions the vehicle has had. Whether or not the operator sees the amount of ore delivered to the ore pass can be controlled for as well. Finally, the presence of both Non-Playable Character Load-Haul-Dumps (NPC-LHDs) and Virtual Industrial Pedestrians (VIPs) can be controlled for. There can be up to three NPC-LHDs in the virtual mine, each of which has a designated location within the mine. Similarly, there can be up to five VIPs in the virtual mine. Again, each of the VIPs has a designated location. Any combination of VIPs and NPC-LHDs can be present within the virtual mine. Figure 6 illustrates the location and movement of the VIPs and NPC-LHDs within the virtual mine, as well as the layout of the mine.

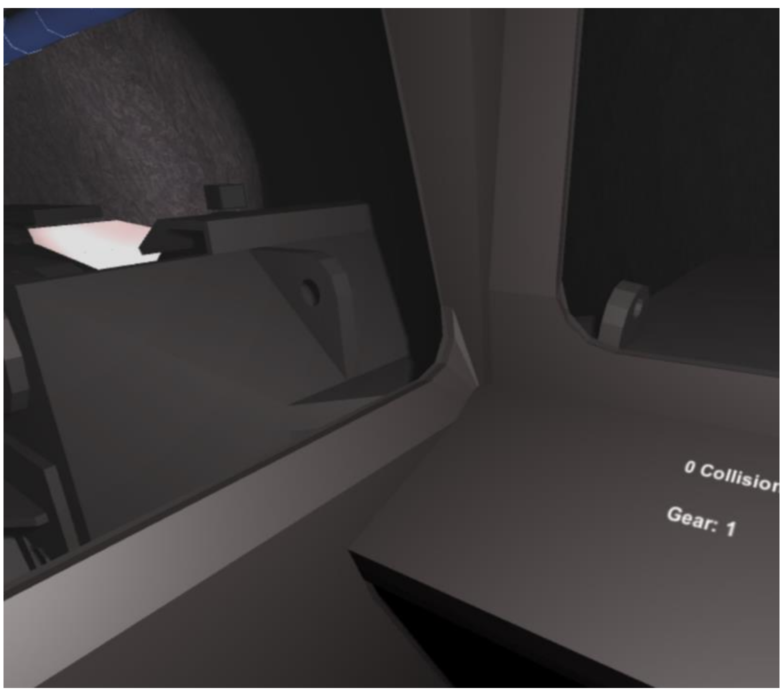


Figure 3. View inside cab of virtual LHD without camera monitor (which was the setting used within this study).

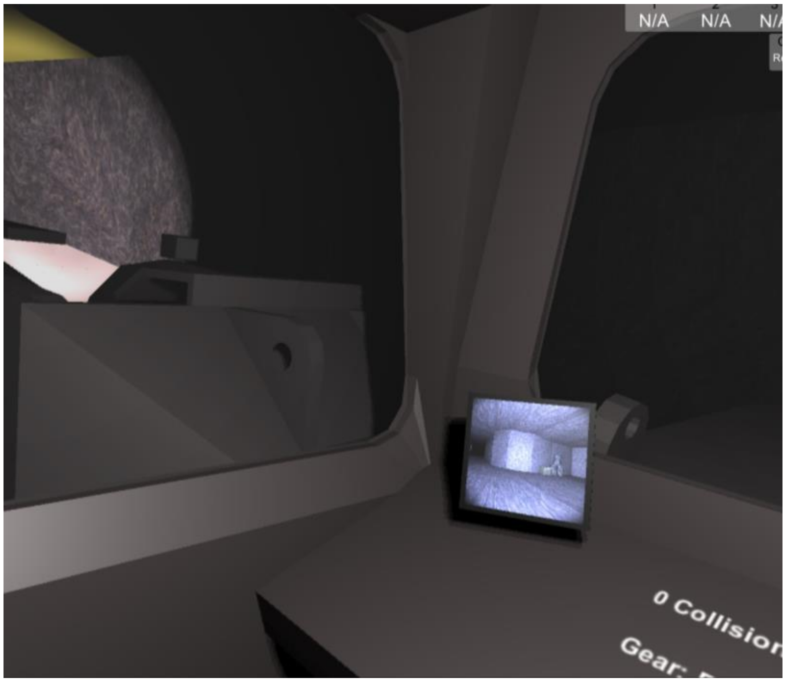


Figure 4. View inside cab of virtual LHD with camera monitor positioned centrally.

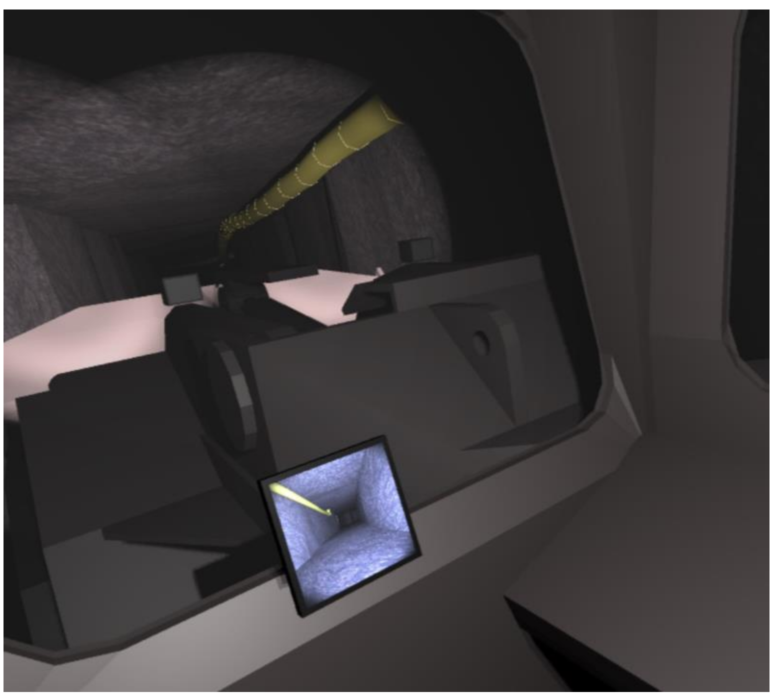


Figure 5. View inside cab of virtual LHD with camera monitor positioned on far left.

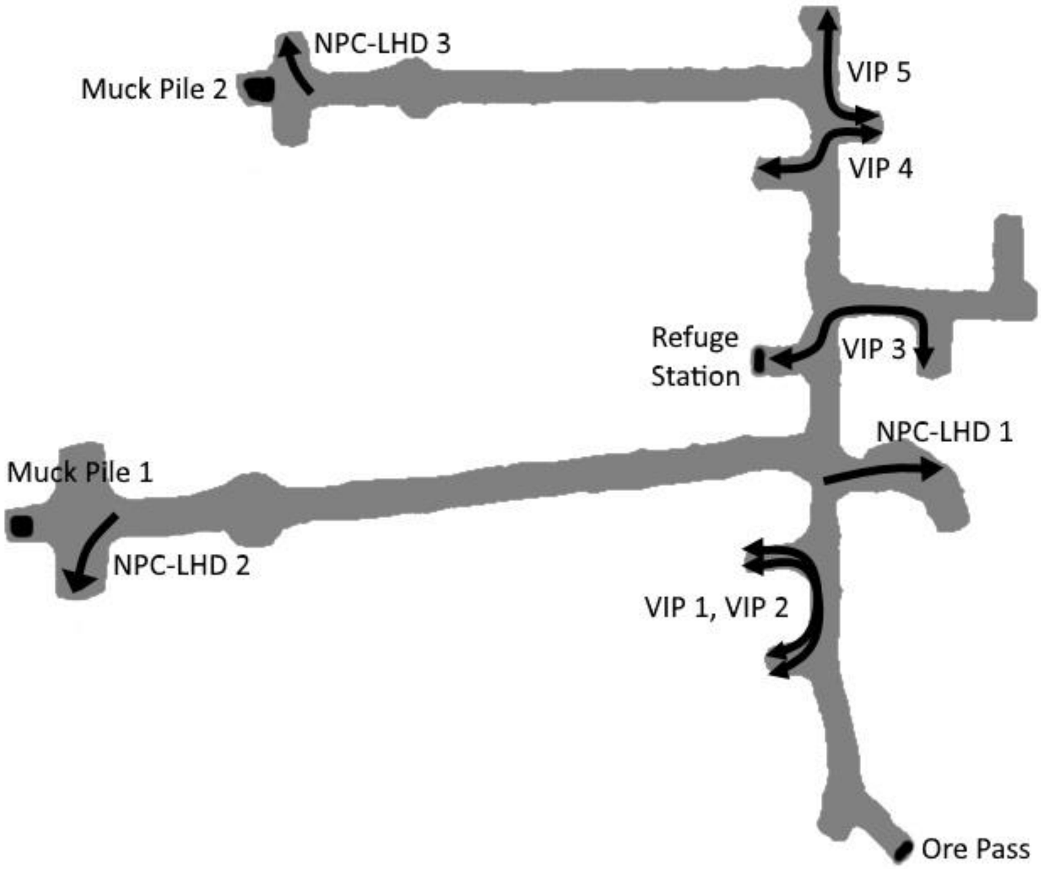


Figure 6. Layout of the virtual mine with the location and movement (as indicated by the arrows) of Virtual Industrial Pedestrians (VIPs) and Non-Playable Character Load-Haul-Dumps (NPC-LHDs).

The measurement of SA within the SAMS was based upon the SAGAT method (Endsley, 1995a; Scholtz et al., 2004). To do this, various aspects of the virtual mine have been designed to allow the researcher to change the simulated experience. These variations include presence of signage to indicate the level (or depth) of the mine; a coloured refuge station door; a broken ventilation pipe; and variable colours of the ventilation pipes. Specifically, it is Level 1 (perception) of Endsley's three stage situational awareness model (Endsley, 1995b) that can be measured within the SAMS. Thus, the modifiable items were aspects of the mine that would simply be observed while operating the simulator. It is assumed that individuals, who answer more SA questions correctly while also doing the main task of operating the simulator, have a higher innate level of situational awareness for this task.

Following the completion of each session, a data-log is produced. The information on the log is divided into three types: reactions, collisions and situational awareness questions (SAQ). Reactions occur when the participant observes and records the presence of a VIP within the VR environment, which is recorded as a perception-response time within the SAMS log. The perception is when a VIP appears within the virtual mine and there is an unobstructed LOS between the operator and the VIP. The response is when the user "tags" the VIP through a button on the joystick. Collisions are counted when the virtual LHD collides with the tunnels/drift of the virtual mine, VIPs or NPC-LHDs. The SAQ log format provides both the correct answer to and the operator's response to the questions asked. These questions will be discussed in more detail later.

The data-log provides additional information for each collision and reaction that occurs. Each reaction includes the calculated reaction time (measured in seconds), the VIP that was viewed, whether the VIP was tagged or not, camera position and rotation coordinates. The reaction time is calculated as the difference between the time at which the VIP is tagged and the time the VIP is theoretically viewed. This view time begins when there is an unobstructed line of sight (LOS) between the VIP and the head of the virtual LHD operator. For example, if the bucket of the LHD obscures the VIP from sight of the operator, then the view time does not start. The camera position and camera rotation coordinates are collected through the Oculus Rift DK2 headset. These coordinates measure where the operator's head is in 3D space and in which direction the operator's head is turned, respectively. As for the collisions, each collision provides the time the collision occurred, the hit location coordinates and the global position coordinates. The hit location is the location on the virtual LHD where the collision occurred. The global position is the location of the operator in the virtual mine when the collision occurred. The location of the collision within the virtual mine can be determined by extrapolating the values from the hit location and the global position. The data-log also provides the gear for each collision, the speed at which it occurred and the type of collision (i.e. VIP, NPC-LHD, tunnels). The camera position and rotation coordinates are provided for each collision as well, which allows researchers to determine where the user was looking when a hit occurred. None of these collision variables were explored further in this thesis work.

2.2 Procedure

This study had a sample size of 21 participants that were recruited from the Laurentian University community. A power calculation was conducted based on Kass et al.'s (2011) correlation between mindfulness and pedestrian collisions ($r = -.61$, $p < .01$). This calculation suggested a sample size of 20 individuals. While there were other correlations conducted in Kass et al.'s study, the results were either insignificant or involved measurements not used within the SAMS. Because using the Oculus Rift headset presents the risk of becoming dizzy, nauseous or faint (Oculus VR, 2014), the data collection took place over two sessions, each approximately 45 minutes in length. However, if participants experienced any of these symptoms, they were not required to continue their involvement with the study. No participants had to withdraw from the study due to these symptoms. An orientation session (Session 1) was conducted to introduce participants to the SAMS and to give each participant time to practice before the data collection trial (Session 2). Only data collected during Session 2 was analyzed. During Session 1, each participant had a tutorial and a practice trial in the SAMS; both of which will be explained later. Figure 7 provides an overview of both sessions.

Session 1
Introduction/Tutorial
Features of LHD introduced
Operation of SAMS explained (joystick, foot pedals)
Layout of virtual mine and definition of a "Trial" introduced
10-15 minutes in SAMS tutorial
Practice Trial
18.9m long LHD
No camera monitor
No VIPS or NPC-LHDs
Broken ventilations pipes: none
Mine level: no signage
Colour of refuge station door: black
Colour of ventilation pipes: all yellow
No sound

Session 2
Data Collection Trials
Review of operation of SAMS
18.9m long LHD
No camera monitor
Sounds of LHD
VIPs and NPC-LHDs present
Situational Awareness questions asked
VIPs "tagged"
Two trials conducted: Trial A and Trial B
Administration of MAAS, ARDES & Experience Questionnaire

Figure 7. Summary of the settings used within the SAMS for the tutorial, practice trial and data collection trials.

Session 1

During Session 1, the participant read and signed an informed consent form. The researcher explained that the simulator provided the virtual reality experience of operating a LHD vehicle in an underground mine. The participants were told that within the simulator they would have the view-point of the operator of an LHD. Participants were shown a model of an LHD (Figures 8) and told that while it was not identical to the LHD used within the simulator, it was quite similar. Various aspects of the vehicle were explained using the model. The researcher demonstrated how the bucket of the LHD can be raised and lowered, and how the angle of the bucket can be changed. The articulation of the vehicle was shown, as was the orientation of the LHD operator within the cab. Furthermore, the researcher explained that this orientation meant that the operator sits perpendicular to the direction of travel. The large blind spot positioned behind the operator (see Figure 8) was illustrated as well. The explanation of the LHD was similar for all participants (Appendix C).

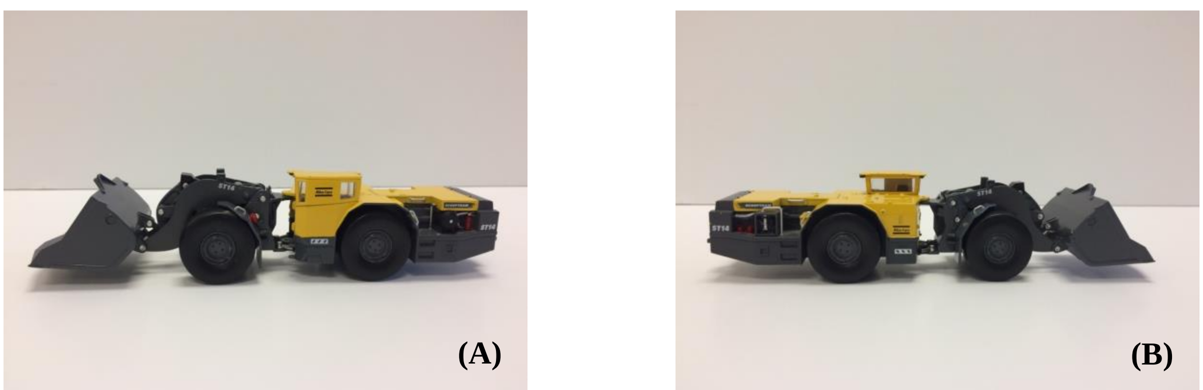
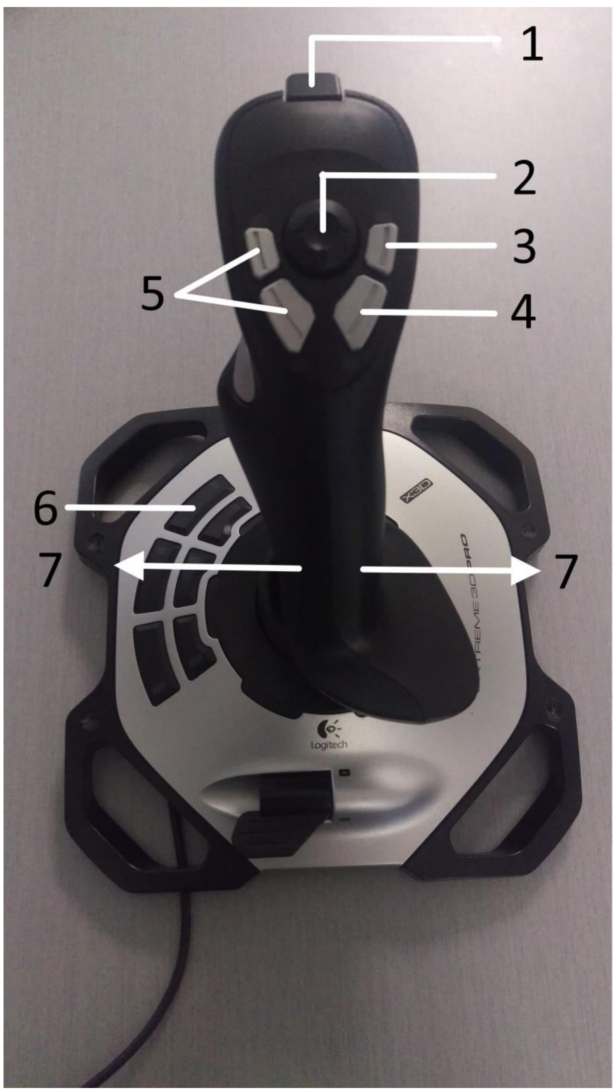


Figure 8. Model of an Atlas Copco 1:50 Scale Scooptram ST14, which was used to orientate participants to the main design and operational features of an LHD: (A) left side of vehicle (B) right side of vehicle.

Following the review of the model LHD, the participants were warned of the possible feelings of discomfort that can occur while using the Oculus Rift DK2 headset. The participants were told that if they had any feelings of discomfort, they could take a break or withdraw from the study without penalty. The researcher explained how to operate the simulator using the foot pedals and the joystick. The participants were told that the accelerator and brake of the foot pedals worked the same way as in an automatic vehicle. An image of the joystick was shown (Figure 9) and was labeled with the buttons used to operate the simulator.



1. Pedestrian Tag
2. Raise/lower arm of bucket
3. Increase gear
4. Lower gear
5. Adjust angle of bucket
6. Re-centre position in vehicle
7. Steering

Figure 9. Joystick used to operate the Situational Awareness Mining Simulator (SAMS).

Each trial within the simulator began with the LHD in the ore pass. The operator drove to each of the two muck piles to collect a load of ore and then returned to the ore pass to deposit the load of ore. A trial was complete after the second load of ore was delivered and the operator turned the LHD around. This was explained to the participants using Figure 10 to illustrate.

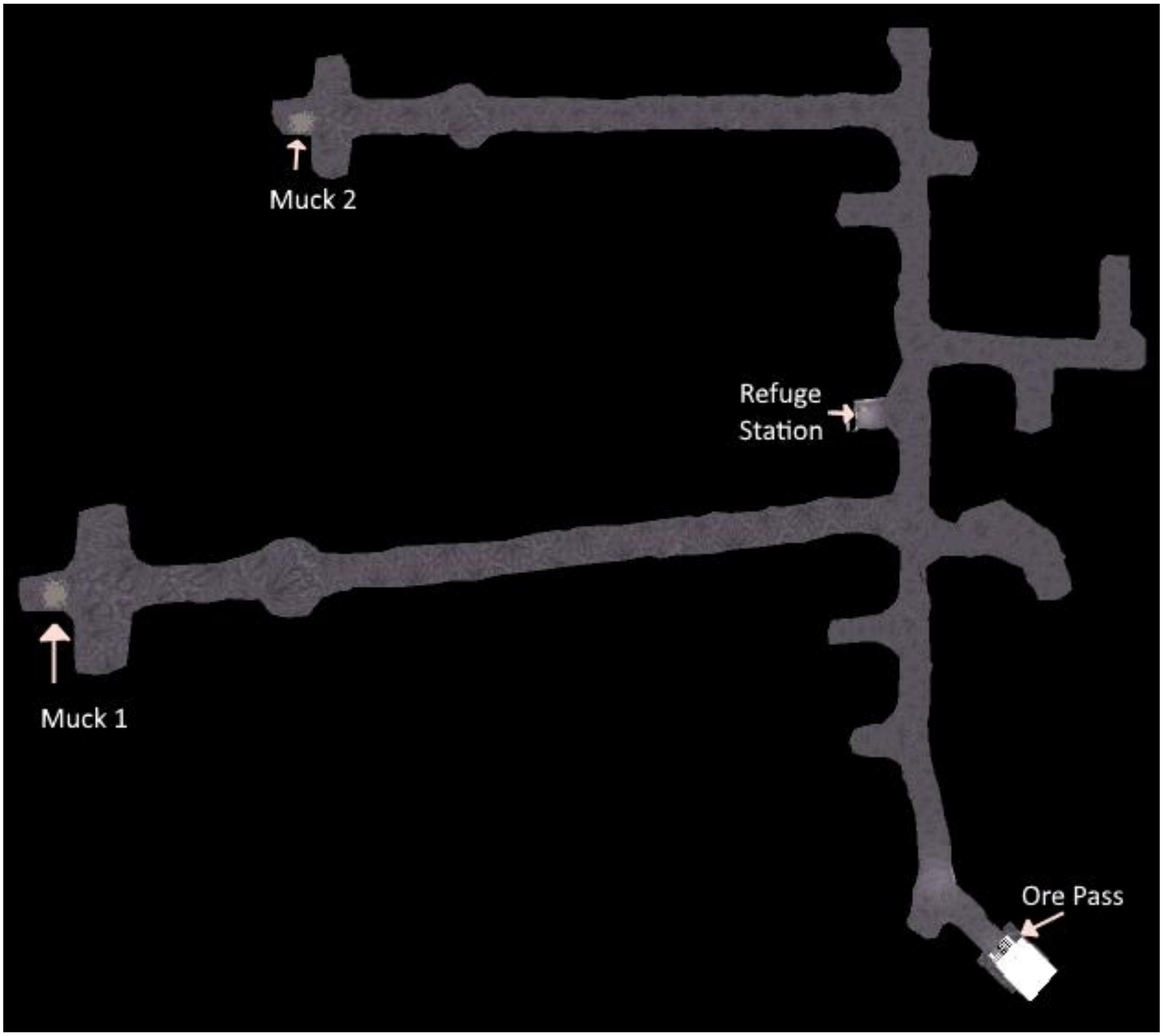


Figure 10. Layout of virtual mine illustrating the location of the ore pass, muck piles and refuge station. Each trial began with the LHD in the Ore Pass.

The participant donned the Oculus Rift DK2 headset and began the tutorial within the simulator. The tutorial reviewed how to operate the LHD using the joystick and foot pedals and gave the operator the opportunity to practice collecting and delivering ore. The tutorial was different than the trial-mode of the simulator because the operator had a view of the mine external to the LHD (Figure 11). A virtual joystick and foot pedals were viewed on the screen with each of the buttons labelled. As these controls are used, the appropriate action can be seen occurring to the LHD. The participant was then instructed to collect and deliver three loads of ore in the tutorial. The tutorial took 10 to 15 minutes to complete.

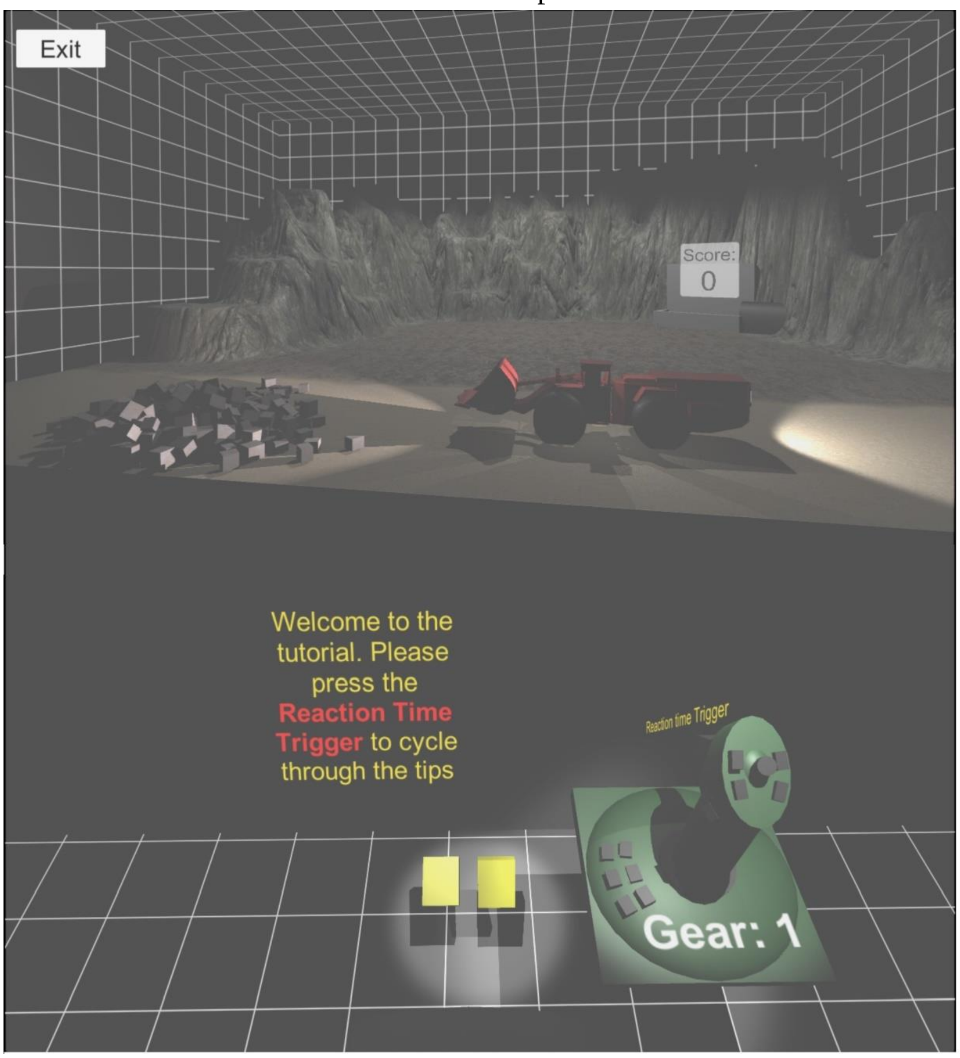


Figure 11. Screenshot of the tutorial within the Situational Awareness Mining Simulator.

Following the tutorial, the participants completed one trial within the virtual mine. They were reminded that this was only for practice and was done to familiarize them with the layout of the mine. The Practice Trial completed during Session 1 had the same settings applied for each participant within the simulator (Figure 7). These settings included driving the 18.9m long LHD with no camera monitor, and the ability to see the total number of collisions the LHD had but not how much ore it had delivered. There were no VIPs, NPC-LHDs or broken ventilation pipes within the virtual mine, nor was there any sound provided by the simulator. Also, all of the ventilation pipes were yellow, there was no signage for the mine level and the door of the refuge station was black. This trial took approximately 15 to 20 minutes to complete. When the Practice Trial was complete, that concluded Session 1.

Session 2

Due to the schedules of both the participants and the researcher, Session 2 took place on either the same day as Session 1 or on a different day. Thus the time between Session 1 and Session ranged between three hours and five days. Session 2 began with a review of the joystick's controls, and participants were told that similarly to Session 1, they would be driving the LHD through the virtual mine to collect ore and deliver it to the ore pass. However, there would be some differences, including the presence of pedestrians (VIPs) that needed to be tagged (perception-response time) and other vehicles (NPC-LHDs) in the mine that needed to be avoided. The participants were instructed to press the appropriate button on the joystick as soon as they saw a VIP in the mining environment, thus "tagging" the VIP. The participants were told that during each of the two trials, the researcher would pause the simulator and ask the participant a few questions before returning to the simulator. These questions were used to measure situational awareness of the individual with the SAMS, but this was not explained as such to the participants. Finally, the participant wore headphones which provided sounds of the LHD vehicle for more realism.

During the two trials of data collection, the researcher monitored what each participant was seeing (as presented by the Oculus Rift headset) and doing on a separate computer monitor. Note, the Oculus Rift DK2 headset provided a three-dimensional image for the user; however only a two-dimensional image (left lens of the Oculus Rift DK2 headset) was viewed on the separate computer monitor by the researcher. The software Nividia ShadowPlay was used to screen-capture video for each of the trials. The video was later used to confirm reaction time for the “missed” VIPs. Once the view time began, the participant had 20 seconds to tag the VIP using the appropriate button on the joystick. If the VIP was not tagged within 20 seconds it was marked as a “missed” VIP.

There were two pre-selected settings in the simulator used as trials: A or B. Each participant completed both Trial A and B and the order of completion was randomized. The components of the virtual mine that varied in Trials A and B are detailed in Table 1. When the situational awareness questions (SAQ) were asked, the simulator was paused at approximately the same location in the mine for each participant. One of these locations was when the LHD was in the tunnel between muck pile 1 and the mine’s main tunnel during its return trip to the ore pass (Figure 12). The simulation was paused at this location for the first set of SAQ in Trial A and for the second set of SAQ during Trial B. The second location was when the LHD had driven past the refuge station on return from muck pile 2 and was returning to the ore pass. The simulator was paused at this location for the first set of SAQ in Trial B and for the second set of SAQ during Trial A. In total, there were six SAQ that were asked; however, not every question was asked during each round of questioning (Table 2). The completion of both Trials A and B took approximately 20 to 30 minutes.

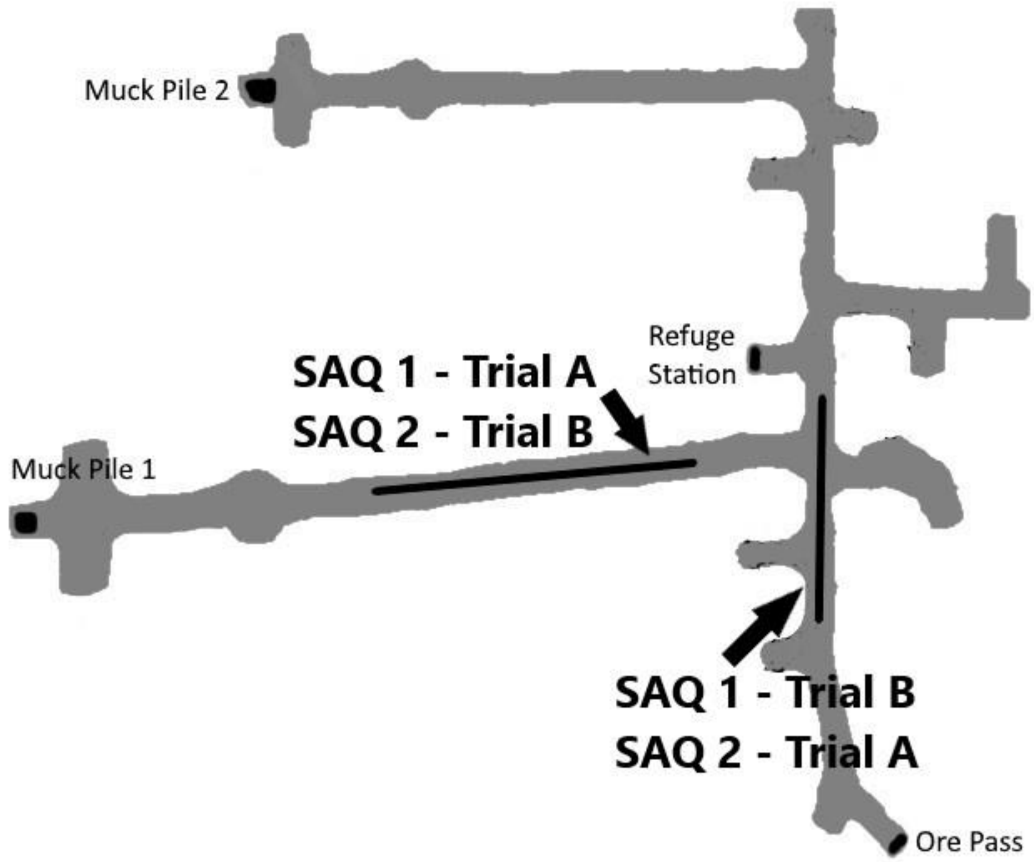


Figure 12. The approximate location of the LHD within the virtual mine when the simulation was paused to ask Situational Awareness Questions (SAQ) is indicated by the black lines.

Table 1. Settings within the SAMS for Trial A and Trial B.

Settings	Trial A	Trial B
VIPs present	1, 3, 4, 5	1, 2, 3, 4, 5
NPC-LHDs present	1, 3	1, 2, 3
First load of ore	Muck 1	Muck 2
Refuge station door colour	Orange	Green
Mine level	8400	4030
Location of broken ventilation pipe	Muck 1	Muck 2
Ventilation pipe colours (Main tunnel, Muck 1 tunnel, Muck 2 tunnel, respectively)	Blue, Yellow, Pink	Yellow, Pink, Blue

Table 2. Situational Awareness Questions (SAQ). "X" denotes the question being asked during the round of questioning.

Question	Trial A Round 1	Trial A Round 2	Trial B Round 1	Trial B Round 2
1. There was signage in the mine labelling the level or depth of the mine. What was that level?	X		X	
2. What colour is the refuge station door?		X	X	
3. How many collisions has the vehicle had?	X	X	X	X
4. What gear is the vehicle currently in?	X	X	X	X
5. What colour is the ventilation pipe in the main drift of the mine?	X			X
6. There is a broken ventilation pipe in the mine. Heading to which muck pile is this broken pipe?		X		X

Following the use of the simulator, the participants completed the Mindfulness Attention and Awareness Scale (MAAS), the Attention-Related Driving Errors Scale (ARDES-US) and a custom, experience questionnaire (Appendices D, E, and F). They were asked to read the instructions for each section and read each question carefully. The scales and questionnaire took approximately 10 to 15 minutes to complete. Once done, that concluded the participant's involvement in the study.

2.3 Data Analysis

2.3.1 Collisions

For each participant, the total number of collisions incurred per trial was tallied. Recall, collisions were defined as when the virtual LHD collided with the tunnels/drift of the virtual mine, VIPs or NPC-LHDs.

2.3.2 Perception-Response Time

For the calculated perception-response times for each participant, the "missed" VIPs were removed and analyzed separately. This was done because all of the "missed" VIPs had a perception-response time of 20 seconds. Including these responses would not accurately reflect a participant's true perception-response time. The remaining perception-response times, which were measured in seconds, were averaged per trial per participant.

"Missed" VIPs were ones which were not tagged within 20 seconds by the participant. For each of the "missed" VIPs, the screen-capture video was reviewed using either Kinovea video player or VLC media player. Reviewing the video allowed the "missed" VIPs to be sorted into one of two categories: unseen or untagged. The first type, unseen VIPs were not visible to the participant and thus were not tagged. Unseen VIPs occurred if the VIP appeared alongside the shadows of the virtual LHD, in the shadows of the virtual mine or if the VIP was too small to be seen in the distance on screen. As described previously, the view time programmed into the SAMS software begins when there is an unobstructed line of sight between the VIP and the participant in the virtual LHD. Thus the view time could begin when the VIP was only a few pixels in size and not easily visible to the human eye. The second type were untagged VIPs and were both visible and seen by the participant but they were not tagged. These untagged VIPs were further analyzed.

For each participant, the fraction of untagged VIPs was calculated by dividing the number of untagged VIPs by the total number of VIPs encountered (VIPs with a recorded perception-response time plus untagged VIPs). This was done for each of the two trials as well as the sum of encountered and tagged VIPs between both trials.

2.3.3 Situational Awareness Questions

When scoring the situational awareness questions, a binary approach was used; answers were scored as either correct or incorrect. The proportion of questions answered correctly per participant per trial was calculated, as was the proportion of correct answers per each question across all participants.

2.4 Statistical Analysis

Data were analyzed using IBM SPSS v22.0 and for each test, the level of significance was set to $p < .05$. The Shapiro-Wilk test was used to test data for normality. Normal data were analyzed using the appropriate parametric test, while non-normal data were analyzed using the coinciding non-parametric test. Furthermore, non-parametric tests were also used when the assumptions required to use a parametric test were not met.

2.4.1 Spearman's Correlations

Spearman's correlations were conducted to determine if there were any linear relationships between the measured variables. Pearson's correlations were not used because no two variables compared were both normally distributed.

2.4.2 Learning Effects of Using SAMS

The Wilcoxon signed-rank test was used to determine if there was a significant difference between the total number of collisions the participants incurred between the first and second trials. Because no assumptions were violated, the paired t-test (instead of the Wilcoxon signed-rank test) was used to determine if there was any significant difference between the number of collisions in the Practice Trial and Trial 1 and between the Practice Trial and Trial 2. The Wilcoxon signed-rank test was used to determine if there was a significant difference in perception-response time between Trial 1 and Trial 2. Again, the Wilcoxon signed-rank test was used to determine if there was a significant difference in the number of untagged VIPs between the two trials. Finally, the paired t-test was used to determine if there was a significant difference in the total number of situational awareness questions answered correctly between Trial 1 and Trial 2.

Comparing the differences between trials may suggest the presence of a learning effect within the SAMS, which will be further discussed in Chapter 4. Furthermore, for Trial 1 and Trial 2, if no significant difference was present, it allowed for the trials to be averaged together for other analyses (i.e. Spearman's correlations).

2.5 Exploratory Analysis

The sample size for this study was too small to use the Chi-Squared test so instead, the Mann-Whitney U test was used. This is because the Mann-Whitney test allows for categorical variables to be compared against continuous variables. While many of the variables collected were measured along a continuous scale, it was possible to group the data, such that it became categorical (i.e. high and low scores on MAAS). Furthermore, the results from the Mann-Whitney test sought to reveal if there were any other relationships present amongst the variables that Spearman's correlations could not reveal. Conducting the Mann-Whitney U test requires that the two groups being compared have approximately the same shape of distribution. In all of the distributions that were compared, this assumption was violated and thus, the test could only compare the differences between the mean ranks of the compared groups and not the differences between medians.

2.5.1 Mindfulness

Mindfulness was categorized as either "high mindfulness" or "low mindfulness" based on the MAAS scores. A median split of the data was done to divide MAAS scores into high and low categories. Scores above the 50^{th} percentile were considered high scores, while scores below the 50^{th} percentile were considered low scores (Grinnell, Greene, Melanson, Blissmer, & Lofgren, 2011; Seear & Vella-Brodrick, 2013).

Next, to evaluate only the extremes of mindfulness, MAAS scores were split into quartiles (Loucks, Britton, Howe, Eaton, & Buka, 2015). The highest 25% of scores were categorized as "high mindfulness" and the lowest 25% of scores were categorized as "low mindfulness". The remaining scores in the middle were excluded from the analysis. Thus, there were five subjects in each of the two categories.

2.5.2 Attention

To evaluate only the extremes of attention, the ARDES-US scores were considered. There was no literature to support the division of ARDES-US scores to further evaluate possible relationships amongst other variables. However, similar to the divisions of the mindfulness scores, a median split was done, dividing the ARDES-US scores into high and low attention scores. Recall that the ARDES-US is reverse scored, with higher scores reflecting individuals more likely of committing a driver-related error due to an attentional failure, while the reverse is true for lower scores. Thus, scores below the 50^{th} percentile were "high attention", while scores above the 50^{th} percentile were "low attention".

Furthermore, the ARDES-US scores were divided into quartiles to evaluate the most extreme values. The highest 25% of scores were categorized as "low attention" and the lowest 25% of scores were categorized as "high attention". The remaining scores in the middle were excluded from the analysis. Thus, there were five subjects in each of the two groupings.

2.5.3 Situational Awareness

To evaluate if there were any present relationships amongst the extremes of situational awareness, SA was categorized as either high SA or low SA. High SA was scored as such when participants answered 75% or more of the SAQ correctly. This cutoff was chosen by the researcher based on the G1 written road test in the Province of Ontario, which requires a minimum of 80% to pass (DriveTest, 2017). Thus, low SA awareness was scored as such when participants answered fewer than 75% of the SAQ correctly. SA was evaluated for Trial 1 and Trial 2 separately.

2.5.4 Sex

Sex was used to determine if being male or female resulted in a relationship amongst the dependent variables. The data was from the self-reported information provided by the Experience Questionnaire.

Chapter 3

3.1 Demographics

Of the 21 individuals in the study, 10 participants were male, 10 participants were female and 1 participant did not disclose their sex. The age of the participants ranged from 19 to 35 years (*M* = 24.3, *SD* = 3.7). All participants had experience driving a vehicle, with a range of 1.5 to 20 years (*M* = 6.98, *SD* = 4.1). Only two of the 21 participants reported having no prior experience with video gaming. The 19 participants with prior video gaming experience had a range of experience of one to 17 years (*M* = 11.4, *SD* = 5.4). Four participants reported practicing mindfulness for a minimum of one hour per week.

Across all participants in both of the trials, there were a total of 718 encounters with VIPs. Of these, 80% (575) of these VIP encounters were tagged. There were a total of 143 “missed” VIPs; 93 unseen VIPs and 50 untagged VIPs. This reflected 13% and 7%, respectively, of the total VIP encounters.

Descriptive statistics for driver performance variables as well as demographics are reported in Table 3.

Table 3. Descriptive Statistics for variables used in the study.

Variable	**Mean**	**Standard Deviation**	**Standard Error of Mean**	**Median**	**Sample size (n)**
Average Collisions	14.2	8.56	1.87	10.5	21
Collisions (Trial 1)	16.1	11.7	2.56	12.0	21
Collisions (Trial 2)	12.2	11.4	2.48	9.00	21
Practice Collisions	29.3	19.3	4.22	24.0	21
Average PRT (sec)	3.03	1.05	.228	3.02	21
PRT (Trial 1) (sec)	3.32	1.62	.352	3.00	21
PRT (Trial 2) (sec)	2.73	1.23	.269	2.29	21
MAAS	3.73	.769	.168	3.87	21
ARDES-US	1.71	.445	.099	1.67	20
Age (as of July 1, 2017)	24.3	3.70	.826	23.9	20
Gaming Experience (years)	11.4	5.36	1.23	13.0	19
Driving Experience (years)	6.98	4.06	.886	7.00	21
Proportion Correct SAQ (Trial 1)	.688	.175	.038	.625	21
Proportion Correct SAQ (Trial 2)	.868	.128	.028	.875	21
Proportion Untagged VIPs (Trial 1)	.081	.095	.021	.050	21
Proportion Untagged VIPs (Trial 2)	.060	.063	.014	.067	21
Proportion Untagged VIPs (Total)	.085	.087	.019	.067	21

3.2 Results – Spearman's Correlations

Spearman's correlations were conducted to determine if there were any linear relationships between the variables (Table 4, Appendix G). While there were numerous correlations that reached significance, not all of these correlations were meaningful (e.g. correlation between average perception-response time and perception-response time in Trial 1).

Table 4. Significant Spearman's correlations between analyzed variables. All listed correlations met p < .05 level of significance. * denotes p < .01.

Variable 1	**Variable 2**	**Spearman's Coefficient**
MAAS	ARDES-US	-.516
MAAS	Proportion Correct SAQ (Trial 2)	.434
Collisions (Trial 1)	Proportion Correct SAQ (Trial 1)	-.507
Collisions (Trial 1)	PRT (Trial 1)	.449
Practice Collisions	Average PRT	.496
Practice Collisions	PRT (Trial 1)	.485
PRT (Trial 1)	Proportion Untagged VIPs (Trial 1)	.536
PRT (Trial 2)	Proportion Untagged VIPs (Trial 2)	.478
Average PRT	Proportion Untagged VIPs (Total)	.573*
Age	Driving Experience	.773*
Gaming Experience	Average Collisions	-.509
Gaming Experience	Collisions Trial 1	-.544
Driving Experience	Average Collisions	-.511
Driving Experience	Collisions Trial 2	-.435
Sex	Practice Collisions	.513
Sex	Gaming Experience	-.574

There was a significant negative correlation between MAAS and ARDES-US scores ($r = -.516$, $p < .05$). Recall that high MAAS scores indicate higher mindfulness, while low ARDES-US scores indicate higher attention levels. The correlation between MAAS scores and collision frequency was not significant, nor was the correlation between ARDES-US scores and collision frequency. Furthermore, neither the correlations between MAAS scores and perception-response time, nor ARDES-US scores and perception-response time were significant.

There was a significant positive relationship between MAAS scores and the proportion of SA questions answered correctly in Trial 2 ($r = .434$, $p < .05$). This same relationship was not significant in Trial 1 ($r = .012$, $p = .959$). Furthermore, there was no significant correlation between ARDES-US scores and the proportion of SA questions answered correctly. There were no other significant relationships between MAAS scores, nor ARDES-US scores and the other variables. However, there was a significant, negative relationship between the number of collisions and the proportion of SA questions answered correctly in Trial 1 ($r = -.507$, $p < .05$). This same relationship was not present in Trial 2 ($r = -.126$, $p = .587$).

There was a significant, positive relationship between collisions in Trial 1 and perception-response time in Trial 1 ($r = .449$, $p < .05$). This same correlation was not significant between collisions and perception-response time in Trial 2 ($r = -.049$, $p = .833$) (Figure 13). There was a significant, positive correlation between the number of collisions in the Practice Trial and the averaged perception-response time across Trials 1 and 2 ($r = .496$, $p < .05$), as well as between collisions in the Practice Trial and perception-response time in Trial 1 ($r = .485$, $p < .05$).

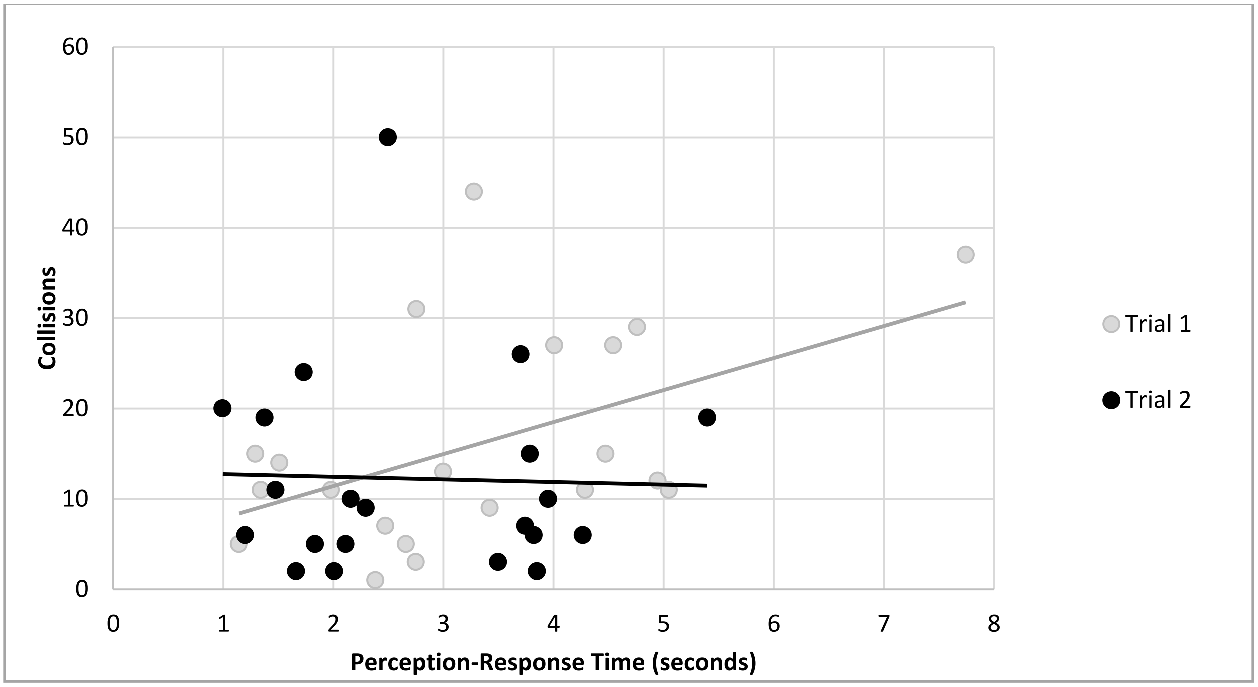


Figure 13. Number of collisions as a function of perception-response time plotted for Trial 1 and Trial 2. Trend lines indicate correlation between the variables.

In Trial 1, perception-response time was positively correlated with the proportion of untagged VIPs (r = .536, p < .05). Again, in Trial 2, perception-response time was correlated with the proportion of untagged VIPs (r = .478, p = .05). Similarly, there was a significant positive correlation between perception-response time averaged across Trials 1 and 2 and the total number of untagged VIPs (r = .573, p < .01).

As expected there was a significant relationship between age and years of driving experience (r = .773, p < .01). Correlational data revealed there was a significant negative relationship between an individual's years of gaming experience and the average number of collisions across Trials 1 and 2 (r = -.509, p < .05), as well as the number of collisions in Trial 1 (r = -.544, p < .05) but not in Trial 2. Similarly, there was a significant correlation between years of driving experience and the average number of collisions across both trials (*r* = -.511, *p* < .05), and the number of collisions in Trial 2 (*r* = -.435, *p* < .05). There was a significant relationship between sex and the number of collisions incurred during the Practice Trial (r = .513, p < .05), with females having a greater number of collisions. This relationship was no longer present during Trial 1 and Trial 2. There was also a negative relationship between sex and gaming experience (r = -.574, p < .05), with males having more gaming experience.

3.3 Results – Learning Effect

The Wilcoxon signed-rank test revealed there was no significant difference in the total number of collisions in Trial 1 (*Mdn* = 12) compared to the total number of collisions in Trial 2 (*Mdn* = 9), *z* = -1.74, *p* = .082. Because there was no significant difference, this allowed the two separate trials to be averaged together for further analysis. A paired t-test indicated that the number of collisions within Trial 1 (*M* = 16.10, *SD* = 11.7) was significantly lower than in the Practice Trial (*M* = 29.3, *SD* = 19.3), *t*(20) = -2.99, *p* < .01, *d* = .65. There was a statistically significant mean decrease of 13.3, 95% CI [4.00, 22.5] in the total number of collisions between the Practice Trial and Trial 1. A paired t-test indicated that the number of collisions within Trial 2 (*M* = 12.2, *SD* = 11.4) was significantly lower than the Practice Trial (*M* = 29.3, *SD* = 19.3), *t*(20), = -3.62, *p* < .01, *d* = .79. There was a statistically significant mean decrease of 17.1, 95% CI [7.24, 27.0] in the total number of collisions between the Practice Trial and Trial 2. Recall that paired t-tests were conducted because no assumptions of the test were violated.

The Wilcoxon signed-rank test also determined that there was no significant difference in the perception-response times in Trial 1 (*Mdn* = 3.00) compared to Trial 2 (*Mdn* = 2.29), *z* = .78, *p* = .43. Again, because there was no significant difference, this allowed Trial 1 and Trial 2 to be averaged together for additional analysis. It was also determined by the Wilcoxon signed-rank test that there was no significant difference between the number of untagged VIPs in Trial 1 (*Mdn* = .050) and the number of untagged VIPs in Trial 2 (*Mdn* = .067), z = -.659, p - .510. Similarly, this allowed the total number of untagged VIPs across both trials to be considered as a summed value.

A paired t-test revealed there was a significant difference in the proportion of correct SA questions answered by participants between Trial 1 and Trial 2 (Figure 14). The total number of SA questions answered correctly was higher during the second trial (M = .87, SD = .13) than during the first trial (M = .69, SD = .17); a statistically significant mean increase of .18, 95% CI [0.069, 0.29], $t(20) = 3.39$, $p < .05$, d = .74.

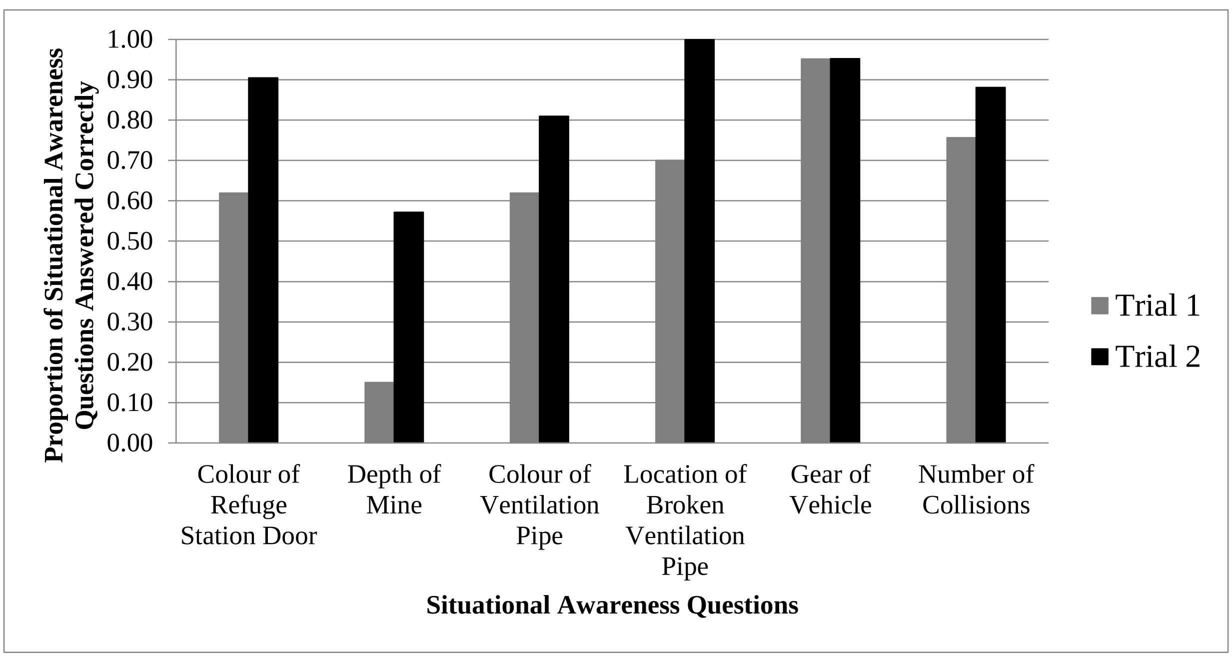


Figure 14. Proportion of situational awareness questions answered correctly across all participants in both trials.

3.4 Results – Exploratory Analysis

3.4.1 Mindfulness

The Mann-Whitney U test revealed there was a difference in the mean rank of ARDES-US scores and MAAS scores when MAAS scores were divided at the median. Specifically, the mean rank ARDES-US scores for high mindfulness (*mean rank* = 7.73) was significantly lower than the mean rank ARDES-US scores for low mindfulness (*mean rank* = 13.89), $U = 19.0$, $z = -2.32$, $p = .02$. For the remaining dependent variables of age, years gaming, years driving, the average number of collisions, the average perception-response time and the proportion of SAQ answered correctly in Trials 1 and 2, there was no significant difference between those defined as having low versus high mindfulness.

Similarly, the Mann-Whitney U test revealed a difference in the mean rank of ARDES-US scores and MAAS scores when the highest 25% and lowest 25% of MAAS scores were evaluated. The mean rank ARDES-US scores for the lowest 25% of MAAS scores (*mean rank* = 7.60) was significantly higher than the mean rank ARDES-US scores for the highest 25% of MAAS scores (*mean rank* = 3.40), $U = 2.00$, $z = -2.20$, $p = .032$. Furthermore, the mean rank scores for perception-response time were significantly different when compared to the divided MAAS scores (Figure 15). The perception-response time for the lowest 25% of MAAS scores (*mean rank* = 7.80 was significantly higher than the perception-response time for the highest 25% of MAAS scores (*mean rank* = 3.20), $U = 1.00$, $z = -2.40$, $p = .016$. There were no other significant differences amongst the remaining dependent variables that were measured.

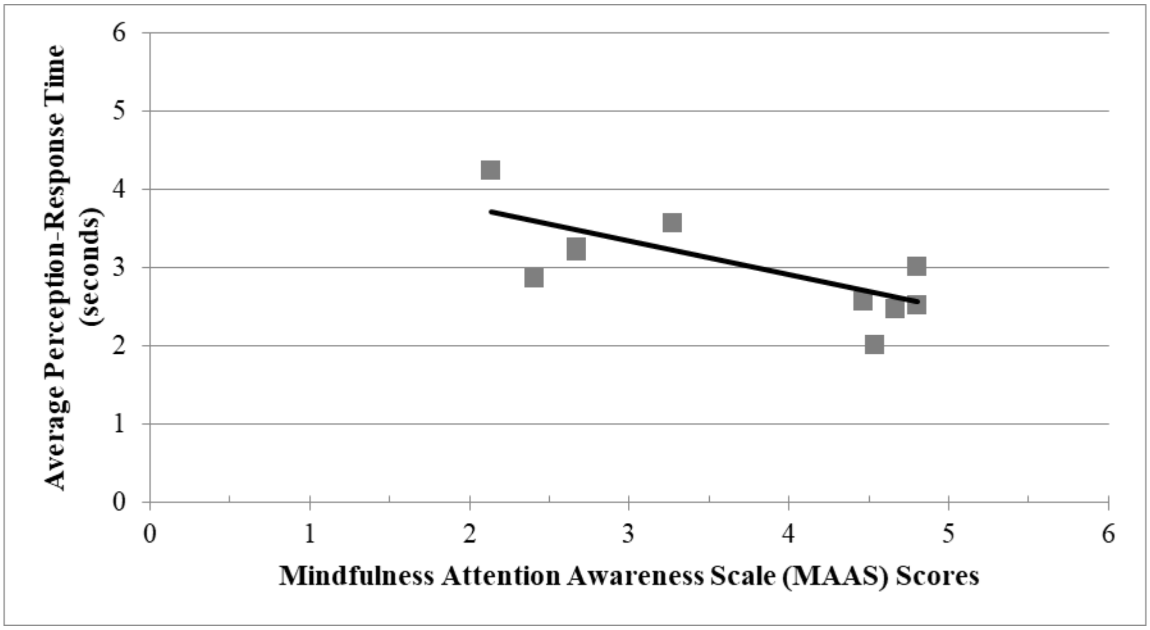


Figure 15. Average perception-response time (in seconds) as a function of Mindfulness Attention Awareness Scale (MAAS) scores for the highest 25% and lowest 25% of mindfulness scores (n = 10). Trend line indicates average perception-response time across all participants (n = 21).

3.4.2 Attention

The Mann-Whitney U test did not reveal any interesting findings when evaluating the median and quartile division of ARDES-US scores.

3.4.3 Situational Awareness

The Mann-Whitney U test did not reveal any significant findings when evaluating high and low levels of SA across both Trials 1 and 2.

3.4.4 Sex

The Mann-Whitney U test results indicated a significant difference in mean rank in gaming experience when scores were divided by sex. The years of gaming experience for males (*mean rank* = 12.81) was significantly higher than for females (*mean rank* = 6.85), $U = 13.5$, $z = -2.37$, $p = .016$. The remaining dependent variables did not reveal any significant findings.

Chapter 4

4.1 Discussion

This study sought to determine the presence of a relationship between driver performance measured in a mining simulator and measures of mindfulness, attention and situational awareness. The main findings did not support the theory of a linear relationship between mindfulness and driver performance in this study because of the absence of a significant correlation between the two variables. However, there was evidence to suggest a relationship between mindfulness and situational awareness, as well as situational awareness and driving performance. These results will be further discussed.

Variables Related to Mindfulness, Attention, Situational Awareness and Driving Performance

As was hypothesized, there was a negative correlation between Mindfulness Attention Awareness Scale (MAAS) scores and Attention-Related Driving Errors Scale-US (ARDES-US) scores. Recall that the MAAS is scored such that higher scores indicate an individual with higher trait mindfulness, while the ARDES-US is scored such that higher scores indicate an individual is more likely of committing a driver-related error due to attentional failure. Thus, the participants with higher mindfulness scores (as measured by the MAAS) had lower attention scores (as measured by the ARDES-US). These results support previous research by Barragán et al. (2016) and Valero-Mora et al. (2015). Furthermore, the average MAAS score for this sample ($M = 3.73$, $SD = .769$) was similar to the average MAAS score measured in 14 samples of college students ($M = 3.8$, $SD = .7$) (Brown, n.d.). In this sample, the average score for the ARDES-US ($M = 1.71$; $SD = .445$) was similar to those reported by Barragán and colleagues (2016) ($M = 1.58$, $SD = .42$).

It was hypothesized that individuals with higher MAAS scores would have faster perception-response times and a smaller number of collisions. The results from Spearman's correlation did not support these hypotheses because the relationship between mindfulness with the measures of driving performance was not significant. However, when evaluating the highest and lowest 25% of MAAS scores with the Mann-Whitney U test, the mean rank of the perception-response times for the lowest 25% of MAAS scores was significantly higher than the mean rank of the perception-response times for the highest 25% of MAAS scores (Figure 15). While this relationship is interesting, it must be noted the relationship was found between the mean ranks and not the median of the scores on a reduced proportion of the dataset, and thus, is not as powerful a relationship. Regardless, this result suggests that future research should explore the extremes of mindfulness and its relationship to perception-response time.

Furthermore, the presence of the positive correlation between perception-response time and number of untagged VIPs suggests that those who are slow to respond to their environment also fail to tag VIPs entirely. This relationship was present in Trials 1 and 2 and amongst the averaged trials. Intuitively, this relationship makes sense because those with slower perception-response times may take longer to register the presence of a VIP and therefore, miss the opportunity to tag the VIP within the allotted 20 seconds. This relationship could not definitively be linked to innate levels of mindfulness.

There was a positive correlation between perception-response time and the number of collisions in Trial 1, suggesting that those with fewer collisions had faster perception-response times. This correlation disappeared during Trial 2 and when compared to both trials averaged together. Recall that statistically, there was no significant difference in the number of collisions or the perception-response time between Trial 1 and Trial 2. However, when the thesis data were plotted (Figure 13), visually there appears to be a decrease in the number of collisions from the first to second trial but the perception-response time appears relatively unchanged. This suggests that perception-response time is more robust to the learning curve of operating in the simulator. Since perception-response time was reasonably static throughout the test session, it is possible that the decrease in collisions (while insignificant) is driving the relationship in Trial 2. Additionally, in Trial 2, there appear to be two distinct groupings of perception-response times around 2 seconds and 4 seconds, although the significance of this observation was not fully explored. Overall, we cannot conclude that those with faster perception-response times have a reduced number of collisions. Either or both variables may not be adequately describing operator performance in the simulator.

This work hypothesized that higher mindfulness, as measured by MAAS, would be connected to faster perception-response times. Interestingly, when the MAAS scores were in numerical order, the highest MAAS scores were not associated with the slowest perception-response times. Conversely, the lowest MAAS scores were not associated with the fastest perception-response times. Instead, the fastest and slowest perception-response times tended to be associated with more mid-range MAAS scores. These associations were noted through visual inspection of the data, and the lack of significant correlation between MAAS and perception-response time. With a sample size of 21 individuals and a narrow range of MAAS scores, any non-linear regression would most likely not yield any significant relationship. We can conclude that the mindfulness variable quantified by MAAS may not play a meaningful role in our mining simulator performance. A second questionnaire, the Mindfulness Questionnaire, that claims to measure another construct of mindfulness has been reported in the literature (Mikulas, 1990, as cited in Kass et al., 2011), and may be worth exploring for future work in this area.

There was a significant difference in the number of situational awareness questions answered correctly between Trial 1 and Trial 2. During Trial 1, approximately 69% of the questions were answered correctly, compared to Trial 2, where nearly 87% of the questions were answered correctly. This suggests that participants became cued to the external environment (of the virtual mine) and that by simply asking individuals about their surroundings they begin to pay more attention to the specific variables about which they were questioned.

While this next relationship was not hypothesized, its occurrence is relevant. There was a negative correlation between collisions and the proportion of SAQ answered correctly in Trial 1. Individuals that were more aware of their surroundings, as measured by SAQ scores, incurred fewer collisions while operating the virtual LHD. However, this relationship was not present between the same variables in Trial 2. Perhaps, individuals that innately have higher levels of situational awareness had fewer collisions in Trial 1 compared to individuals with innately lower levels. By this, it is meant that individuals whom were only able to answer a SAQ correctly after being exposed to both the SAQ and the situation would be considered to have a lower innate level of situational awareness. It was hypothesized that individuals with higher mindfulness scores would answer more situational awareness questions (SAQ) correctly at any point in the trials. This relationship was only significant in Trial 2 with individuals with higher MAAS scores answering more SAQ correctly. This supports the research by Kass and colleagues (2011) that reported a positive relationship between mindfulness and situational awareness. Recall that across all participants, 18% more SA questions were answered correctly in Trial 2 compared to Trial 1. It may be possible that less mindful individuals were less aware of their surroundings, and the amount of attention they paid towards the mining environment did not improve until after they were aware to look for specific things during the first trial. It appears that MAAS scores do not correlate to natural or baseline situational awareness, and also, that all participants spent the first trial in a learning phase. The expected relationship between high mindfulness and good situational awareness only became apparent once people were more adept at driving the LHD machine, and secondly, had been alerted that there was a reason to pay attention to the external environment. Thus, the increase in SAQ without a significant change in collisions may simply be a learning effect of participants getting better at answering SAQ because they knew what to look for within the simulator. The upside to this observation is that we have shown that it is possible to increase Level 1 SA, and that has implications for improving awareness and decreasing complacency in the workplace. Once overcoming the physical challenge of navigating the simulator, the participants with higher MAAS scores demonstrated higher levels of SA. Additionally, we have rationalized that cueing operators leads to a significant increase in Level 1 SA. This has implications for testing SA-type workplace interventions since mindfulness is known to be a trainable state of mind (Bishop et al., 2004; Brown & Ryan, 2003).

It was also hypothesized that individuals with lower ARDES-US scores would answer more situational awareness questions correctly. This relationship was not present in either of the two trials. In fact, there was no linear relationship present between these two variables. It is possible this is due to the limited range of scores that the ARDES-US ($M = 1.58$, $SD = .42$) is capable of measuring, or because this scale does not measure any meaningful component of situational awareness.

The null findings between mindfulness and driver performance mirror the previous research that evaluated driver performance and mindfulness in a driving simulator by both Kass et al. (2011) and Valero-Mora et al. (2015). While different measures of driver performance were used, Valero-Mora and colleagues (2015) did not find any significant relationship between mindfulness (as measured by MAAS) and either lateral or longitudinal control of a vehicle. Some of the measures of driving performance were different in the study by Kass et al. (2011) compared to the measures used in this study, which again, makes it slightly more difficult to draw conclusions. Furthermore, the measure of mindfulness was done using the Mindfulness Questionnaire (Mikulas, 1990, as cited in Kass et al., 2011) and not the MAAS. It is likely that these two different mindfulness questionnaires measure different constructs and thus, it is difficult to draw any meaningful conclusions with these results. The study by Kass and colleagues (2011) used speeding and stopping violations, as well as vehicular and pedestrian collisions as measures of driving performance. While the study by Kass et al. (2011) did not report any specific numbers of the frequency of pedestrian collision in their study, within the SAMS, pedestrian (VIP) collisions were a rare event, with fewer than 2% of the collisions (11 collisions total) involving pedestrians. The vast majority of the collisions occurred between LHDs and the walls of the mining environment, and these collisions generally happened when the operator drove the machine around a corner in the virtual mine, or when the vehicle was frequently being switched between gears to maneuver to a new direction.

Similarly, there was no significant relationship between attention, as measured by the ARDES-US, with the driving performance measures of collisions and perception-response time. Ledesma et al. (2010, 2015) and Valero-Mora et al. (2015) provided evidence of a relationship between collision frequency and both lateral and longitudinal control of a vehicle, respectively, with ARDES scores. The fact there was no relationship in this study between driver performance and attention scores may be explained by the use of the American version of the ARDES, ARDES-US. Barragán and colleagues (2016) found that the ARDES-US was not able to significantly predict the likelihood of an individual being involved in a collision while driving (p = .69). There is a version of the ARDES validated for English speakers in the United Kingdom that has shown that those with lower ARDES scores were more likely to have reported collisions (Peña-Suárez et al., 2016). The ARDES-UK was not used in this study because it was thought that the ARDES-US would more accurately represent the dialect and driving terms most familiar to the average Canadian. Although, this study did not measure collisions reported by the participants in their own driving experiences; it measured the ability of participants to learn the simulator and become proficient in operating a virtual LHD. This may explain why there was no significant relationship between driving performance and ARDES-US scores.

A negative relationship was present between the total number of collisions in Trial 2, and the average number of collisions with years of driving experience. This result suggests that more experienced drivers may not need as much time to become competent within the SAMS compared to individuals with less driving experience. It is also possible that an individual's driving experience may influence how they perform within the simulator. Another interpretation may be that those with more experience driving a vehicle are involved with fewer collisions, and thus are safer drivers. However, this should be interpreted with caution because the measures of driving performance were conducted within a simulator and not in an actual vehicle. Furthermore, this does not mean that age is necessarily indicative of a safer driving record because the correlation between age and average collisions was not significant (p = .524). Also, with more years of driving experience, individuals may become more cautious and less risk averse while driving a vehicle. This does not mean that those with greater years of driving experience should have higher ARDES-US scores (Attention-Related Driving Errors Scale-US). This is because the ARDES-US measures the likelihood of having an accident due to an attention-related error (Ledesma et al., 2015) and not the likelihood of having an accident. Again, it is possible that the ARDES-US was not an appropriate scale to measure simulator performance, and that is why there was no relationship.

Variables Related to Personal Experiences of Participants

The negative relationship between both the average number of collisions and the number of years with video gaming experience suggests that individuals with more years of video gaming experience will incur fewer collisions in the mining simulator compared to individuals with fewer years of gaming experience. This relationship is no longer present during Trial 2. Perhaps, additional time spent within the Practice Trial (even 10 minutes) would further reduce the learning effect that exists with the situational awareness mining simulator (SAMS). We would hypothesize that testing a group of miners with real-world experience on these virtual LHD machines would demonstrate even better simulator performance.

The negative relationship between gaming experience and sex, suggests that males have significantly more experience playing video games compared to females. (However, this may be only relevant to this specific sample because in Canada approximately 49% of gamers are female (Entertainment Software Association of Canada, 2017)). This may explain why there was a relationship between the participants' sex and collisions during the Practice Trial. It is possible that males had fewer collisions during this trial due to their greater gaming experience, compared to females. However, this difference did not continue into Trials 1 and 2, which also points to the necessity of using a practice trial period in the SAMS prior to data collection to bring all participants to equal footing. Perhaps the advantage of gaming experience only exists for males until the learning curve of the SAMS has been mastered. Afterward, both males and females may be equally adept at operating the SAMS. These results reinforce the importance of a Practice Trial to remove any present gender bias.

4.2 Limitations

One of the limitations of this study was its sample size of 21 individuals. The power analysis conducted suggested a sample size of 20 individuals based on the correlation between mindfulness and pedestrian collisions in Kass et al.'s 2011 study. At the time, it was unknown how frequently collisions between pedestrians and the driven LHD would occur within the SAMS. After the completion of the study, it was revealed that fewer than 2% of the collisions within the SAMS involved VIPs (pedestrians). This most likely explains why a significant correlation was not present between mindfulness and collisions. Future research may consider coding collisions as either against the mining environment or other, with other encompassing both VIPs and NPC-LHDs. Furthermore, a larger sample size, or a stricter definition of what constitutes collisions, may have resulted in significant relationships amongst mindfulness and driver performance and situational awareness, as well as attention and driver performance and situational awareness.

One of the largest limitations in this study was the unknown learning effect of the SAMS. There appears to be a learning effect because the total number of collisions decreased significantly between the Practice Trial and Trial 1 and the Practice Trial and Trial 2. However, it is currently unknown how much time is required for the learning effect to disappear. It is also possible that there is a plateau effect; that eventually individuals will stop improving after a certain amount of time spent within the simulator or that once they believe they have mastered the simulator, their performance decreases again as boredom sets in. Unfortunately, the risk of side effects from using the Oculus Rift DK2 headset for long periods makes it more difficult to evaluate how long this would take. Future research should include work that identifies the optimal length of tutorial versus practice trials.

Additionally, the situational awareness questions (SAQ) were evaluated on a binary scale. Answers that were close to the correct answer were scored as incorrect. For example, if a participant answered that the level of the mine was “840” instead of the actual level of 8400, this response was considered incorrect. In the future, an alternate coding for the SAQ could be correct, incorrect or incorrect but close to correct. It is possible that this would reveal a different relationship between the number of correctly answered SAQ and the other variables, such as mindfulness and driver performance.

Another limitation relating to the SAQ was the questions themselves. Because of the apparent learning effect of participants answering more questions correctly during Trial 2, it could be argued that the SAMS does not accurately measure Level 1 of situational awareness. If more components within the SAMS could be varied, then there could be a sufficient number of questions such that each participant is only exposed to each question once. Thus, this would reduce some of the learning effect present in this edition of the simulator.

Both the coding of the “missed” VIPs and the structural design issues of the SAMS are limitations that should be addressed before further research is conducted. It cannot be certain if any of the VIPs “missed” by the participants were seen or unseen because it was the researcher’s decision on how the “missed’ VIPs were coded. This also includes the length of time participants had before a VIP was considered “missed”. Recall that this study allowed only 20 seconds before a VIP was marked as “missed” in the data-log. Before changing the coding of “missed” VIPs, the design of the simulator should first be improved to reduce the likelihood of unseen VIPs occurring. These changes could include the location of VIPs within the virtual mine to reduce the appearance of them in shadows or on inclines, or to increase the number of pixels required before the view time begins.

Another limitation relating to the SAMS is that it is currently only programmed to measure Level 1 of situational awareness. Situational awareness is a hierarchical structure, with three levels: perception, comprehension and projection (Endsley, 1995b; Endsley & Garland, 2000). Obviously, it is important to not only be able to identify current hazards but to know how to act accordingly when one is encountered, or to predict a possible dangerous situation and stop it from occurring. Future research should include updating the SAMS so that it can measure Level 2 and Level 3 of situational awareness.

The scales and the measures of driver performance used may not have been appropriate for this study. While this study measured situational awareness and collisions similarly to the study by Kass et al. (2011), mindfulness was not measured using the same scale. As was mentioned earlier, Kass et al. (2011) used the Mindfulness Questionnaire and this study used the Mindfulness Attention Awareness Scale. Additionally, this study used the same scales (MAAS and ARDES) that were used by Valero-Mora et al. (2015) but not the same measures of driving performance. Recall that Valero-Mora et al. (2015) used mean speed and minimum time to line crossing as measures of driving performance and this study used collisions frequency and perception-response time. Because of the differences in the scales and the measures of driver performance that were used, it is likely the same constructs were not being measured. It also makes it more difficult to draw meaningful conclusions from the results obtained. Also, the scales used have very limited ranges in their scores, which may have contributed to the limited findings in this study. If future research continues to look at various cognitive human factors that may be associated with situational awareness and driver performance, then the Cognitive Failures Questionnaire (Broadbent et al., 1982), the Attention Related Cognitive Errors Scale

(Cheyne et al., 2006) or the Concentration Scale (Krawietz, Mikulas, & Vodanovich, as cited in Kass et al., 2011) could be utilized.

The statistical analyses conducted evaluated only linear relationships amongst the variables. If non-linear statistical tests were conducted, different relationships may have been found. However, with the limited sample size, any relationship found was not likely to be significant. With a larger sample size, the quartile split of the MAAS scores may have yielded more meaningful results. Furthermore, by transforming the data of the nonparametric variables or by conducting partial correlations, other significant relationships may have been discovered.

Another possible limitation relating to the sample used was that it was a convenience sample. Participants were recruited from within the university community. It is possible that the participants do not accurately represent the general population because they were all students at the university. Furthermore, the sample only included one individual with experience driving mining equipment, which is the population that this research is applicable to.

While there were numerous limitations in this study, we believe that it has provided primary evidence to suggest a relationship between mindfulness and situational awareness. Future research in this area will address both the learning effect and structural limitations of the SAMS.

Chapter 5

5.1 Future Research and Implications

Prior to conducting future research studies with the SAMS, there are various aspects of the simulator that could be improved to remove variability and improve realism of the experience. For instance, adding a second gaming joystick to the simulator would be more realistic because LHDs require two joysticks to operate. This update would require the simulator's operator to use both joysticks to maneuver the vehicle as well as deposit and deliver ore within the virtual mine, and would be a more accurate representation of operating an actual load-haul-dump.

Next, adding haptic feedback to the operation of the simulator would also contribute to its realism. Haptic feedback could be used for the general operation of the virtual LHD but more importantly, to provide the user with knowledge that a collision had occurred. The current version of the simulator provides realistic engine sounds, but only a minor movement if a collision occurs. This may have affected the collision data in unknown ways since users had no feedback about their driving skill. Therefore, a main recommendation is for sound to be added for when collisions occur between the LHD and the virtual environment. Alternately, a jarring sensation could be used as haptic feedback when a collision occurs. This could be achieved through a special glove that is worn by the participant that shakes or vibrates, depending on the sensation needed. It may be possible to alter a joystick to provide this same jarring sensation. A seat pad could be used to produce vibration; the vibration of LHD and the sensation of driving over the uneven terrain of the mine.

As was previously described, the SAMS is currently designed such that it only measures Level 1 of situational awareness (SA), perception. Ideally, the SAMS will be able to measure the three levels of SA. Before that happens, the current Level 1 SAQ need to be improved. All SAQ asked should be based on scenarios and hazards relevant to the mining industry, specifically underground mining. For instance, some of the current SAQ asked about the colour of certain items within the virtual mine, which were easy to implement for novice users but are certainly not relevant to improving the safety of mining.

To ensure that the questions asked are relevant, safety professionals familiar with the hazards of underground mining could be consulted when designing new aspects of the simulator. Similarly, information could be drawn from the Mine Safety and Health Administration (MSHA), which records the type of accidents that occur in all fatal and non-fatal mining accidents that occur in the United States (MSHA, 2017). In a future version of SAMS, Level 1 of SA could be measured by presenting various hazards to the operator (of the simulator) and have him or her identify the hazard. Level 2 of SA (comprehension) could be measured by having the operator identify which category of hazard is present (i.e. electrical, fire, or falling rock) (as categorized by MSHA) (MSHA, 2017). For Level 3 of SA (prediction), the operator would have to determine based on the information provided if it was safe to continue working in the area. This method would follow the Situational Awareness Global Assessment Technique (SAGAT) as was described earlier.

However, a limitation of using novice students for participants is that they may not recognize or even comprehend mining hazards, and likely cannot project to knowing how to react, as is required for Level 3 situational awareness. A study by Eiter et al. (2018) evaluated hazard recognition in individuals with varying levels of mining experience and discovered that safety professionals had a significantly higher accuracy at identifying hazards compared to students with no mining experience. Thus, a future study evaluating situational awareness with the SAMS may need to use a sample of participants with experience in mining, whether as experienced miners or as safety professionals. This may require the SAMS to be somewhat mobile as it can be difficult to recruit this cohort of participants into a university setting.

In addition to updating the design and capabilities of the SAMS, the study research could be designed differently. Before being introduced to the simulator, a larger sample size, perhaps 100-200 individuals could complete a mindfulness-type questionnaire. Subsequently, only individuals with mindfulness scores closer to the extremes of the scale would be selected to continue further in the study. Ideally, the difference between individuals scoring higher on such a scale compared to those scoring lower would be a statistically significant one. This would allow the research team to explore the relationship between mindfulness and driver performance, as well as mindfulness and situational awareness in more depth. It would also facilitate intervention studies that target the least mindful type of person, and ensure that workplace interventions will be meaningful.

Findings in this work suggested that participants began to answer more situational awareness questions correctly once they had been cued as to the type of items to be looking for. These preliminary findings may suggest a method by which workplaces can combat complacency in the workplace. Vigilance is necessary to combat the effects of distracted driving and as such, the SAMS may provide a platform on which interventions designed to increase vigilance can be tested while operating VR mining equipment. These methods may also be applied to other workplaces where complacency is a concern. Asken and Paris (2009) suggested visual cues can be used to remind workers not to become complacent. The goal of testing this theory in a simulator would be to see which cues, visual reminders or questions are most effective at increasing vigilance of operators, leading to more awareness of their operating surroundings.

Whether mindfulness training improves the driver performance and situational awareness of individuals has yet to be determined. This study was unable to provide evidence of a strong relationship between mindfulness levels and situational awareness and driver performance. However, even with these results, mindfulness training is known to have benefits in terms of improving health (Bishop et al., 2004; Drew de Paz et al., 2014), reducing stress and absenteeism, and improving productivity and job performance (Jamieson & Tuckey, 2017; Lomas et al., 2017). Training study participants (i.e. university students) or underground miners in mindfulness techniques would benefit them in various aspects of their lives even if future research determines there is no benefit of this practice in increasing situational awareness or improving the safety of driving performance.

5.2 Conclusion

After completing this study, we were unable to conclude that there is a definitive relationship amongst mindfulness and situational awareness. However, it can be concluded that there is no linear relationship between attention (as measured by the ARDES-US) and situational awareness or driver performance. Also, the negative correlation between MAAS and ARDES-US scores supports previous work by Barragán et al. (2016) and Ledesma et al. (2015) that more mindful individuals are less likely of having an attention-related error while driving.

The simulator used in this study was shown to have a learning curve associated with it. This means that participants demonstrated incredibly varied numbers of collisions early on in their use of the simulator, and some improved at different rates than others. Further, participants had a strong learning effect related to answering the situational awareness questions, meaning that once they knew what types of things to look for in their environment, they did much better at answering those questions. As a result, the learning effect of the simulator limits the results of this study, and requires that caution is taken when interpreting significant relationships. Any future research conducted using the SAMS will first require determining when the learning effect dissipates.

This study provided preliminary results that suggest a positive relationship between mindfulness and situational awareness, as well as driver performance (as measured by decreasing collision frequency) and situational awareness. However, at this juncture, we would not recommend that mindfulness training be used as a method to improve situational awareness amongst load-haul-dump operators. This is because, the strength of these relationships cannot be ascertained since Spearman's correlations were used, and the relationships were only significant when the trials were analyzed separately. Furthermore, this type of intervention may not be well received by its target population, unless implemented in a bottom-up approach. Further simulator studies using the target population would be needed before recommending a mindfulness intervention for a mining workplace.

The increase in the number of situational awareness questions answered correctly during the second trial demonstrated that cueing individuals into details about their surroundings can improve Level 1 of situational awareness. Questioning drivers about their external environment forces them to pay attention to these surroundings, which may increase situational awareness and decrease complacency. This idea of cueing should be further evaluated within the SAMS but also could be implemented in actual vehicles through directly questioning the driver or through devices, such as a heads-up display.

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APPENDIX A. RESEARCH ETHICS BOARD APPROVAL

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 / Modifications to project X / Time extension	
Name of Principal Investigator and school/department	Alison Godwin, School of Human Kinetics
Title of Project	Ergonomic evaluation of proximity detection systems for underground mining vehicles
REB file number	2015-11-10
Date of original approval of project	December 02, 2015
Date of approval of project modifications or extension *(if applicable)*	March 08th, 2016 June 16, 2016 May 29, 2017
Final/Interim report due on: *(You may request an extension)*	December, 2017
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, PHD, Chair, *Laurentian University Research Ethics Board*

APPENDIX B. PARTICIPANT RECRUITMENT

Participants needed for research in virtual reality in occupational health and safety.

Purpose: This study will evaluate the driving behaviours of individuals operating virtual mobile mining equipment in a virtual underground mine. Participants will use Oculus Rift. Participation requires two sessions, each approximately one hour in length. This research is being conducted as a requirement for the degree Masters in Human Kinetics.

For more information about this study, or to participate in this study, contact Carolyn Knight at ce_knight@laurentian.ca

This study has been reviewed and accepted by Laurentian University's Review Ethics Board.

APPENDIX C. INFORMED CONSENT

LaurentianUniversity
UniversitéLaurentienne

Ergonomic evaluation of proximity detection systems for underground mining vehicles

I, ________________________, am interested in participating in the study by Alison Godwin from Laurentian University. The purpose of the study is to investigate how participants perform in a mining simulator. This will be done by measuring driving behaviors in the simulator, asking question about what happened in the simulator and measuring my reaction time inside the simulator.

If I am selected to operate the virtual reality mining simulator, I will do so for about 30 minutes while wearing an Oculus Rift headset. There is a chance that the Oculus Rift will make me feel nauseous or dizzy. This likelihood will be reduced by using special lenses that are fit to my body. The risk of injury due to dizziness is small because I will be seated. I am aware that if I feel any nausea or other discomfort, I should inform the researcher immediately, quit the simulation and remove the headset without standing up. Subsequently I will remove myself from the study.

After I have finished the VR session of this study, I will be asked to complete questionnaires that quantify my personality and my likelihood of experiencing a cognitive failure. The questionnaires might take me as long as 30 minutes to complete. I understand that the questionnaires might include questions that generate worrisome or negative emotions. I should feel no pressure to complete the questionnaires if this occurs and I understand that speaking with my family physician or a psychiatrist might help me process those emotions. I am aware that my responses to these questions will not be stored in conjunction with personal information. Information about my age and gender will be stored separately as hard copy. In no circumstances will my name be linked to the code that is given to my responses.

I have been informed that only members of the research team will have access to the data collected. My individual results will not be reported in publications. Results from this study will only be reported as averages. **My participation is strictly voluntary** and I am free to withdraw from completing the study details at any moment. I am aware that my participation and my performance will have no bearing on my academic marks or ranking. 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 computer (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 (toll free number 1 800 461 4030) 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, 2017 using the contact information on this form.

☐ I agree not to discuss the questions asked within the simulator, nor the questionnaires used in the study

☐ I agree to participate in this study.

Participant's Signature: ________________________ Date: ________________________

APPENDIX D. DESCRIPTION OF LOAD-HAUL-DUMPS FOR PARTICIPANTS

The following is the script used for all participants when the features of the load-haul-dump were explained. The Atlas Copco 1:50 Scale Scooptram ST14 model shown in Figures 8 and 9 was used during explanation.

This is a model of a load-haul-dump or LHD. This vehicle is similar to the one within the simulator.

1. There is the **bucket** that can be raised and lowered. The angle of the bucket can also be changed. *(Demonstrate movement of bucket)*

2. The vehicle is **articulated**, meaning there is a joint in the vehicle. As the vehicle turns, you will notice this articulation. *(Demonstrate articulation of joint).*

3. The **orientation of the operator** within the cab of the vehicle is such that the operator sits perpendicular to the direction of travel. When the operator is sitting in a neutral position, he is facing forward. When the operator turns to his left, he will be facing towards the bucket (or the front end of the vehicle). When the operator turns to his right, he will be facing the rear of the vehicle. *(Remove cab protector and demonstrate the different directions the operator faces depending on how he is twisted in seat).* You will notice directly behind the operator is a blind spot. These features will be represented within the simulator.

APPENDIX E. SCALE 1: MINDFULNESS ATTENTION AWARENESS SCALE (MAAS)

Scale 1

Day-to-Day Experiences

Instructions: Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item.

1	2	3	4	5	6
Almost Always	Very Frequently	Somewhat Frequently	Somewhat Infrequently	Very Infrequently	Almost Never

I could be experiencing some emotion and not be conscious of it until some time later.	1	2	3	4	5	6
I break or spill things because of carelessness, not paying attention, or thinking of something else.	1	2	3	4	5	6
I find it difficult to stay focused on what's happening in the present.	1	2	3	4	5	6
I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.	1	2	3	4	5	6
I tend not to notice feelings of physical tension or discomfort until they really grab my attention.	1	2	3	4	5	6
I forget a person's name almost as soon as I've been told it for the first time.	1	2	3	4	5	6
It seems I am "running on automatic," without much awareness of what I'm doing.	1	2	3	4	5	6

1	2	3	4	5	6
Almost Always	Very Frequently	Somewhat Frequently	Somewhat Infrequently	Very Infrequently	Almost Never

I rush through activities without being really attentive to them.	1	2	3	4	5	6
I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.	1	2	3	4	5	6
I do jobs or tasks automatically, without being aware of what I'm doing.	1	2	3	4	5	6
I find myself listening to someone with one ear, doing something else at the same time.	1	2	3	4	5	6
I drive places on 'automatic pilot' and then wonder why I went there.	1	2	3	4	5	6
I find myself preoccupied with the future or the past.	1	2	3	4	5	6
I find myself doing things without paying attention.	1	2	3	4	5	6
I snack without being aware that I'm eating.	1	2	3	4	5	6

APPENDIX F. SCALE 2: ATTENTION-RELATED DRIVING ERRORS SCALE-US (ARDES-US)

Scale 2

Instructions: People can experience situations like those described below unintentionally while driving a car. Please read each item and indicate how often you experience the described situations while you drive.

1	2	3	4	5
Never	Seldom	Sometimes	Often	Almost Always

When driving to a familiar place, I unintentionally drive past it because I was not paying attention.	1	2	3	4	5
I signal a maneuver but unintentionally make another (for example, I turn on the right-turn signal, but turn left instead).	1	2	3	4	5
When driving through an intersection, I fail to pay attention and don't see a car coming the other way.	1	2	3	4	5
Suddenly, I realize I'm lost or took the wrong route when driving to a known destination.	1	2	3	4	5
When I enter an intersection, instead of looking in the direction of oncoming traffic, I look in the opposite direction.	1	2	3	4	5
At a street corner, I fail to notice that a pedestrian is crossing the street.	1	2	3	4	5
I unintentionally hit an object or car behind me because I didn't realize it was there.	1	2	3	4	5
I fail to notice that the vehicle in front of me has slowed down, and I have to brake abruptly to avoid a crash.	1	2	3	4	5
Another driver honks at me because I've failed to realize that the traffic light has turned green.	1	2	3	4	5

1	2	3	4	5
Never	Seldom	Sometimes	Often	Almost Always

Another driver honks or flashes their lights at me because I didn't realize that my headlights are on high beam.	1	2	3	4	5
For a brief instant, I forget where I am driving to.	1	2	3	4	5
When driving somewhere, I make more turns than I have to.	1	2	3	4	5
Following the traffic in front of me, I unintentionally drive through a traffic light that has just turned red.	1	2	3	4	5
I try to accelerate, but then realize that my car is in neutral or first gear.	1	2	3	4	5
I attempt to turn on a feature in my car, but I turn on another one instead (for example, instead of turning on the windshield wipers, I turn on the lights).	1	2	3	4	5
I head out to a destination and suddenly realize I'm going the wrong way.	1	2	3	4	5
I realize that I've failed to see the traffic light because I was not paying attention.	1	2	3	4	5
I unintentionally shift gears incorrectly or shift into the wrong gear.	1	2	3	4	5

APPENDIX G. EXPERIENCE QUESTIONNAIRE

CROSH CRSST
centre for research in occupational safety and health at Laurentian University | centre de recherche sur la santé et sécurité au travail à l'Université Laurentienne

Experience Questionnaire

Please take the time to fill out this short questionnaire which aims to provide a summary of your experience with driving, virtual reality and mining related activities.

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

Date of Birth (YYYY/MM/DD): ____

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

Please answer the following questions as accurately as possible.

1. Do you have a driver's license? **Yes** or **No**

If yes, what class is your driver's licence (i.e. G1, G2, G, M)?

____

____

If yes, how long have you had your driver's licence?

____

____

If yes, approximately how many hours per week do you drive?

____

____

2. Do you have any experience with underground mining operations? If yes, describe:

____

____

3. Have you ever operated any kind of heavy machinery/equipment (i.e. forklift, dump truck)?

____

____

____

4. 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: ______________________________

5. Do you have any experience with virtual reality? **Yes** or **No**

If yes, which specific type of virtual reality devices have you used?_________________

____

____

If yes, approximately how many hours in total have you used virtual reality devices?

____

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 gaming system(s) did/do you use: ___________________________

____

____

____

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

____

____

7. Do you know what mindfulness is? **Yes** or **No**

8. Do you practice mindfulness? **Yes** or **No**

If yes, please list the activities you use to practice mindfulness: ____________________

____

____

____

____

If yes, how long have you been practicing mindfulness? __________________________

____

If yes, approximately how many hours per week do you practice mindfulness?

____

APPENDIX H. SPEARMAN’S CORRELATIONS

Spearman's correlations were conducted to determine if there were any linear relationships between the variables. The level of significance was set to p < .05. In the table below, * denotes a level of significance of p < .05, while ** denotes a level of significance of p < .01.

	1.	2.	3.	4.	5.	6.	7.
1. Average Collisions	-	.696**	.806**	.149	.201	.407	-.125
2. Collisions (Trial 1)		-	.241	.130	.276	.449*	-.056
3. Collisions (Trial 2)			-	.062	.143	.283	-.049
4. Practice Collision				-	.496*	.485*	.351
5. Average PRT					-	.827**	.575**
6. PRT (Trial 1)						-	.143
7. PRT(Trial 2)							-
8. MAAS							
9. ARDES-US							
10. Age							
11. Gaming Experience							
12. Driving Experience							
13. Correct SAQ (Trial 1)							
14. Correct SAQ (Trial 2)							
15. Untagged VIPs (Trial 1)							
16. Untagged VIPs (Trial 2)							
17. Untagged VIPs (Total)							
18. Gender							

	8.	9.	10.	11.	12.	13.	14.
1. Average Collisions	.096	-.038	-.151	-.509*	-.511*	-.301	.137
2. Collisions (Trial 1)	.027	-.021	-.123	-.544*	-.181	-.507*	.158
3. Collisions (Trial 2)	.051	.083	-.246	-.356	-.435*	.028	-.126
4. Practice Collision	-.052	-.105	-.108	-.172	-.116	-.100	.058
5. Average PRT	-.353	.077	-.153	-.091	-.131	.006	-.415
6. PRT (Trial 1)	-.234	.009	-.319	-.177	-.316	-.231	-.438*
7. PRT(Trial 2)	-.175	-.031	.183	-.057	.328	.283	-.077
8. MAAS	-	-.516*	.009	.111	-.108	.012	.434*
9. ARDES-US		-	-.142	.059	.012	-.106	-.223
10. Age			-	.174	.773**	.113	.051
11. Gaming Experience				-	.117	.123	-.058
12. Driving Experience					-	.213	-.123
13. Correct SAQ (Trial 1)						-	-.191
14. Correct SAQ (Trial 2)							-
15. Untagged VIPs (Trial 1)							
16. Untagged VIPs (Trial 2)							
17. Untagged VIPs (Total)							
18. Gender							

	15.	16.	17.	18.
1. Average Collisions	.247	-.081	.248	.382
2. Collisions (Trial 1)	.406	.035	.421	.305
3. Collisions (Trial 2)	.080	.026	.102	.296
4. Practice Collision	.119	-.020	.137	.513*
5. Average PRT	.461*	.438*	.573**	.243
6. PRT (Trial 1)	.536*	.305	.593**	.208
7. PRT(Trial 2)	.059	.478*	.193	.364
8. MAAS	-.283	-.213	-.344	-.043
9. ARDES-US	.118	.148	.173	.164
10. Age	.168	-.096	.008	-.289
11. Gaming Experience	.215	.067	.126	-.574*
12. Driving Experience	.073	.141	.003	-.279
13. Correct SAQ (Trial 1)	-.109	.271	-.084	.009
14. Correct SAQ (Trial 2)	-.355	-.318	-.385	.245
15. Untagged VIPs (Trial 1)	-	.421	.956**	-.332
16. Untagged VIPs (Trial 2)		-	.610**	-.118
17. Untagged VIPs (Total)			-	-.213
18. Gender				-