MEASURING ATTENTION, WORKING MEMORY AND VISUAL PERCEPTION TO REDUCE THE RISK OF INJURIES IN THE CONSTRUCTION INDUSTRY

by

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ABSTRACT

MEASURING ATTENTION, WORKING MEMORY AND VISUAL PERCEPTION TO REDUCE THE RISK OF INJURIES IN THE CONSTRUCTION INDUSTRY

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The construction industry has consistently held one of the highest injury rates among all sectors and failure to recognize hazards due to poor selective attention, cognitive overload, and distractibility have been identified as critical human factors that lead to accidents. Considering that falls are the leading cause of deaths in the construction industry and accountable for over 33% of all construction worker deaths, this project investigated the extent to which worker characteristics (work experience, safety training, and previous injury involvement), personality dimensions (extraversion, neuroticism, conscientiousness, agreeableness, and openness to experience), working memory load and workplace conditions (e.g. time pressure) interact to influence visual attention and the identification of fall hazards. By continuously monitoring the eye movements of participants using eye-tracking technology, this study identified precursors of human error by carrying out a batch of visual search tasks to: (i) evaluate the influence of worker characteristics on visual attention and hazard identification as workers viewed 35 construction-scenario images containing 115 fall hazard areas of interests (AOIs); ii) investigate the effect of working memory load on hazard recognition for various personality traits while performing a visual attention task of identifying fall hazards across 231 AOIs and memorizing 3-digit and 6-digit strings of numbers (simulating low and high memory load conditions respectively) in a secondary cognitive task, and iii) examine the impact of time pressure on attention to fall and hand injury hazards as participants installed 27 pieces of 40 ft2 shingles standing on a low-sloped roof model 4ft wide, 6ft long and 3ft high in two experimental conditions—a baseline study without time pressure and a second manipulation with a 7-minute time limit. Multilevel analyses of data revealed that work experience, safety training and individual differences in the conscientiousness, agreeableness and openness to experience personality dimensions demonstrated significant direct associations with visual attention and superior hazard identification performance. Furthermore, residential roofers may be at a heightened risk of slip, trip, fall and hand injury hazards as a result of impaired visual attention due to time pressure. Findings have wide implications for improving safety performance and would assist organizations to assign workers to suitable tasks based on a combination of their cognitive abilities and personality variables to reduce the risk of injury among vulnerable workers whose attention may become impaired when handling multiple tasks in dynamic environments. In addition, this research is a proof of concept to construction managers on the need to prevent tight work schedules that induce time pressure and promote risk-taking, impact hazard awareness and increase workers' susceptibility to fall and hand injury hazards.

CHAPTER ONE: INTRODUCTION

1.1 Overview

Humans are finite beings whose capacity for information processing is limited. Problematically, this limited attention capability hinders in-depth situation awareness and risk analysis. The resulting human errors that occur when decision-making breaks down represent the main casual factors in up to 80% of all workplace accidents across various industries (Heinrich et al. 1980; Shappell and Wiegmann 1997), and are a leading cause of construction accidents (Abdelhamid and Everett 2000; Garrett and Teizer 2009). When workers make risky or inattentive decisions, human errors that translate to unsafe behavior, poor hazard identification and misperception of risk (Kahneman et al. 1982) can occur and yield bodily injuries. While such errors undermine workers' safety in any industry, environments with latent hazards—such as those prevalent on dynamic construction worksites—drastically increase the risk of an incident as construction workers must simultaneously execute tasks, identify and attend to known hazards, and respond appropriately to new hazards in order to prevent undesirable outcomes and uncontrolled risks (Rozenfeld et al. 2010). Notably, with more than 60,000 fatal injuries occurring every year on construction projects globally (Lingard 2013) and at least 1,200 deaths and 460,000 disabling injuries occurring in the construction industry domestically in each of the past 15 years (BLS 2015), these shocking statistics speak to the need for a determined and coordinated effort to evaluate new approaches to address this intransigent problem and safeguard the lives of millions of construction workers. Since one of the root causes of human error that can lead to occupational accidents is a worker's inattention when searching for potential or active hazards, a great deal of research has been directed toward hazard-identification strategies to improve safety management. These studies include accident root–cause tracing modelling (Abdelhamid and Everett 2000), failure mode and effect analysis (Stamatis 2003), fault-tree analysis (Brooke and Paige 2003), information retrieval framework and case-based reasoning (Goh and Chua 2009), and job-hazard analyses (Rozenfeld et al. 2010). However, some of these strategies are not effective for construction because of the dynamic and complex nature of construction sites and the lack of standardization in construction processes (Abdelgawad and Fayek 2012).

1.2 Motivation and Research Objectives

The majority of current construction-focused hazard identification strategies fall into two categories: retrospective or predictive approaches (Shorrock and Kirwan 2002). The retrospective approach relies on learnings from past reported incidents to come up with a framework for future learning (Goh and Chua 2009; Mitropoulos and Namboodiri 2011). The predictive approach, on the other hand, identifies hazards in the pre-construction phase using different kinds of modeling tools and brainstorming techniques (Hoła 2010; Esmaeili 2012; Esmaeili et al., 2015a; Esmaeili et al., 2015b). While valuable in construction-safety management, both approaches substantially ignore the role of human factors and the cognitive processes at play when workers engage in hazard identification activities. Because these current approaches incorrectly assume that all workers have a similar ability to identify hazards when exposed to a risky situation (Fleming 2009), a worker-centric approach that can assess human error in accidents will provide new insights into the role that worker characteristics, attentional and cognitive processes, and workplace factors (e.g. time pressure) play in risk analysis and risk management in construction.

The primary objective of this research is to determine the extent of influence of worker characteristics, cognitive overload, individual differences and time pressure on hazard identification using real-time data from eye movement patterns.

Among all related factors, worker characteristics such as work experience, level of training, and previous exposure to injury play an influential role in hazard recognition (Huang et al. 2007; Aroke et al. 2020). These characteristics influence an individual's risk perception, which, over time, determine the risk tolerance of an individual and the decision to either engage in, or avoid hazardous situations. Utilizing a moderated mediation model, this study investigated the strength of associations between worker characteristics, personality traits, visual attention and hazard identification. Moderated mediation models clarify the means by which an independent variable transmits its effect to a dependent variable through a mediator, and how this effect may be potentially conditional on the value of a moderator variable. While this technique has been applied in other domains (e.g. Preacher et al. 2007; Wang and preacher 2015; Carvalho et al. 2019), it is novel to construction safety. In this study, it is hypothesized that visual attention will mediate the association between worker characteristics and hazard identification performance, and the overall influence of worker characteristics on hazard recognition will vary as a function of individual differences in personality traits. Applying the moderated mediation technique will clarify the extent to which personality traits are pivotal factors that strengthen the effect of worker characteristics on safety performance by accentuating the influence of work experience, training and injury exposure on workers' attentional allocation and visual search strategy across hazardous scenes. In the interest of workers' safety, it will be beneficial to identify the combination of worker characteristics and individual differences that can predict future risk-taking behaviors or the likelihood of involvement in a construction-related incident.

Apart from the potential influence of worker characteristics on visual attention and hazard identification, holding more information than necessary in memory may adversely impact the ability to perceive hazards adequately in a dynamic environment. While working memory may help workers identify and process a certain hazard within salient locations, it becomes a contributory risk to safety where preoccupation with an item or situation may lead individuals to miss other dangers in the construction environment. Working memory has been shown to be critical to comprehension (Daneman and Carpenter 1980), inhibiting distracting information (Conway et al. 2001), updating moment-to-moment goals (Hasher et al. 1999), and guiding attention and eye movements to similar items in the environment (Olivers et al. 2006). Therefore, , this research will harness psychological knowledge about how attention and working-memory capacity influence safety performance during multitasking situations by manipulating working memory load as participants hold information in memory while completing visual attention tasks.

Drawing on the benefits of the multilevel modeling (MLM) technique that has been widely applied in various fields—including but not exclusive to multivariate behavioral research (e.g. Kim and Hong 2020), statistical science (e.g. Zhang et al. 2009) and experimental psychology (e.g. Hu et al. 2020)—this study will employ the MLM technique to investigate the association between working memory load, personality traits, visual attention and hazard-identification. This integrative approach of assessing mediating and moderating effects concurrently with nested data (in this case, individuals nested within low and high working memory groups) is a beneficial strategy for construction management studies to assess the effect of multi-dimensional factors (such as visual, cognitive and individual factors) on safety performance in construction-safety discussions.

In addition to the potential effect of individual factors such as worker characteristics and cognitive overload on safety performance, certain workplace factors (such as time pressure) may have a detrimental influence on visual attention and increase the potential for injuries. The requirement to complete tasks as quickly as possible under time pressure is one of the reasons for increased risk-taking, as workers compromise their safety in response to pressure to meet up with schedule or production requirements. Thus, when operating under the clock, safety and production demands compete for workers' limited attention or effort, and conflict with the concentration needed to protect workers from hazards in the work environment.

Particularly when performing hazardous activities (such as roofing tasks which require careful processing of a large amount of safety-related information at elevated heights), time pressure will likely restrict the amount of information considered, the thoroughness with which decisions are evaluated, and the extent to which visual attentional cues are utilized (Kelly and Karau 2012; Rajapakse et al. 2019). Such restrictions may deteriorate thinking and judgement, causing workers to superficially scan the surrounding in search for safety hazards, and ultimately increasing the likelihood to cut safety corners and exhibit unsafe behavior. Moreover, increased pressure to perform tasks may also heighten emotional stress levels, allowing fewer cognitive deliberations that may impair attention and increase the propensity to make risky choices (Ordonez and Benson 1997; El Hajia et al. 2019). Therefore, considering the danger associated with this high-risk occupation and how a lapse in visual attention may contribute to falls and other safety incidents, this study will examine the impact of time pressure on attention to hazards and workers' susceptibility to hand injuries and slip, trip and fall incidents during a simulated roofing activity.

To this end, the present research will identify precursors of human error by implementing multiple eye-tracking experiments in the laboratory using a combination of safety variables, including worker characteristics (e.g., work experience, safety training and injury exposure), individual differences (e.g., personality traits), attentional indicators (eye movements), well-established cognitive manipulations (e.g., working-memory load) and attention-restricting workplace factors (e.g., time pressure) to predict and subsequently mitigate the human errors that lead to accidents in dynamic environments.

1.3 Dissertation Organization

This project investigates the precursors of human errors from inattention, cognitive overload, individual differences, and time pressure to reduce the risk of injuries in the construction industry. The following is an outline of how this dissertation is structured.

Chapter 1 gives an overview of construction safety and background to the study. The motivation and research objectives derived from the current safety practices and need for a worker-centric approach to investigate the potential for human error in construction risk analysis and management are also presented.

Chapter 2 investigates the moderating effect of personality traits in the association between worker characteristics (work experience, training, and previous injury exposure) and hazard-identification performance through attentional indicators of eye movements. It also provides empirical evidence for the potentially pivotal role of worker characteristics and dispositional traits with regard to hazard-identification performance on jobsites.

Chapter 3 analyzes the influence of working memory load on hazard identification, together with the mediating effect of visual attention and moderating impact of personality dimensions underlying this link. Implications for workers' visual attention, cognitive impairment and safety performance are discussed.

Chapter 4 investigates the effect of time pressure on attention to safety hazards and workers' susceptibility to hand injuries and slip, trip, and fall incidents during a simulated roofing task. Insights into the risk compensation paradigm, workers' tradeoff between safety and productivity, and the potential impact of time pressure on construction performance are provided.

Chapter 5 summarizes the research findings and concludes the dissertation. It also discusses future research extensions and opportunities, as well as the limitations of the research.

CHAPTER 2: USING WORKER CHARACTERISTICS, PERSONALITY AND ATTENTIONAL DISTRIBUTION TO PREDICT HAZARD IDENTIFICATION PERFORMANCE: A MODERATED MEDIATION ANALYSIS

2.1 Abstract

This study investigated the moderating effect of personality traits in the association between worker characteristics (work experience, training, and previous injury exposure) and hazard-identification performance through mechanisms of attentional indicators of eye movements. Attentional distribution, search strategy, and hazard-identification performance of participants were examined across 35 construction-scenario images containing 115 fall hazards. Results indicated that individuals with more work experience and safety training were better at hazard identification independent of visual attention and regardless of personality. Indicators of visual attention did not mediate links between worker characteristics and hazard identification at any level of personality. However, individual differences in conscientiousness and openness-to-experience revealed significant direct associations between (a) worker characteristics and indicators of visual attention and (b) visual attention and hazard identification. This study provides empirical evidence for the potentially pivotal role of worker characteristics and dispositional traits with regard to hazard-identification performance on jobsites. These findings can empower safety managers to identify at-risk workers who are injury prone, design intervention strategies, and implement personalized safety trainings to improve the hazard-identification skills of workers.

2.2 Introduction

The construction industry has consistently held one of the highest incidences of injuries and fatalities among all sectors. Each year in the United States, thousands of accidents are consistently reported and which lead to permanent disabilities, injuries, deaths, and heavy losses (Wallace and Vodanovich 2003, Alexander et al. 2017, Hinze et al. 2017, Chan et al. 2018, Bhandari et al. 2020). Failure to recognize hazards due to poor selective attention, mental errors, and distractibility are identified as critical human factors that lead to accidents (Wallace and Vodanovich 2003, Hasanzadeh et al. 2017). Questions remain as to the extent of the impact of limited attentional resources on workers' ability to identify sources of danger in dynamic construction environments, where construction workers are required to divide their attention properly to identify hazards on a jobsite (Aroke et al. 2020). A breakdown of attentional control—resulting in cognitive errors—is a contributing factor to the high rate of workplace injuries (Martin 1983), thus raising the stakes for understanding the importance of proper attentional distribution in hazardous construction environments.

In parallel, previous literature has provided empirical evidence that accidents do not only happen by chance or due to unsafe site conditions alone. Rather, accidents are also linked to numerous factors within an individual (Davids and Mahone 1957, Hasanzadeh et al. 2020). Considerable evidence suggests that demographic and psychological factors associated with worker characteristics could increase the likelihood of accident involvement (e.g., *work experience:* Choudhry and Fang 2008, Lee and Nussbaum 2013, Roberts et al. 2015, Haluik 2016, Alwasel et al. 2017; *injury exposure:* Westaby and Lee 2003, Mullen 2004, Huang et al. 2007, Floyd and Floyd 2014, Pek et al. 2017; *training:* Visser et al. 2012, Sacks et al. 2013, Taylor 2015; *personality traits:* Barrick et al. 2013, Beus et al. 2015, Pourmazaheriana et al. 2017, Gao et al. 2020; *sensation seeking:* Oliver et al. 2002, Bohm and Harris 2010, Knight et al. 2012, Man et al. 2017, Hasanzadeh et al. 2020). For example, a study conducted by Roberts et al. (2015) found that the level of attentional resources required to perform a task decreases when knowledge, skill, and experience increases. Likewise, experience assisted skilled workers in assessing hazards significantly faster than novice workers (Dzeng et al. 2016, Hasanzadeh et al. 2017b; Aroke et al. 2020). Alwasel and his team (2017) also found that novices sustained relatively more injuries on jobsites than experienced workers. As such, novices tend to miss relevant cues and may be less able to process important elements required for the successful performance of a task (Lee at al. 2008).

Furthermore, Sacks et al. (2013) asserted that the skill to identify or assess risks is largely acquired through training and experience and is among the key factors that determine workers' safety behavior. Training skills were found beneficial in reducing the cognitive distractions that decrease situational awareness and hamper operational safety (Visser et al. 2012). Additionally, researchers have observed that inadequate training, reduced safety awareness, and poor retention of relevant safety knowledge are significant contributing factors to the incidence of injury and fatalities on job sites (Walkins 2011, Le et al. 2015). Similarly, previous experience with injuries increases the perception of risk associated with the performance of a task (Hasanzadeh et al. 2017a). Notably, individuals who have more information in memory about a danger encountered or avoided in the past are more likely to successfully navigate through potentially dangerous situations by taking precautions to reduce the likelihood of future injury (Westaby and Lee 2003). However, when a person's risk perception deviates from objective risk as a result of having no prior involvement in injury, actions in critical situations may lead to an accident (Rundmo 1992). Since past accidents alert workers to hazards in the workplace, workers without injury experience are more likely to misperceive or misjudge the associated risks while performing a task (Harrel 1990, Mullen 2004) which may increase the tendency to engage in unsafe behaviors.

Accident-proneness theories stipulate that personality traits may predispose individuals to a higher likelihood of accident involvement (Greenwood and Woods 1919, Kunce 1967, Hinze 1997, Templer

2012). Past work also suggests that some people may be unusually prone to cognitive failures, making them more susceptible to injuries in the work environment (Davids and Mahone 1957, Walumbwa and Schaubroeck 2009, Cobb-Clark and Schurer 2012, Fang et al. 2016, Gao et al. 2020). Therefore, to effectively manage individuals with unique backgrounds and to maintain a reasonable standard of safety, researchers often utilize personality-based assessments to predict workplace rule compliance and safety behavior, as documented in several domains (Martin 1983, Hansen 1989, Arthur and Doverspike 2001, Pourmazaheriana et al. 2017, Hasanzadeh et al. 2019, Gao et al. 2020). Although the impact of individual characteristics on the safety performance of workers has been examined in previous literature (e.g., Beus et al. 2015, Lee and Dalal 2016, Uppal 2017, Man and Chan 2018), the extent to which construction workers' characteristics impact their attentional processes remains an empirical question.

Building upon these past studies of how workers' characteristics influence their safety performance, the present study empirically weighs the impact of workers' characteristics on attentional distribution and hazard-identification, especially in terms of the interaction between demographic and psychological variables, attentional allocation, and the hazard-identification performance of workers within the construction industry. The study presented here investigated the extent to which personality traits influence the relationship between worker characteristics (work experience, training, and previous injury exposure) and hazard-identification skill. The results of this study offer insights into the significance of years of experience, training, and previous accident involvement to safety performance for different categories of workers based on their personality traits. In the long-term, the findings of this study can mitigate incidents on construction sites by helping in identifying at-risk workers and tailoring training to their unique characteristics.

2.3 Background

2.3.1 Impact of Worker Characteristics on Safety Performance

The extent to which construction workers may engage in risk-taking behavior varies among individuals with different demographic and psychological characteristics (e.g., Christian et al. 2009, Holte et al. 2015, Raad and Mlacic 2015, Feng et al. 2017, Oshioa et al. 2018). These characteristics influence an individual's risk perception which, over time, forms the risk tolerance of a person. Moreover, these characteristics impact the attentional distribution of an individual and play a pivotal role in the decision to engage in or avoid hazardous scenarios. While significant years of experience working on construction sites appear to improve the hazard-recognition performance of some workers (Knoll 2014), workers are usually made to undergo a series of trainings in the workplace. Though traditional training programs attempt to improve safety knowledge, workers mostly rely on their observation and experience from workplace injuries and near misses to make safety-related decisions when confronted with hazards (Fang et al., 2016). Among all related factors, worker attributes such as their work experience, level of training, and previous exposure to injury play an influential role in hazard-recognition performance (Hasanzadeh et al. 2017). Additionally, the positive impact of these attributes on safety performance in the workplace has been established in various studies (Huang et al. 2007, Walkins 2011, Sacks et al. 2013, Kaskutas et al. 2013). Therefore, in the interest of workers' safety, it is beneficial to identify individual differences among construction workers that can predict future risk-taking behaviors or the likelihood of being involved in an incident. A brief overview of these characteristics from existing literature is provided in subsequent sections:

2.3.1.1 *Work experience*

The concept of familiarity and perception of hazards suggests that work experience is negatively correlated with work injury (Maiti, 2007). Inexperience, on the other hand, is one of the factors responsible for the disproportionate number of occupational fatalities and lost-time injuries suffered by construction workers, with the rate of injuries decreasing substantially as the length of service increases (Ringen and Seegal, 1995). It is also the case that experience has a positive effect on safety performance, as evidenced by the findings of many researchers. For example, Hasanzadeh et al. (2017) compared the search patterns of experienced and novice workers in a hazard-identification experiment and found that as construction workers gain more experience, their hazard-identification skills improve, enabling them to search and examine scenes more efficiently. Another study correlated workers' background and attitude towards safety with their accident records and observed a strong relationship between experience and the level of safety performance (Sawacha et al. 1999, Lee et al. 2008, Kaskutas et al. 2013). A further study observed that an experienced worker may have accumulated an assortment of skills in their career and may recall knowledge from similar situations to help complete a potentially dangerous task safely (Haluik 2016). Similarly, experienced workers are more likely to engage in a sequence of safe actions when dealing with unexpected or highly stressful situations (Choudhry and Fang 2008, Chang et al. 2016) because their depth of knowledge and skill acquired over time will be positively related to their safe performance (Burke et al. 2002, Roberts et al. 2015). These results suggest work experience will improve hazard-identification skills in complex hazardous construction environments due to the relatively reduced level of attentional resources required to perform tasks, even when task demands increase.

2.3.1.2 *Training*

Inadequate training and poor retention of construction knowledge are identified as contributing factors to high injury and fatalities rates in the construction industry (Walkins 2011). Workers who have not been trained may find it challenging to recognize and subsequently avoid potential hazards associated with the task, which may put them at a greater risk of injuries in hazardous construction environments (Toole 2002). Compelling evidence in the literature supports the effectiveness of training on safety performance: Dong and his colleagues (2004) documented the benefit of effective safety and health training in reducing the incidence of work-related injuries among construction laborers. The outcome of their study suggested that training increased workers' awareness about the importance of their behaviors toward avoiding injury and reduced their willingness to accept the prevailing levels of occupational risks. A similar study by Sacks et al. (2013) found that receiving training and experience in performing stone cladding and cast-in-situ concrete tasks significantly improved the safe behavior of workers by improving their abilities to sustain attention and identify and assess risks. The results of related research by Kaskutas et al. (2013) suggested that training residential foremen could increase the use of fall protection, improve safety behaviors, and enhance on-the-job training and safety communication on worksites. Likewise, inadequate training and language barriers were suggested as contributors to the high rate of injury and fatality among Latino workers and exposed them to a significant risk of danger on the job (O'Connor et al. 2005). Though these outcomes demonstrate the importance of training in improving workers' safety performance, the results of the study conducted by Hasanzadeh and her team (2017) showed that the basic safety training (i.e., OSHA 10-h certificate) might not considerably improve hazard-detection skills. Therefore, the dynamics of the construction environment suggest that developing innovative and interactive training techniques can significantly improve workers' hazard-detection skills and situational awareness when compared to the adoption of low-engagement training delivery methods that offer a prescriptive performance of standardized work procedures (Hasanzadeh et al. 2017). As a result, high-engagement training will help workers identify, avoid, or prevent hazards that may put them at risk of injuries on construction sites.

2.3.1.3 *Injury exposure*

Often times, the unpalatable experience of an injury or near miss increases the risk perception and safety conscientiousness of workers such that they become more alert to dangers on worksites and increase their precautionary behaviors (Huang et al. 2007). Moreover, the unpleasant mental images formed by workers with injury experience usually impacts their perception of risk in scenarios that appear similar to their past experiences. With a heightened risk perception due to previous injury experience, workers reduce their willingness to take chances, thus increasing the tendency of these workers to perform safely on the job (Rundmo 1992, Floyd and Floyd 2014). To illustrate the effect of past injury exposure on safety performance, research conducted by Westaby and Lee (2013) detected that individuals with more information in memory from a prior experience of injury were more likely to successfully navigate through potentially dangerous situations because such injury experience guided their precautionary responses in high-exposure environments. Similarly, in a study that observed the eye-movement patterns of workers to determine their attentional allocation when identifying hazards during an eye-tracking experiment, Hasanzadeh et al. (2017) found that workers with past injury exposure returned their attention more often to hazardous areas compared to workers with no record of injury. Taken together, the outcome of these studies suggests that prior encounters with near misses and injuries may be predictors of workers' future safety-related behaviors.

2.3.2 Personality Traits and Accident Involvement

Past research has indicated that besides worker demographics, variations in the disposition of individuals—such as psychological traits—can also influence their safety-related responses to hazardous situations. Personality traits assess the interpersonal orientation of people (Man and Chan, 2018). They are conceptualized as stable individual characteristics that explain an individual's aptitude to specific patterns of behavior, cognition, and emotions (Goldberg 1992, Pourmazaheriana et al. 2017). More importantly, personality traits have been suggested as the individual characteristics that influence both safety behavior and the probability of accident occurrence (Gao et al. 2020).

The connection between personality traits and safe performance has been evident in various studies. For instance, early research examined the effect of personality on the cognitive failure of workers and their subsequent accident involvement and found conscientiousness to be negatively related to unsafe work behaviors and accidents (Martin 1983). Gao and his team (2020) also observed that negative emotions associated with neuroticism tended to strain interpersonal relationships and prompted distracted thinking that adversely affected workers' safety behaviors. Likewise, the result of a study by Pourmazaheriana et al. (2017) detected that individuals with low levels of openness had an improved ability to focus on tasks and were less likely to become involved in incidents. A similar study by Hansen (1989) observed that some characteristics associated with neuroticism and social maladjustment were significantly related to accidents.

In driving-related studies, vehicle crashes were found to be as likely related to driver personality traits as to the knowledge of vehicle operation and driving rules (Arthur and Doverspike, 2001). Similarly, Ehsani et al. (2015) examined the association between drivers' personality, risky driving behavior, and near-crashes, and discovered that conscientious drivers engaged in fewer dangerous driving maneuvers and were involved in fewer crashes. Furthermore, Schwebel and his colleagues (2006) asserted that three personality traits—sensation-seeking, conscientiousness and hostility—play a critical role in predicting risky driving behavior. Likewise, Clarke and Robertson (2005) reported that individuals low in both agreeableness and conscientiousness were more likely to be involved in accidents. This is similar to the findings of Postlethwaite and his team (2009), who identified that individuals with higher levels of cognitive ability were more likely to demonstrate regular safety behaviors regardless of their levels of conscientiousness.

In another study, Hogan and Foster (2013) sought to identify the personality dimensions related to overall safety performance and predictive of occupational accidents and injuries. Their results comprehensively captured the tendencies of various individual characteristics and their unique contributions to workplace safety. The researchers observed that individuals who were easily stressed (high neuroticism), who had difficulty getting along with others (low agreeableness), who needed to be the center of attention (high extraversion), and who were easily bored and required stimulation (high openness) were more likely to engage in unsafe behaviors.

Taken together, these studies show that dispositional factors such as personality traits are predictors of safety-related behaviors. However, further inquiry is needed to examine if personality traits moderate the impact of demographic variables on hazard-identification performance.

2.3.3 Big five personality traits and safety performance

Although several methods have been suggested for assessing personality traits, one of the most prevalent and reliable personality assessment techniques is the Big Five personality traits model developed by Goldberg (1992). To evaluate the unique contributions of each personality trait as predictors of workplace accidents, the Big Five personality dimensions are summarized as follows:

Extraversion is defined as overconfidence, intolerance, and aggression, which can be expressed as a need for sensation and excitement (Man and Chan 2018, Fielden et al. 2015). Due to the outgoing nature of people high in extraversion and their propensity for stimulation in the external world, several empirical studies have supported a positive relationship between extraversion and accident involvement (Jonah 1997, Henderson 2004, Clarke and Robertson 2005, Barrick et al. 2013). Christian and his colleagues (2009) found that the sensation-seeking inclination of the trait may lead people to engage in risky behavior. Additionally, researchers hypothesize that extraverted individuals may be more likely to cut corners or work unsafely to complete tasks faster or gain advantage over coworkers (Barrick et al., 2013).

Agreeableness is characterized by cooperativeness, trust, altruism, tender-mindedness, and compliance (Clarke and Robertson 2005, Beus et al. 2015). Traits associated with this dimension include being courteous, flexible, trusting, good-natured, cooperative, forgiving, soft-hearted, and tolerant (Barrick and Mount 1991). Since agreeableness is related to the goal of cooperation among team members, it is expected that this personality trait would motivate workers to behave more safely

(Gao et al. 2020). Traits associated with low agreeableness encompass belligerence, hostility, aggression, and an inability to cooperate effectively with others. Individuals with low-agreeableness traits are more likely to respond aggressively to situations, thus increasing their potential for accident involvement (Jonah 1997, Clarke and Robertson 2005, Graziano et al. 2007, Templer 2012).

Conscientiousness refers to the extent to which people are dependable, careful, thorough, persistent, hard-working, and motivated in pursuing and accomplishing goals (Barrick and Mount 1991, Man and Chan 2018). Individuals who score low on this trait may be more likely than others to be inattentive, ignore rules, and be at greater risk of workplace accidents (Hogan and Foster 2013). Since conscientiousness is related to the goal of achievement, this trait may reduce the likelihood of such individuals to engage in unsafe behaviors (Gao et al. 2020). Furthermore, because highly conscientious individuals are predisposed to pursuing the higher-order goal of accomplishment and less likely to violate safety rules; this personality trait consistently predicts safety-related behavior (Clarke and Robertson, 2005, Barrick et al., 2013). In effect, conscientious workers are less likely to engage in risky events by allocating sufficient attention across hazardous scenes to identify hazards and react suitably for a safe outcome (Hasanzadeh et al. 2019).

Neuroticism is defined as the tendency to experience frequent and intense negative emotions such as anxiety, depression, and irritability in response to stress (McCrae & Costa 1987, Henderson 2004, Barlow et al 2014). Whereas people who are low in neuroticism (emotionally stable) tend to be calmer, secure, and more confident, highly neurotic individuals are usually preoccupied with distractions, negative emotions, and external stressors that adversely affect safety-related behaviors (McCrae and Costa 1987, Beus et al. 2015). More so, many studies have found a strong correlation between neuroticism and accident involvement (Hansen 1989, Clarke and Robertson 2005, Gao et al. 2020). For instance, Hansen (1989) contended that the increased accident involvement of neurotics is a result of their distractibility from the task at hand due to a preoccupation with anxieties and worries.

Openness to experience refers to an individual's active imagination, preference for variety, and intellectual curiosity (Cullen et al. 2002). High scorers on openness are creative, unconventional, curious, broadminded, and cultured (Clarke and Robertson 2005). In contrast, people who are low on the openness trait are more conservative and demonstrate a liking for ideas that are familiar and conventional (Costa and McCrae 1992). These individuals may be unwilling to deviate from the status quo and are usually more comfortable in following routines and procedures that reduce uncertainty (George and Zhou 2001). However, persons highly open to experience typically hold a lower level of risk perception, leading to an increased tendency to exhibit risk-taking behaviors (Pourmazaheriana et al. 2017, Man and Chan 2018).

2.3.4 Visual Attention and Safety Performance

The eyes are the most active of all human sense organs, continually moving as they scan and inspect details of the visual world (Noton and Stark 1971). These sensory receptors have finite capacities and are unable to attend to everything in their surroundings at once (Nilsson 1989). Therefore, the human brain, in accord with the eyes, must process information selectively in a variety of domains due to limited attentional resources (Luck and Ford, 1998).

Selective attention— the process through which attention of focused on objects of interest while filtering out distracting competing information —is the pathway to conscious experience, affecting our ability to perceive and process various sensory information and stimuli in the environment (James 1890). It denotes the allocation of limited processing resources to deal effectively with some stimuli or tasks at the expense of others (Kowler et al., 1995). Because attention is often directed toward the point one looks at, such selective sensory processing is needed by construction workers during their serial scanning of objects in order to break down complex scenes for effective visual search performance. In addition, directing one's gaze systematically towards objects of interest and suppressing focus from other distracting elements aids effective processing—and detection—of potentially hazardous situations (Bhoir et al., 2015; Hasanzadeh et al., 2019).

As the movement of the eyes plays an important role in understanding and analyzing visual perception, eye tracking has gained some traction over the years as a technique that facilitates inquiry into the visual and cognitive processes of humans (Salvucci and Goldberg 2000). The most commonly used measures to explore oculomotor behavior in eye-tracking studies are fixations and saccades. When viewing an object, the eyes alternate between fixations—when they are aimed at a fixed point in the visual field—and rapid movements called saccades. Each saccade leads to a new fixation on a different point in the visual field (Noton and Stark 1971). Since visual acuity is suppressed during saccades—with very little visual processing taking place—perception mostly occurs during fixations, making them an important metric for measuring attention and cognitive processes (Salvucci and Goldberg, 2000). Additionally, eye movements reflect information processing and are useful when assessing attention during search (Zhao et al. 2014). Considerable evidence suggests that the paths the eyes follow when inspecting a scene provide visual cues for the perception and recognition of significant events by the brain (Moore and Fallah 2001). Thus, eye tracking provides a reliable approach to tracking workers' focus of attention (Fang and Cho 2015, Hasanzadeh et al. 2017,2018,2019, Aroke et al. 2020, Liko et al. 2020). An important benefit of studying eye movements using this technique is its ability to capture—and measure—eye activity continuously and objectively throughout a visual task without interruption (van de Merwe et al. 2012). Therefore, the current study utilized eye-tracking technology to examine the influence of individual characteristics on attentional allocation and hazard-identification. The research also examined the extent to which personality variables moderate — that is, enhance or diminish — the detection of obvious and concealed dangers.

2.3.5 Point of Departure

Although worker characteristics have been shown to significantly impact the safety behavior of workers, little is known about the extent to which personality variables impact this association. One explanation for high injury rates in the construction industry is that workers are unable to identify hazards, analyze the magnitude of those risks, and/or make timely precautionary decisions in dynamic and complex construction environments (Sacks et al. 2013, Hasanzadeh et al. 2017b). This hazard-identification ability—a multi-component cognitive skill—is fundamental to effective safety management and largely depends on the experience and personality of individuals (Deery 1999, Fang and Cho 2015). When safety risk is accurately recognized, workers are more likely to adopt responsive safety measures to prevent injuries and fatalities (Arezes and Miguel 2008). Given how many activities take place concurrently on job sites, safety decisions often face severe time constraints, underscoring the crucial role attention plays in ensuring the safety of workers in dangerous environments. Accordingly, research needs to fill a current gap in knowledge regarding (1) how workers with different individual characteristics distribute their attentional resources to process visual information during hazard-identification activities and (2) how their search strategies might change due to their individual characteristics.

The present study applied a moderated mediation model to (1) understand the role of attention (indicated here via eye movements) as a mediator of the effect of worker characteristics on hazard-identification, and (2) explore the impact of personality traits as moderators of the relationship between worker characteristics and hazard-identification. Specifically, the research team examined the following hypotheses:

2.3.6 Hypotheses

Hypothesis 1: Cognitive processing (especially visual attention) will mediate the impact of worker characteristics on hazard-identification performance.

While various studies have established the positive influence of work experience, training, and injury exposure on the vigilance of workers in complex surroundings (e.g. Sawach et al. 1999, Dong et al. 2004, Westaby and Lee 2013, Hasanzadeh et al. 2017, Aroke et al. 2020), previous research has generally overlooked the questions of how workers' characteristics (i.e., work experience, safety knowledge, and previous injury exposure) influence their visual search strategies when scanning a scene for hazards, and how differences in attentional allocation and search strategies may impact the hazard-identification performance of workers. Accordingly, by monitoring empirical measures of attention coupled with worker-characteristic data, this study will evaluate how worker characteristics impact the hazard-identification performance of workers.

Hypothesis 2: Personality traits will moderate the associations between worker characteristics, attention and hazard-identification performance.

Given previous empirical findings (e.g., Beus et al. 2015, Lee and Dalal 2016, Feng et al. 2017, Man and Chan 2018, Gao et al. 2020), personality traits may moderate the impact of worker characteristics on hazard-identification performance. Consequently, the present authors hypothesize that the effect of worker characteristics (i.e., work experience, training, and injury exposure) on hazard-identification performance will be lessened or intensified by different personality traits (i.e., extraversion, neuroticism, conscientiousness, agreeableness, and openness to experience).

2.4 Research Methodology

To test the research hypotheses, the influence of personality dispositions on the relationships between worker characteristics, visual attention, and hazard-identification was examined. Data collection and analysis are described in subsequent sections.

2.4.1 Data Collection

2.4.1.1 *Participants*

In total, 51 human subjects (31 construction workers and 20 undergraduate students with work experience in construction) were recruited to participate in the experiment. Construction workers were general laborers with an average of 12 years of experience in the residential and commercial sectors of the construction industry. Years of experience varied as follows: less than 1 year (37%), 1-5 years (24%) and more than 5 years (39%). 45% of recruited workers had received the Occupational Safety and Health Administration (OSHA) 10-h/30-h training, while 55% acquired onsite/informal safety training. All recruited students who represented novices in the current study had fewer than five years of experience. Of these participants, 5% had received the OSHA 10-h/30-h training, while 15% acquired onsite/informal safety training. No form of training was reported among 80% of the students.

Regarding injury exposure, a total of 33% of the participants reported that they had been exposed to an injury on the job. All participants had a normal or corrected-to-normal vision. All research procedures were approved by the Institutional Review Board (IRB) of George Mason University.

2.4.2 Experimental design

Thirty-five high-quality construction-site images were selected from a pool of 150 images obtained from the safety managers of the Construction Industry Institute (CII). These snapshots were taken from residential and commercial construction sites across the United States. The selected images comprised potential and active hazardous scenarios, including ladder, housekeeping, fall-to-a-lower-level, fall-protection systems, struck-by, electrocution, and caught-in-between hazards. The associated construction trades in the images included carpenters, roofers, electricians, plumbers, painters, general laborers, equipment operators, ironworkers, painters, masons, and welders. Because falls are the leading cause of deaths in the construction industry and accountable for 33.5% of all construction worker deaths (Jahangiri et al. 2019; BLS, 2020; JFABIAN, 2021), the current study focused on fall hazards.

Areas of interests (AOIs) that contained active and potential hazards were defined by five safety managers in the preliminary stages of the research. This process involved a review of each image to identify the hazards and associated risks in each scenario. The safety managers had at least ten years of work experience in residential and commercial building construction. In total, the safety managers identified 115 fall hazards in the images; these hazards included ladder, fall-to-lower-level, and fall–protection system hazards and provided the basis for examining subjects' hazard-identification skills. Participants first provided consent to participate and then filled out demographic and personality assessment questionnaires. Eye movement data was collected during the experiment via an SR Research Eyelink II eye tracker (Fig. 2.1), which tracks eye-movement patterns in real-time using corneal reflections and pupil tracking at a rate of 500Hz. The Eyelink II eye tracker uses two miniature cameras mounted on the headset to continuously monitor subjects' viewing paths and gaze points as they attend to a scene. Participants were seated approximately 45 centimeters (cm) from the computer screen on which they observed scenario images. Thresholds for detecting the onset of saccadic movements were accelerations of 8,000°/s2 , velocities of 30°/s, and distances of 0.5° of visual angle. Movement offset was detected when velocity fell below 30°/s and remained at that level for 10 consecutive samples. Calibration, validation, and drift corrections for each participant's point of gaze were performed before the experiment commenced.

Based on the findings of our previous studies (e.g., Hasanzadeh et al. 2017, 2018, Aroke et al. 2020), two fixation-related eye movement measures were used as dependent variables: time-to-first-fixation and dwell time. Time-to-first-fixation measures the amount of time (in milliseconds) between when an image appears on the screen and when a participant focuses on an area of interest defined by the safety professionals. This fixation-derived metric generally assesses the depth of cognitive processing of visual information and the spatial distribution of attention (Zhao et al. 2014). Dwell time is the total duration each participant viewed each AOI over the course of a trial. This fixation-derived metric reveals how much time participants spent scanning a scene for important targets as a result of cues in the images that aid perception (Jacob and Karn 2003). In other words, dwell time indicates the relative importance of the AOI to an individual. These measures allow the authors to determine how quickly an AOI is fixated and how long it is processed, which serves as a direct proxy for attentional allocation.

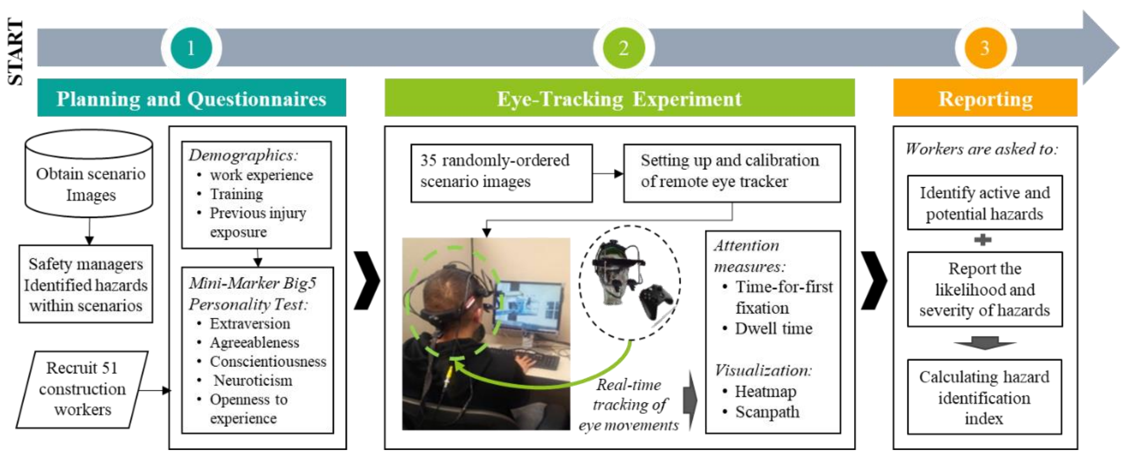


Figure 2.1. Data collection procedure

Images appeared for a maximum of 20 seconds, and the participants were asked to search for active and potential hazards in each scenario image. At the end of each trial, the participants verbally reported the number and type of recognized hazards. It took about 15-20 minutes for each participant to complete the entire experiment.

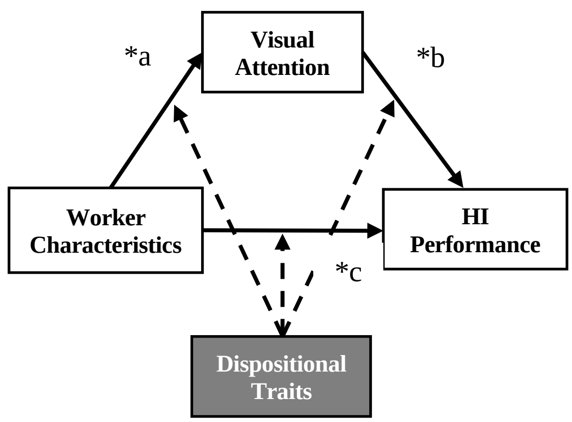
2.4.3 Data Analysis

2.4.3.1 *Moderated mediation model*

To investigate the strength of the associations between worker characteristics, personality traits, visual attentional distribution and hazard-identification, the authors proposed a moderated mediation model. A mediation model investigates the means by which an independent variable (X) exerts its impact on the dependent variable (Y) through an intervening mediator (M) (Preacher et al. 2007, Edwards and Lambert 2007). This dynamic signifies that the independent variable X influences the mediator variable M, which in turn impacts the outcome or response variable Y (Wang and Preacher, 2015). Moderation occurs when the strength or direction of the relationship between two variables differs across levels of a third variable (W), or moderator (Baron and Kenny 1986, Preacher et al. 2007, Edwards and Lambert 2007) and can be implemented with mediation analysis to examine how direct, indirect, and total effects vary across levels of a moderator variable (Edwards and Lambert 2007). In other words, in moderated mediation models, the means by which an independent variable X transmits its effect to a dependent variable Y through a mediator M is potentially conditional on the value of a moderator variable W (Hayes 2015).

Given the dearth of moderated mediation models in the area of occupational safety (e.g., Xia et al. 2020), the authors drew on research from existing studies that have explored the technique in other domains, such as behavioral research (e.g., Preacher et al. 2007), structural modeling (e.g., Wang and Preacher 2015), organizational development (e.g., Lan et al. 2017), and social psychology (e.g., Thorrisen 2013, Barnir et al. 2011, Carvalho et al. 2019, Kao et al. 2019).

Building on existing literature regarding worker characteristics and safety performance, the model in this study assumed worker characteristics have both direct and indirect effects on hazard-identification performance. We hypothesized that years of experience, training received, and previous injury exposure will influence the visual search patterns of the workers, which will in turn impact hazard-identification performance. Furthermore, the authors hypothesized that personality traits will moderate the overall effect of worker characteristics on hazard-identification performance, with the influence of worker characteristics varying as a function of individual differences in personality traits. This investigation was conducted using a moderated mediation model (Fig. 2.2).



*Paths a, b, c

Figure 2.2. A moderated mediation model showing personality traits as moderators in the association between worker characteristics, visual attention, and hazard-identification.

The moderated mediation model was developed to reveal where personality traits act as moderators in the association between: (1) worker characteristics and hazard-identification; (2) worker characteristics and visual attention; (3) visual attention and hazard-identification. Note that we tested a separate moderated mediation model for each of the three worker characteristics (i.e., work experience, safety training, and previous injury exposure) and for each of the five personality traits (extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience).

2.4.4 Measures

2.4.4.1 *Predictor variables: worker characteristics*

The independent or predictor variables were worker characteristics—work experience, safety training, and previous injury exposure—work experience (ranged from “no experience” to “highly experienced”), and injury exposure, which was categorized based on whether participants had never been injured or possessed work-related injury experience. The training was classified according to whether they received no training, informal onsite training, or the formal OSHA 10-h/30-h training.

2.4.4.2 *Dependent variable: hazard-identification performance*

Participants were asked to scan scenes and verbally report the identified hazards. The research team recorded their responses and took notes on the identified hazards. Subsequently, the hazard-identification index (adopted from Carter and Smith 2006, and Hasanzadeh et al. 2017b) for each subject was derived by dividing the number of fall hazards identified by the total number of potential and active fall hazards within each scenario image (Eq. 1). The average performance of workers was calculated based on the average of their HI-Index across 35 scenario images.

$$\text{HI Index for each image} = \frac{\text{Number of fall hazards identified by worker}}{\text{Total number of (potential and active) fall hazards}} \qquad \text{Eq. 1}$$

2.4.4.3 *Mediator variable: visual attention*

We investigated whether visual attention mediated the effect of worker characteristics on hazard-identification performance, with time-to-first fixation and dwell time serving as proxies for attention.

2.4.4.4 *Moderator variable: dispositional personality traits*

The Big Five personality dimensions were assessed using the 40-item mini-marker inventory of Saucier (1994). These items comprise forty (40) personality descriptions and represent an established subset of the 100 adjective markers developed initially by Goldberg (1992). The Big Five personality questionnaire included an array of broad traits that described the attributes of extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience. Participants completed the questionnaire and reported how accurately each trait described them on a 7-point Likert scale ranging from one (very inaccurate) to seven (very accurate). Personality scores for each dimension are based on the responses to the corresponding questions. All Cronbach alpha values for each trait were greater than the suggested acceptable level (i.e., a reliability coefficient of 0.70 or higher). Scores below the 25th percentile comprised low levels, while those between the 25th and 75th percentile constituted average levels. Similarly, scores above the 75th percentile were indicators of high levels of a personality dimension.

2.4.5 Analytic strategy

The research hypotheses were tested using the nonparametric bootstrap procedure in Statistical Package for the Social Sciences (SPSS) 26.0 PROCESS Macro, developed by Hayes (2013). This procedure was also used to obtain 95% confidence interval estimates to test the mediation effects in the model.

Bootstrapping is a nonparametric resampling technique that involves repeatedly drawing samples from the data and estimating the indirect effect of the independent variables on the dependent variable through the mediators in each resampled data set (Preacher and Hayes 2008, Raes et al. 2013). When this process is repeated randomly with replacement over a thousand times, an empirical approximation of the sample under study is generated and used to construct confidence intervals to estimate the conditional indirect effects of the predictor variables on the outcome through the mediator variables (Boelen and Klugkist, 2011). In the present study, 5,000 bootstrap samples were generated using random sampling with replacement from the data set. The generated lower-and upper-level 2.5% confidence intervals were used to estimate the conditional indirect effects of the independent variable on the dependent variable via the mediators. The 95% confidence interval for the conditional indirect effects of work experience, injury exposure, and training on hazard-identification performance were probed at low, medium and high moderator values. We also examined conditional direct effects in the presence of significant interactions. In the context of a relatively modest sample size, we also considered interactions and conditional effects with $p < .10$ but discuss them as trending toward significance and emphasize the need for replication in future research.

The multi-collinearity, reliability, and correlation among the five personality traits were examined to ensure the fitness of the variables for inclusion in the study. Multi-collinearity refers to a high linear relation between two or more variables. Inter-item correlations greater than 0.80 may pose challenges with the reliability of the model parameter estimates (Allen 1997). To avoid problems of multi-collinearity, the authors ascertained that the mediators, moderators, and predictors were not correlated beyond acceptable statistical limits using Pearson's correlation analysis. The results showed that all inter-item correlations were below 0.80. Also, the correlation between the mediator variables (dwell time and time-to-first-fixation) was 0.49.

2.5 Results

2.5.1 Descriptive Statistics and Correlation Between Variables

Five subjects were excluded from the experiment due to calibration issues that resulted in missing values for the oculomotor metrics. Data from four participants were deemed unusable and removed from subsequent data analysis due to substantial missing values in the survey. Eventually, 41 sets of responses were considered valid and included in the analysis (Work experience: < 1 year (46%), 1-5 years (24%), > 5 years (30%); Training: No training (51%), informal training (24%), OSHA 10Hr/30Hr (25%); Injury exposure: No injury (66%), previously injured (34%)).

For the predictor variables, work experience was positively correlated with training (r = 0.604, p = 0.000) and injury exposure (r = 0.478, p = 0.002). A similar relationship was observed between training and injury exposure (r = 0.358, p = 0.022). The mediators, dwell time and first fixation, were moderately correlated (r = 0.487, p = 0.001). Moreover, a moderately positive association was observed among the moderators. Extraversion was positively correlated with agreeableness (r = 0.358, p = 0.021), conscientiousness (r = 0.288, p = 0.068), neuroticism (r = 0.624, p = 0.000), and openness (r = 0.401, p = 0.009). Agreeableness was weakly positively associated with conscientiousness (r =0.180, p = 0.259), neuroticism (r = 0.350, p = 0.025), and openness (r = 0.344, p = 0.028). Furthermore, conscientiousness was positively related with neuroticism (r = 0.318, p = 0.043) and openness (r = 0.299, p = 0.057), similar to the relationship observed between openness and neuroticism (r = 0.324, p = 0.038).

2.5.2 Mediation Model

As detailed above, mediation is an analytical concept used to examine whether an independent variable (IV) conveys an impact on a dependent variable (DV) through an intermediate variable (Tofighi and Thoemmes 2014). In mediation analysis, it is assumed that the total effect of an IV on a DV is composed of a direct effect of the IV on the DV, as well as the indirect effect of the IV on the DV via the mediator (M) (Boelen and Klugkist 2011). Accordingly, a direct effect measures the impact of the independent variable on the outcome variable, controlling for the influence of the intervening variables. Mediation, or an indirect effect, is said to occur when the effect of an independent variable on a dependent variable is transmitted via a mediator (Preacher et al. 2007, Preacher and Hayes 2008). As shown in Table 2.1, the direct effects of work experience (B = 0.010, p = 0.000) and training (B = 0.063, p = 0.017) on hazard-identification were positive and significant, implying that these characteristics enhanced the ability to identify the fall hazards in the construction images, controlling for the effects of visual attention (Fig. 2.3).

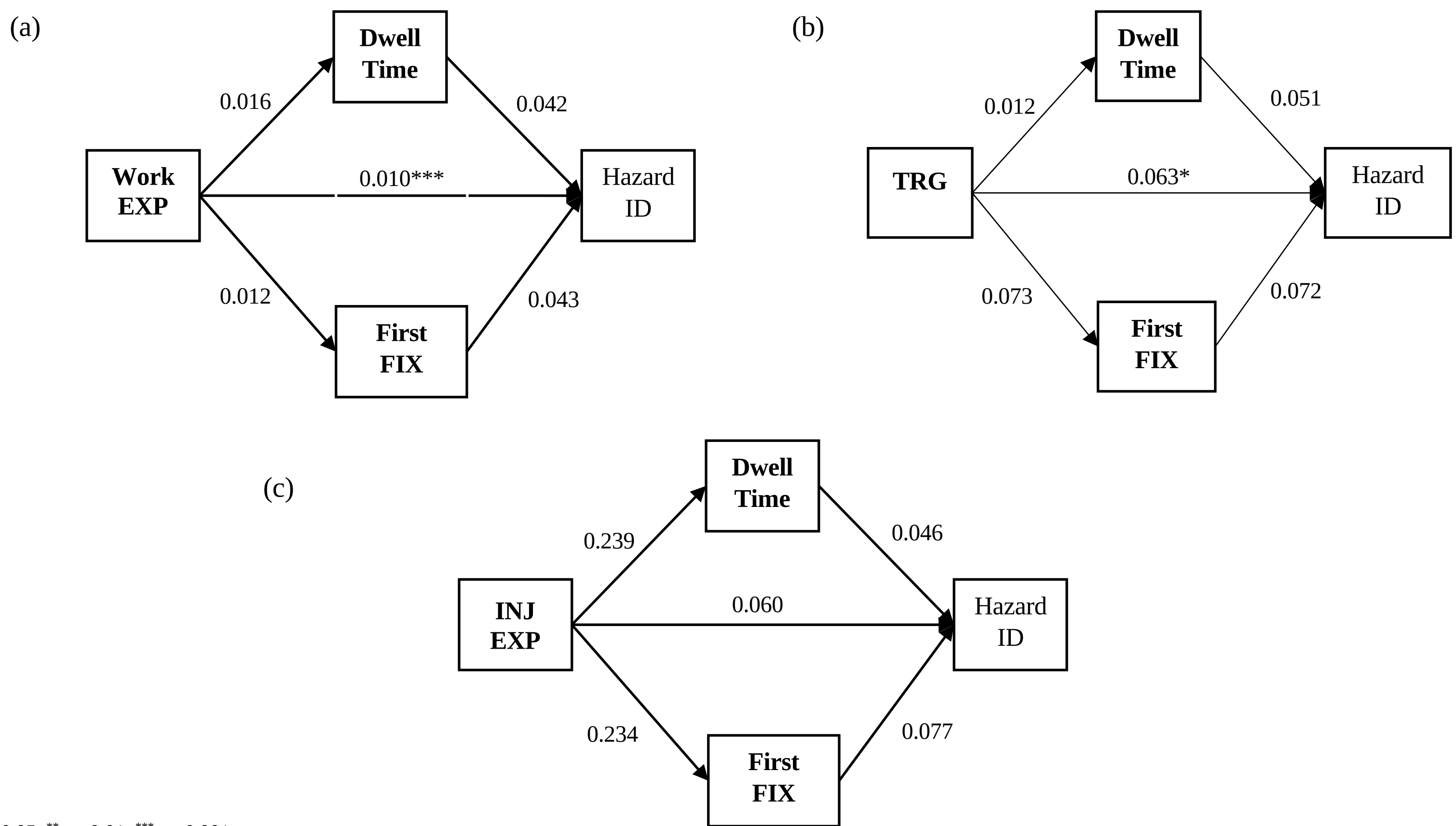
Table 2.1. Influence of worker characteristics and visual attention on hazard-identification performance

Outcome	Predictor in Each Model	Effect	Mediator	R^2	*F*	*Model P-value*	*B*	L-CI	U-CI
Hazard ID	Work Experience	Direct		0.502	12.419	0.000***	0.010	0.006	0.014
		Indirect	Dwell Time				0.001	-0.001	0.002
			First Fixation [a*]				0.001	-0.001	0.002
	Training	Direct		0.316	5.687	0.003**	0.063	0.012	0.114
		Indirect	Dwell Time				0.001	-0.014	0.023
			First Fixation [a*]				0.005	-0.010	0.025
	Injury Exposure	Direct		0.231	3.708	0.020*	0.060	-0.037	0.157
		Indirect	Dwell Time				0.011	-0.023	0.045
			First Fixation [a*]				0.018	-0.008	0.063

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

[a] First Fixation= time-to-first-fixation. L-CI: Lower confidence interval; U-CI: Upper confidence interval.

Concerning the influence of visual attention, the effect of work experience, training, and injury exposure on hazard-identification through the mediators—dwell time and time-to-first-fixation—straddled zero. This suggests that the data did not provide sufficient evidence of mediation and hypothesis 1 was not supported. However, given the possibility of the presence of indirect effects of visual attention at certain levels of personality dimensions, the research team proceeded to test the second hypothesis.



$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

[a] First Fixation= time-to-first-fixation. L-CI: Lower confidence interval; U-CI: Upper confidence interval.

Figure 2.3: Unstandardized estimates of model paths demonstrating effects of worker characteristics and visual attention on hazard-identification performance

2.5.3 Moderated Mediation Model

To test *Hypothesis 2*—personality traits will moderate the direct and indirect associations between worker characteristics and hazard-identification performance through dwell time and time-to-first-fixation—a moderated mediation model was examined (Figure 2-2). The coefficient of variation (R^2) and corresponding p-value for hazard-identification is reported for each model demonstrating the degree of variability in hazard-identification explained by all predictors in the model. The nonparametric percentile bootstrap resampling method—resampled 5,000 times to derive the 95% confidence intervals—was used to test conditional direct and indirect effects at different levels of personality traits. Table 2.2 below provides a summary of results from the moderated mediation models for those models that had a significant interaction between a personality trait and one of the predictors in the model.

Table 2.2: Summary of significant interactions and conditional direct effects across models

Predictor	Moderator	Outcome	Mediator	Variable	β	t-value	p-value	L-CI	U-CI	R^2	Model p-value
WORK EXPERIENCE	Conscientiousness	TTFF	-	Work Experience	0.106	2.152	0.038**	0.006	0.205	0.201	0.038**
				Conscientiousness	0.003	0.231	0.819	-0.026	0.032		
				Int_1 (Path a)	-0.003	-1.900	0.065*	-0.005	0.001		
		Hazard ID		Work Experience	0.003	0.193	0.848	-0.027	0.033	0.629	0.000****
			Dwell Time		-0.417	-2.283	0.029**	-0.789	-0.046		
			TTFF		-0.645	-2.186	0.036**	-1.244	-0.045		
				Conscientiousness	-0.061	-3.098	0.004***	-0.102	-0.021		
				Int_2 (Path b)	0.011	2.433	0.021**	0.002	0.021		
				Int_3 (Path b)	0.020	2.443	0.020**	0.003	0.037		
	Openness	Dwell Time	-	Work Experience	-0.212	-1.852	0.072*	-0.444	0.020	0.151	0.106
				Openness	-0.049	-1.997	0.053*	-0.098	0.001		
				Int_1 (Path a)	0.005	2.073	0.045**	0.001	0.010		
		TTFF	-	Work Experience	-0.077	-1.489	0.145	-0.181	0.028	0.185	0.054*
				Openness	-0.023	-2.104	0.042**	-0.045	-0.001		
				Int_1 (Path a)	0.002	1.820	0.077*	0.000	-0.004		
TRAINING	Conscientiousness	TTFF	-	Training	1.262	2.778	0.009***	0.341	2.182	0.220	0.025**
				Conscientiousness	0.021	1.200	0.238	-0.015	0.057		
				Int_1 (Path a)	-0.031	-2.594	0.014**	-0.055	-0.007		
		Hazard ID		Training	0.056	0.275	0.785	-0.358	0.470	0.421	0.007***
			Dwell Time		-0.274	-1.158	0.255	-0.754	0.207		
			TTFF		-0.749	-1.761	0.088*	-1.614	0.117		
				Conscientiousness	-0.055	-2.083	0.045**	-0.109	-0.001		
				Int_3 (Path b)	0.024	2.040	0.049**	0.001	0.048		

INJURY EXPOSURE	Conscientiousness	TTFF	-	Injury Exposure	1.767	2.263	0.030**	0.185	3.349	0.206	0.035**
				Conscientiousness	0.008	0.547	0.588	-0.023	0.039		
				Int_1 (Path a)	-0.040	-1.977	0.056*	-0.081	0.001		
	Openness	Hazard ID		Injury Exposure	0.075	0.289	0.775	-0.453	0.603	0.366	0.024**
			Dwell Time		-0.351	-1.695	0.099*	-0.773	0.070		
			TTFF		0.170	0.461	0.648	-0.580	0.920		
				Openness	-0.024	-1.692	0.1	-0.052	0.005		
				Int_2 (Path b)	0.011	1.936	0.061*	-0.001	0.022		

$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$; $^{****}p < 0.001$. TTTF: time-to-first-fixation; Interactions: Int_1 - Predictor X Moderator; Int_2- Dwell time X Moderator; Int_3- TTFF X Moderator

2.5.4 Work Experience

The results revealed that ***conscientiousness*** moderated one of the "a paths" from predictor (work experience) to mediator (time-to-first-fixation), as there was a trend toward a significant interaction ($p < .10$) between work experience and conscientiousness ($B = -0.003$, $p = 0.065$) suggesting that the effect of work experience on time-to-first-fixation varied as a function of conscientiousness. An examination of the conditional direct effects revealed that work experience was positively associated with time-to-first-fixation at low levels of conscientiousness ($B = 0.024$, $p = 0.009$). The conscientiousness personality dimension also moderated both "b paths" from mediators—dwell time and time-to-first-fixation—to outcome (hazard identification) as evidenced by significant interactions between dwell time and conscientiousness ($B = 0.011$, $p = 0.021$), and time-to-first-fixation and conscientiousness ($B = 0.020$, $p = 0.020$). The conditional direct effects suggested that dwell time was positively associated with hazard identification at high levels of conscientiousness ($B = 0.076$, $p = 0.020$), while time-to-first-fixation was positively associated with hazard identification at moderate ($B = 0.123$, $p = 0.037$) and high levels ($B = 0.244$, $p = 0.010$) of conscientiousness.

The results also demonstrated that the ***openness*** personality trait moderated the "a path" from the predictor (work experience) to both mediators due to interactions between work experience and the openness personality dimension predicting dwell time ($B = 0.005$, $p = 0.045$) and time-to-first-fixation ($B = 0.002$, $p = 0.077$) paths (note that the interaction predicting time-to-first-fixation was trending toward significance with $p < .10$). An inspection of the conditional direct effects revealed that work experience was positively associated with dwell time ($B = 0.029$, $p = 0.088 < 0.1$) and time-to-first-fixation ($B = 0.019$, $p = 0.018$) at high levels of openness.

2.5.5 Training

The ***conscientiousness*** personality dimension moderated one of the "a paths" from training to time-to-first-fixation as evidenced by a significant interaction between training and conscientiousness (*B* = -0.031, *p* = 0.014). An examination of the conditional direct effects revealed that training was positively associated with time-to-first-fixation at low levels of conscientiousness (*B* = 0.261, *p* = 0.009). Furthermore, conscientiousness moderated one of the "b paths" from mediator (time-to-first-fixation) to outcome (hazard identification) as evidenced by a significant interaction between time-to-first-fixation and the conscientiousness personality dimension (*B* = 0.024, *p* = 0.049). An examination of the conditional direct effects revealed that time-to-first-fixation was positively associated with hazard identification at moderate (*B* = 0.160, *p* = 0.038) and high (*B* = 0.304, *p* = 0.015) levels of conscientiousness.

2.5.6 Injury Exposure

Conscientiousness moderated one of the "a paths" from predictor—injury exposure—to mediator (time-to-first-fixation), as there was a trend ($p < .10$) toward a significant interaction between time-to-first-fixation and conscientiousness (*B* = -0.040, *p* = 0.056). The effect of injury exposure on time-to-first-fixation varied across levels of the conscientiousness, and the conditional direct effects suggested that injury exposure was positively associated with time-to-first-fixation at low (*B* = 0.460, *p* = 0.008) and moderate (*B* = 0.249, *p* = 0.051) levels of conscientiousness, with a stronger effect of injury exposure on time-to-first-fixation at lower levels of conscientiousness.

Openness moderated one of the "b paths" from mediator—dwell time—to outcome (hazard identification) as there was a trend ($p < .10$) toward a significant interaction between dwell time and openness (*B* = 0.011, *p* = 0.061), suggesting that the effect of dwell time on hazard identification varied across levels of the openness personality dimension. A review of the conditional effects signaled that dwell time was positively associated with hazard identification at moderate (B = 0.058, p = 0.049) and high levels (B = 0.142, p = 0.017) of openness.

2.5.7 Conditional Indirect Effects

Despite several instances of significant moderation of specific paths within the larger mediation pathway, conditional indirect effects did not reach significance at low, medium, or high levels of conscientiousness or openness (95% CIs contained zero).

2.6 Discussion

An integrated moderated mediation model was applied to examine (1) the role of eye movements (attentional indicators) as mediators of the relationship between worker characteristics and hazard-identification performance and (2) the influence of personality traits as moderators of these associations. Accordingly, two hypotheses were proposed.

In the current study, *hypothesis 1* was not supported due to insufficient evidence of a mediation through visual attention in the association between the independent variables—work experience, training and injury exposure — and hazard-identification. However, there was a statistically significant *direct* positive influence of work experience and safety training on hazard-identification when controlling for visual attention. Nonetheless, due to the possibility of the presence of significant indirect effects through visual attention at certain levels of personality dimensions, the research team proceeded to test the second hypothesis.

Likewise, *Hypothesis 2* could not be confirmed because the overall pathway from all three predictors (work experience, training and previous injury exposure) to hazard identification through both mediators failed to attain significance at any level of the personality dimensions. However, it was noteworthy that several specific paths within the larger model involving visual attention were moderated by two of the personality traits under investigation – conscientiousness and openness. As such, the unique ways that individuals process information from the environment, due to individual differences in personality, may explain why some workers recognize or fail to identify hazards at jobsites. This result is consistent with the results of other empirical studies regarding the role of visual attention and personality dimensions in construction safety (e.g., Dzeng et al. 2016, Hasanzadeh et al. 2017b, McCabe et al. 2017, Hasanzadeh et al. 2018, Hasanzadeh et al. 2019, Aroke et al. 2020, Liko et al. 2020). More importantly, the findings of the present study revealed that an individual's strategy when allocating limited attentional resources is impacted by worker characteristics, especially their work experience and the intrinsic and extrinsic safety knowledge (i.e., previous injury exposure and safety training).

2.6.1 *Conscientiousness*

Regarding results specific to conscientiousness, the findings of the current study suggest that conscientiousness was a moderator of the effects of certain worker characteristics on visual attention indicators. Specifically, work experience, training and injury exposure were positively associated with time-to-first-fixation at *low* levels of conscientiousness. Thus, workers who had significant years of experience, who had received at least the OSHA 10hr training, and who had been previously injured, but with low scores on conscientiousness were the slowest at fixating on the fall safety hazards. This outcome provides empirical evidence that positive worker characteristics may be less important predictors of safety performance for workers low in conscientiousness. Individuals low in conscientiousness have been characterized as careless, impulsive, spontaneous, disorganized and indifferent, lacking self-control or respect for authority and social order (Clarke and Robertson, 2005; Pourmazaheriana et al. 2017). Low conscientiousness has been regarded as a valid and generalizable predictor of deviant work behavior and accident involvement because these individuals tend to engage in impulsive behaviors, ignoring potential consequences to themselves or others (Gao et al. 2020; Kern 2020). Moreover, lack of carefulness and poor safety conscientiousness increase vulnerability to fall accidents because such workers exhibit low thoroughness through a lack of forward planning, failure to follow rules and regulations, and an absence of a logical approach to decision making when executing tasks in dynamic environments (Clarke and Robertson 2005; Arifuddin et al. 2020).

On the other hand, there was some evidence that a relatively longer time-to-first-fixation and an increased scanning time (i.e., dwell time) across hazardous scenes predicted hazard identification for those high in conscientiousness. This outcome is in keeping with the findings of previous research (e.g. Fleming and England 2020; Landay et al. 2020; Zhang et al. 2020) that personality differences in hazard identification may be partly explained by individual differences in attention. Thus, personality buffering may clarify why workers high in conscientiousness were able to generate high hazard identification scores despite recording the greatest time-to-first-fixation and scanning times when viewing construction images in search for fall safety hazards. As a result, when workers are highly conscientious, their carefulness and detail orientation may help direct their available cognitive resources toward safety-relevant behavior (Postlethwaite et al. 2009; Fleming and England 2020; Zhang et al. 2020), and assist them to identify a significant amount of obvious and concealed fall hazards despite expending a long time to fixate on the hazards initially or scan various areas of interest in search for hazards. Therefore, a long time-to-first-fixation and dwell time may be less important predictors of safety performance for workers high in conscientiousness.

Conscientiousness has been identified as the only personality that correlates well across criterion measures of job performance and consistently predicts safety performance in various occupational settings (Pourmazaheriana et al. 2017; Xu et al. 2020). Conscientious individuals are described as thorough, achievement-striving, self-disciplined, dutiful, orderly, detail-oriented, diligent, organized, hardworking, careful, efficient, planful, socially responsible, rule-following, and risk-avoiding (Postlethwaite et al. 2009; Gao et al. 2020). Empirical studies support significant correlations between conscientiousness, fewer accidents and limited safety violations because individuals high in conscientiousness tend to avoid unsafe and risky behaviors when making choices but take active and balanced approaches to stressors, believing that they possess internal and external resources to cope in stressful situations (Hogan and Foster 2013; Kern 2020; Xu et al. 2020). As a result, various studies emphasize the usefulness of personality-based assessment, particularly measures of conscientiousness, for predicting workplace rule compliance and safety behavior (Postlethwaite et al. 2009; Xu et al. 2020; Xia et al. 2021). Particularly, conscientiousness predicts numerous favorable outcomes such as safety compliance, safety participation, safe behavioral intentions and hazard identification (Postlethwaite et al. 2009; Fleming and England 2020; Gao et al. 2020; Zhang et al. 2020) because this personality trait is associated with vigilance, care, detail orientation and greater visual fixation which directly impact safety performance evaluations. Conversely, the imprecise nature of less conscientious workers makes them vulnerable to cognitive failures that can adversely affect decision-making in critical situations, thereby increasing their susceptibility to sustain injuries in constantly evolving surroundings (Hasanzadeh et al. 2019). The scan paths and heatmaps for experienced workers in the highly conscientious group provided additional insights to how experienced workers who scored high on the conscientious personality dimension distributed their attention across the construction images to identify a significant amount of fall safety hazards. Specifically, an experienced and highly conscientious worker exhibited a different search strategy compared with a less conscientious worker with similar work experience (Fig. 2.4).

(a) (b) (c)

(d) (e) (f)

Figure 2.4: Attentional distributions (heat maps) (images courtesy of David Ausmus, with permission): (a) original picture; (b) attentional distribution of an experienced, highly conscientious worker (c) attentional distribution of an experienced, less conscientious worker (images courtesy of David Ausmus, with permission): (d) original picture; (e) search strategy of an experienced, highly conscientious worker who had received safety training; (f) search strategy of a less conscientious worker who had received safety training.

2.6.2 *Openness*

Results specific to openness indicated that the openness-to-experience personality dimension was a moderator of the influence of work experience on visual attention indicators—due to evidence of a positive association between work experience and dwell time, and work experience and time-to-first-fixation—at *high* levels of openness. Thus, workers who had significant years of experience but high scores on openness were the slowest at fixating on the fall safety hazards and spent the longest time scanning the scenes in search of these hazards. As a result, the expected positive influence of work experience on visual attention was attenuated with high scores in openness.

Previous empirical studies contend that the nature of workers highly open to experience is closely associated with risk-seeking and a greater risk of accident involvement (Pourmazaheriana et al. 2017; Man and Chan 2018; Zhang et al. 2020; Xia et al. 2021). Openness to experience reflects active imagination, aesthetic sensitivity, receptiveness to inner feelings, preference for variety, intellectual curiosity, and independence of judgment (Cullen et al, 2002, Clarke and Robertson 2005; Zhang et al. 2020). Individuals with high scores in openness are characterized as unconventional and broad-minded, typically holding a lower level of risk perception and a tendency to exhibit risk-taking behaviors (Man and Chan, 2018; Xia et al. 2021). As a result, openness positively correlates with unsafe behavioral intentions and a likelihood to seek novel experiences for construction workers with high score on this personality dimension (Zhang et al. 2020). In contrast, people who are low in openness are more conservative and demonstrate a liking for tasks that are familiar and conventional rather than novel and unique (Costa & McCrae, 1992). These individuals may be unwilling to deviate from the status quo, but comfortable with following routines and procedure that reduce uncertainty (George and Zhou, 2001). Accordingly, 'closed' individuals may possess an ability to focus on the task at hand and as such, be at a reduced risk of accident–involved.

Highly open workers tend to be inquisitive, adventurous and daring due to a penchant for experimentation, thereby increasing their susceptibility to rule violations (Gao et al. 2020; Zhang et al. 2020). Such workers are more likely to challenge authority or break existing safety traditions when they become dissatisfied with traditional or routinized environments due to their impulsiveness and willfulness. (Xia et al. 2021). Preference for variety and motivation to attain higher goals of autonomy may cause these workers to pursue greater control of their activities in the workplace, thereby increasing their propensity to ignore safety regulations and explore other actions associated with risk-seeking intentions and experimentation (Pourmazaheriana et al. 2017; Zhang et al. 2020). In the current study, the controlled nature of the hazard identification activity may have unfavorably impacted the attention of highly open workers—as evidenced by a long time-to-first-fixation on fall safety hazards and an increased scanning time across the construction images in search of glaring and concealed hazards—who often seek thrill and experimentation that was minimal in the laboratory task. Conversely, workers low in openness are more conservative and tend to avoid risks, with a preference for conventional tasks which may favorably influence their visual attention and scanning behavior. They also have an improved ability to focus on tasks and are less likely to become accident–involved as a result of their incurious nature (Pourmazaheriana et al. 2017).

However, the outcome of statistical analysis of the injury exposure model disclosed that dwell time was positively associated with hazard identification as evidenced by the visual indicator (dwell time) predicting hazard identification for workers with moderate and high scores on openness, but with a stronger effect at *high* levels of openness. Although workers highly open to experience are more injury prone in a dynamic construction environment due to elements of active imagination, preference for variety, intellectual curiosity, and independence of judgment (Cullen et al. 2002, Guo et al. 2020, Zhang et al. 2020), these properties appeared to assist them in detecting hazards as these workers explored the areas of interest—though in a relatively longer dwell time— and distributed their attention across the scenes broadly to make a more effective utility of the visual field when scanning for both obvious and concealed fall hazards, generating the highest hazard-identification index compared with moderately open workers. This finding resonates with the outcome of previous studies (Costa and McCrae 1992, George and Zhou 2001, Cullen et al. 2002, Homan et al. 2017), which contend that individuals who are highly open to experience possess a variety of perspectives and ideas to explore new ways of doing things and are more adaptable to changing circumstances, as a result of the wide range of experience they encounter in the work environment. However, it is noteworthy that while some characteristics of workers highly open to experience may have facilitated hazard-identification in the laboratory task, this study may be replicated on a dynamic worksite to further ascertain the susceptibility of these workers to injury in complex surroundings and how their approach to hazard identification may change when searching for fall safety hazards in a non-controlled environment.

Fig 2.5 demonstrates differences in the attentional allocation of previously injured workers: a worker who scored high in the openness to experience trait distributed his attention across the scene in a balanced manner to assess all potentially hazardous areas and, as a result, achieved a higher hazard-identification performance.

(a) (b) (c)

Figure 2.5: Attentional distributions (heat maps) (images courtesy of David Ausmus, with permission): (a) original picture; (b) attentional distribution of a previously injured worker who scored high in openness, and (c) attentional distribution of a previously injured worker who scored low in openness.

This study has practical implications for academia and practice. It offers a new theoretical perspective based on empirical evidence regarding the impact of individual differences on the hazard-identification performance of construction workers. Most of the previous studies within this domain focused on subjective survey data. However, the present study incorporated an objective measure of attention to better understand why workers' hazard-identification abilities may be a function of individual differences. Contrary to existing safety literature—which mostly focused on individual differences as separate predictors of unsafe behavior—this study investigated this research question systematically by modeling the hazard-identification performance of workers based on a combination of individual characteristics as predictor, mediator, and moderator variables. This study also broadens our understanding of the role workers' demographic and psychological differences play in their safety performance when exposed to risks at jobsites by clarifying the personality dimensions that may underlie associations with worker characteristics and hazard-identification. Studying the link between certain personality dimensions, visual attention and worker characteristics may be utilized as safety screening tools that would assist organizations to develop selection schemes to scrutinize employees, and assign workers to suitable tasks or designing additional safety interventions for potentially at-risk workers based on their likely safety performance to reduce the risk of accidents in construction environments.

Despite the potential benefits of this study to advancing research and practice, it is important to recognize its limitations. First, workers that participated in the study were recruited from Virginia and Nebraska, which may limit the generalizability of the findings. Future studies may replicate the research by recruiting workers randomly from major parts of the country. Secondly, the current study only considered the personality dimensions of individual participants. However, due to the possibility that personality may manifest favorably in groups, future studies may consider studying groups of workers and investigate the possible interplay of various personalities and the extent to which crew interactions may influence safe behavior. Lastly, the laboratory experiment provided an opportunity to expose workers to several construction safety scenarios, including 115 hazards. However, future studies may expand the findings of this research by examining how hazard-identification dynamics may vary in an environment with multiple safety targets.

2.7 Conclusion

The present study systematically examined the mediating and moderating effects of worker characteristics, dispositional personality traits, and cognitive processing on the hazard-identification performance of workers when exposed to hazardous fall scenarios. Specifically, an integrated moderated mediation model was developed and tested to simultaneously examine visual attentional allocation as a mediating mechanism and dispositional personality traits as moderating factors linking worker characteristics and hazard-identification performance. Overall, this study provides theoretical and empirical evidence regarding a positive association between work experience, training, past injury exposure, and hazard-identification for workers who were highly conscientious and open to new experiences.

Interestingly, our results show personality traits are the pivotal factors that strengthen the worker characteristic effects by accentuating the influence of work experience, training and injury exposure on workers' attentional allocation and visual search strategy across hazardous scenes. The present study contributes to the body of knowledge within the construction safety field by showing that dispositional personality traits may not only influence workers' hazard-identification performance but may also affect how workers distribute their attention when exposed to various hazardous situations. This study also explains how the impacts of worker characteristics (work experience, training, and injury exposure) on their hazard-identification skills can be strengthened or weakened due to personality traits. Beneficially, the integrative approach of assessing mediating and moderating effects together yielded insights that could not be achieved by incorporating piecemeal approaches to examining mediation or moderation effects independently. Consequently, this study also provides an example for ways future construction management studies may harness multi-dimensional factors when assessing the effects of different demographic and psychographic traits in construction-safety discussions.

CHAPTER 3: WORKING MEMORY LOAD AND PERSONALITY TRAITS AS PREDICTORS OF HAZARD IDENTIFICATION PERFORMANCE: A MULTILEVEL MODEL ANALYSIS

3.1 Abstract

This study examined the influence of working memory load on hazard identification, together with the mediating effect of visual attention and moderating impact of personality dimensions underlying this link. The Forward Digit Span test was employed to evaluate the extent to which low and high memory conditions impacted the visual search strategy of workers as they memorized three- (low load) and six- (high load) digit string of numbers while identifying fall protection and fall-to-lower-level safety hazards in 17 low- and 18 high- working memory experimental trials concurrently. Multilevel analyses of data from 38 respondents revealed that hazard identification performance deteriorated 3.4 and 1.2 times more under high working memory load conditions compared with the low load alternative when participants identified fall-to-lower-level and fall protection hazards respectively. Similarly, the association between working memory load and hazard identification was mediated by visual attention, while the conscientiousness and agreeableness personality dimensions demonstrated significant moderation of this relationship. Participants high on both traits displayed superior hazard identification performance under high memory load conditions, suggesting that these workers are likely to be more attentive to hazards when performing multiple tasks in complicated surroundings. Findings would potentially have wide implications for improving safety performance, including the use of selection techniques to assign workers to tasks based on a combination of their cognitive abilities and personality variables

to reduce the risk of injury among vulnerable workers whose attention may become impaired when handling multiple tasks in dynamic environments.

3.2 Introduction

The ability to control attention—which is required for numerous cognitive tasks—closely relates to working memory and its capacity. While attention enables the detection, filtering, and comprehension of stimuli through effective allocation of limited cognitive resources, working memory is utilized for the temporary storage of information necessary for a range of cognitive tasks such as reasoning, learning and comprehension (Baddeley 1986; Cohen 2013). Against this backdrop, attentional control difficulties might reflect poor working memory ability because both rely on similar brain regions for optimal functioning (Burgess et al. 2010). Furthermore, the inability to exert and maintain executive control— the component of attention that monitors and controls information processing necessary to produce voluntary action such as decisions making, error detection, and planning—is a contributory factor in many injuries, such as falls, slips, and trips (Mohammadpour et al. 2016; Chen et al. 2018). Attentional control is associated with the ability to suppress interfering information while maintaining attention to task-relevant stimuli (Conners 2009). However, the amount of information an individual can actively process is severely limited due to the capacity of the working memory because individual differences in working memory are significantly impacted by individual differences in the ability to control attention (Arrington et al. 2014; Fukuda et a. 2016). This may explain why workers with similar experience and safety education possess varying hazard recognition skills and respond to stimuli in complex environment at different rates.

Although multiple items may be held in working memory, very few are relevant in guiding present behavior (Fulvio and Postle 2020). In the busy world of construction, distractions are constantly present, competing for workers' attention as they attempt to focus on executing multiple tasks, while avoiding dangerous equipment and safety hazards on the jobsite. However, working memory distractions may be task-relevant (*e.g., keeping the steps required to install an electrical conduit in mind while repairing a wiring system concurrently*) or task-irrelevant (*e.g., holding a list of family members to contact at the close of work in memory while performing a high-risk activity on site*). These distractions impair cognitive performance and deplete the attentional resources required to fuel the main task, thereby increasing the potential for error (Craik 2014; Zickerick et al. 2020). Notably, effective utilization of limited cognitive resources will aid the comprehension of the construction environment, which will, in turn, allow the interpretation of multiple information and the detection of counterproductive stimuli that may lead to disastrous consequences such as bodily injuries. Thus, a reduced ability to control one's attention as a result of retaining information in memory may increase vulnerability to distractions and unsafe decisions that may put workers at risk of accidents.

One explanation for high injury rates in the construction industry is that workers are unable to identify hazards, analyze the magnitude of those risks, and/or make timely precautionary decisions (Sacks et al. 2013). This hazard identification ability—a multi-component cognitive skill—is fundamental to effective safety management and largely depends on the experience and personality of individuals (Deery 1999; Fang and Cho 2015; Aroke et al. 2020). When safety risks are accurately recognized, workers are more likely to adopt responsive safety measures to prevent injuries and fatalities (Arezes and Miguel; 2008). Thus, because potential dangers in complex environments may go unnoticed when workers become preoccupied with multiple tasks, and unsafe behavior is often associated with workers' insufficient vigilance and misperception of risks, understanding how priority is established and controlled in working memory according to task demands can yield potential benefits in reducing the currently alarming injury rate in the construction industry. Given the large number of activities that take place concurrently on job sites, safety decisions often face severe time constraints, underscoring the crucial role working memory plays in ensuring the safety of workers in dangerous environments. Accordingly, by tracking eye movement patterns under differential cognitive load conditions, this research will fill a current gap in knowledge regarding (1) whether visual attention mediates the effect of working memory load on hazard identification, and (2) the influence of personality traits as moderators of the relationship between working memory load and hazard identification.

3.3 Background

Human beings by their very nature make mistakes, making it illogical to expect error-free performance from employees. It is without surprise, therefore, that human error has been widely implicated in up to 80% of workplace accidents in complex high-risk systems such as aviation (Amalberti and Wioland 2020), petrochemical (Abbassinia et al. 2020), healthcare (Cacciabue and Vella 2010), construction (Bussier and Chong 2020), mining (Yaghini et al. 2018), and nuclear power industries (Ahn et al. 2019). In the construction sector especially, many errors happen daily when performing complicated tasks involving higher mental processes (Einarsson 1999).

Although human error is a complex construct, it generally encompasses occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome (Reason 1990; Sanders and McCormick 1993), resulting from slips (*e.g. attentional failure*), lapses (*e.g. memory failure*) or mistakes (*e.g. failure of intention*). Particularly, errors from attention and memory failures can result from task saturation and mental fatigue that can bring about a loss of situational awareness. Situational awareness measures an individual's perception of elements in the environment over time and space, understanding of their meaning, and predicting their situation in the future which forms the basis of subsequent decisions and actions in safety-critical situations (Shappell and Wiegmann 1997; Grech et al. 2002; Gutzwiller and Clegg 2013; Falkland and Wiggins 2019).

While mechanical failures in the workplace are diagnosable and manageable, errors are symptomatic of human fallibility and are the least controllable aspects of accident causation (Shappell and Wiegmann 1997; Reason 2005). Therefore, reducing the potential for human errors deserves major attention in construction safety and risk analysis so that construction employees who work in risky environments can avoid serious consequences that may result from attention and memory failure.

3.3.1 Visual attention

It is also the case that cognitive psychologists consider human error the result of one or multiple failures in three stages of the cognition process: hazard awareness, recognition and decision making (Fang et al. 2018; Liao et al. 2021). When workers miss hazards, they underestimate the risk of a situation and make decisions under cognitive limitations that increase the potential for injury. Therefore, the ability to recognize hazards is fundamental to minimizing job site risks for construction workers. Particularly, most dynamic environments are characterized by complexity and far more information than the perceptual system can process simultaneously, because a small portion of the information hitting the retinas reaches conscious visual experience (Dodd and Shumborski 2009; Brady et al 2019). Since humans are severely limited in their ability to process all information in the visual environment concurrently, relevant information is selected at the expense of others (Pashler 1998; Ricker et al. 2010). Posner et al. (1998) conceptualized three attention networks that perform distinct roles. They include the *alerting network* that controls the general state of responsiveness to sensory stimulation, the *orienting network* which selects a subset of sensory information for privileged processing, and the *executive attention network*, which is utilized when access to the central, limited-capacity system is keenly required. Accordingly, visual attention plays a central role in the processing of sensory input and is the mechanism that enables the detection, filtering and comprehension of visual stimuli from cluttered visual scenes (Dodd and Wilson 2009; Chen et al. 2018; Brady et al 2019).

3.3.2 Working memory

Working memory is the mental workspace where information is encoded, stored and manipulated in a highly active state and made available for a variety of complex cognitive activities such as comprehension, learning, and reasoning (Baddeley and Hitch, 1974; Baddeley 1992). This limited capacity store has both processing and storage functions, and serves as the site for processing incoming information and storing the products resulting from these processes (Ricker et al. 2010). It is also essential for both learning and retrieval and supports our ability to retain, accrue and manipulate information over short periods of time (Atkinson and Shiffrin 1968; Woodman and Chun 2006). Though working memory mediates most of our conscious interactions with the world (Ricker et al. 2010), humans are severely limited in their ability to memorize visual information over short periods of time (Mayer et al. 2007). Because working memory holds information that is processed in an available state, its size and functioning affect one's ability to think and solve problems (Daneman and Carpenter 1980). The amount of information that can be maintained for quick and easy access at any given time, and protected from proactive interference with other items in the visual world is also limited (Ricker et al. 2010). Similar to the limitation of visual information processing, the number of objects that can be simultaneously attended among distractors is restricted. Some studies (e.g. Duncan et al. 1994; Cowan 2001) contend that only about four objects can be maintained in working memory, while others (e.g. Miller et al. 1960) argue that about seven items can be remembered and repeated, give or take a few, depending on the type of items to be recollected and the capacity of the individual.

Working memory is a multi-component system that includes not only a short-term memory store but also executive processes that operate on the contents of memory (Han and Kim 2004; Cowan 2008).

3.3.3 Short-term memory

Short-term memory reflects faculties of the human mind that is responsible for a range of memory phenomena including memory span and the recency effect in free recall (i.e., the brain's ability to hold up a limited amount of information in a very accessible state temporarily) (Cowan 2008). Items held in the short-term storage decay over time unless control processes are employed to refresh the components using rehearsal (Atkinson and Shiffrin 1968). Alternatively, a number of items smaller than the capacity limit could remain in short-term storage until they are replaced by other items (Daneman and Carpenter 1980).

3.3.4 Executive processes

Executive processes coordinate information from separate subsystems and are required for allocating attention and organizing maintained information in the working memory (Baddeley, 1992). Furthermore, the executive processes are responsible for actively keeping track of examined locations during a visual search and prevent revisitations (*memory hypothesis*). The memory hypothesis maintains that loading the executive working memory with a secondary task will increase the rate of item revisitations, ultimately culminating in a less efficient search and poor performance (Petterson et al. 2008).

Alternatively, executive functioning is utilized to process and identify stimuli, regarded as the *identification hypothesis*. This hypothesis suggests that when executive processes are actively employed in other tasks, items may require a longer time to get identified or may be unprocessed as a result of *inattentional blindness* (Craik 2014). Inattentional blindness occurs when an observer engaged in a resource-consuming task fails to notice an unexpected although salient stimulus appearing in their visual field (Mack and Rock 1998), which may be inconsequential (e.g. failing to notice your colleague in the meeting room as you give a presentation) or catastrophic (e.g. failing to notice a co-worker in close proximity to a moving crane). In the current study, it is possible that participants may examine a hazardous item during the visual search task but fail to identify a potentially dangerous situation within their field of view due to a focus on the secondary working memory task.

Likewise, the executive processes control the disengagement of attention by inhibiting queued shifts of attention especially during visual search tasks that require participants to look away from an object that suddenly appears (*attentional disengagement hypothesis*; Roberts et al. 1994). The potential for premature shifts of attention may result in inadequate processing of objects in the visual field, in addition to interference from a secondary executive task which can cause participants to look at an object rather than away from it.

In like manner, the executive control may be employed in the programming of eye movements (*saccade- programming hypothesis*; Petterson et al. 2008). This hypothesis contends that engaging in a concurrent executive task interferes with eye movement programming and increases the potential for saccade-targeting errors.

3.3.5 Relationship between attention and working memory

It is widely agreed by cognitive psychologists that attention and working memory are closely related as presented in a number of working memory models (Fig. 3.1). The ability to selectively process information in the environment (attention) and retain task-relevant information in an accessible state over time (working memory) are important cognitive functions (Fougnie 2008). However, because working memory and attention share common capacity-limited cognitive and neural resources, these resources become depleted in dynamic environments like construction sites where a high demand is made on both processes, often resulting in interference (Desimone and Duncan 1995; Mayer et al. 2007).

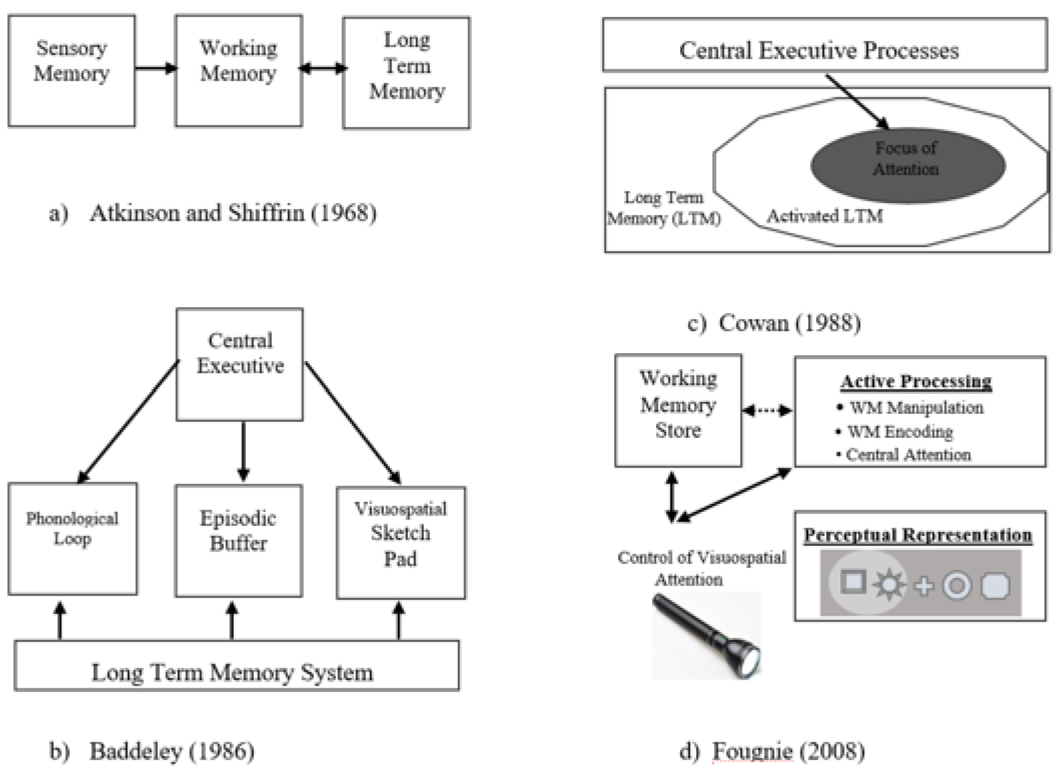


Figure 3.1. Models of working memory as conceptualized by: (a) Atkinson and Shiffrin (1968); (b) Baddeley (1986); (c) Cowan (1988); and (d) Fougnie (2008)

Attention and working memory work at different stages of processing but share similar features in that both mechanisms are concerned with the control of information, operate at the interface between perception and action, and have limits in their information-processing capacity (Mayer et al. 2007; Fougnie 2008). Distinctively, however, working memory influences the allocation of selective attention but the latter is important for filtering irrelevant input and encoding and manipulating information in working memory (Desimone and Duncan 1995; Souza and Oberauer 2017). Attention is also considered the mechanism through which information is stored and retrieved from working memory, in that one needs to focus attention on a spatial location and perceive a stimulus before it is transferred to working memory for ongoing cognition and action (Dodd and Shumborski 2009; Theeuwes et al. 2011).

Construction workers are required to maintain situational awareness to perceive stimuli from tasks and the external environment, while constantly making estimations of their safety in relation to materials, equipment and other obstacles. Certain tasks also require sustained attention and consume a large proportion memory capacity otherwise available for storage, such that overloading the working memory may result in blunders and memory lapses with disastrous consequences.

Thus, considering the temporal nature of construction crews and diversification of tasks, maintaining one’s vigilance in such safety-critical atmosphere requires constant attention and the use of high-level cognitive functions that challenge working memory and impact worker’s safety, productivity and efficiency (Dember and Warm 1979; Wittbrodt et al. 2010; Hedayati et al. 2021).

Such situation causes mental fatigue and affects a worker's ability to anticipate hazardous events in the environment, thereby increasing hazard detection failures due to change blindness (Solomon et al. 2021), inattention and vigilance lapses, all of which heighten the risk of injury (Zhang et al. 2015; Li et al. 2020). Therefore, maintaining a high level of mental concentration and remaining cognitively in control of a task when working in a constantly evolving surrounding with distracting visual stimuli is critical to safe performance.

3.3.6 Impact of working memory on visual search

The successful execution of most goal-directed behavior requires orienting attention efficiently to task-relevant objects in the visual world (Oh and Kim 2004). Locating an item of relevance among a vast amount of information is crucial, especially in dynamic environments that make the most demand on individuals' limited-capacity visual system. Unless an object is already attended or draws attention to itself directly, a visual search operation is required to select the relevant object among other distracting stimuli (Hollingworth and Luck 2009).

Visual search tasks have long been utilized by cognitive scientists to investigate the deployment of attention to targets within complex arrays of conflicting visual information (e.g. Oh and Kim 2004; Woodman and Chun 2006; Mayer et al. 2007). For instance, Woodman and Luck (2004) sought to determine whether maintaining spatial information in visual working memory impaired the efficiency of a concurrent visual search task and found that visual search efficiency and spatial memory accuracy were both impaired when the search and memory tasks were performed concurrently.

In a related study (Han and Kim 2004), the authors examined the involvement of working memory in search using a dual-task paradigm in which participants performed a visual search while maintaining information in working memory. The researchers observed that participants who performed a visual search task with a secondary task that involved counting backward by threes took longer to complete their search because the counting task interfered with visual search by preventing the central executive from contributing to the search process.

Mayer and colleagues (2007) combined visual search and delayed discrimination of complex objects, while independently modulating the demands on selective attention and working memory encoding. The research detected that several visual, parietal and premotor areas showed overlapping activation in the brain for the two task components and were severely reduced in their working memory load response under the condition with high attentional demand. These results indicated that encoding into visual working memory and selective attention require a high degree access to common neural resources.

Hollingworth and Luck (2009) investigated the interactions among visual working memory, attention and gaze control in a visual search task that was performed while a color was held in memory for a concurrent discrimination task. The outcome revealed that when the color of the adjacent distractor matched a color maintained in visual working memory, execution of the secondary saccade was impaired, suggesting that the current content in memory biased saccade targeting mechanisms that directed gaze toward target objects during the visual search.

Taken together, findings from these studies propose that memory representations exert a strong influence on the visual search process, affecting not only selective attention but working memory. As a result, when a visual search task is performed with a secondary working memory task concurrently, interference between the two tasks is expected to occur which may decrease search efficiency (Woodman et al. 2001; Han and Kim 2004). Since working memory capacity is limited to a small number of items (Woodman and Chun 2006), careful utilization of attentional resources is required during demanding visual search tasks in complex environments, especially when working memory is overloaded with irrelevant information that can impact worker safety.

3.3.7 Individual differences in working memory

Working memory processes are essential in human cognition because one must be able to keep information in mind while processing it to function intellectually and socially (Ricker et al. 2010). However, a possibility exists that people differ in their cognitive abilities, such that individual differences in both processing efficiency and storage capacity contribute to overall differences in working memory performance (Cowan et al. 2006). Notably, individuals who demonstrate higher working memory spans have more efficient executive functions when a visual task consumes less attention and leaves more room for storage (McCollough and Vogel 2008). Individual differences in working memory are also predictive of intellectual aptitude and performance in complex cognitive tasks, such as reasoning, memorization and reading span, since both storage and processing must be engaged concurrently to assess working memory capacity (WMC) (Kyllonen and Christal 1990; Cowan 2008; Unsworth and Spillers 2010).

However, theories of attentional control posit that the primary determinant of individual differences in WMC and superior performance in cognitive tasks is one's ability to control attention (Engle et al. 1999; Engle and Kane 2004). This scope of attention has been identified as a fundamental component of WMC which determines the number of items that can be held in focus during a visual search (Cowan et al. 2006). As a result, some cognitive psychologists contend that individual differences in WMC is not strictly about memory storage, but high WMC individuals have greater attention control capabilities and are better at actively maintaining goal-relevant information in the presence of potent internal and external distractions (Baddeley 1986; Engle and Kane 2004). To buttress this view, some studies (e.g. Conway et al. 2001; Engle and Kane 2004) highlighted the difference between high and low WMC individuals on low-level attention tasks in which high WMC individuals were better at controlling aspects of their attention in contrast to low WMC participants who recorded significant difficulty in remembering more items than their focus of attention could handle, even though the demand on memory was low. Similarly, other studies (e.g. Heitz et al. 2004) that measured WMC quantitatively by the number of items recalled on a complex cognitive task observed that the scores on such measures reflected attention-control ability, rather than units of information held in the short-term store. High performers on the task were able to multitask in dual-task situations (that is, maintain goal-relevant information and deal with interference through inhibition of prepotent responses), in addition to strategically allocating resources toward the primary and secondary components of the task to maximize span scores. Therefore, scores in tasks that require controlled attention needed to maintain and retrieve items in memory while preventing attentional capture from other distracting stimuli in the visual environment can reveal high-order cognitive abilities.

3.3.8 Personality and safety performance

Maintaining attention control on construction sites is also influenced by the internal state of individuals and time-independent personality traits (Kaspar and König 2012). Personality refers to relatively stable intellectual, emotional, and functional styles that describe a person and is reflected in various aspects of an individual's life (Costa and McCrae 1995). It may be conceptualized as intraindividual consistencies and inter-individual uniqueness in propensities to behave in identifiable ways in light of situational demands (Tett and Guterman 2000). Personality traits are indicators of individuals' behavioral, cognitive and emotional tendencies (Dhou 2019). They are fundamental determinants of safety behavior that predispose an individual to perform safely or otherwise, and cannot always be effectively controlled by formal workplace rules and regulations (Beus et al. 2015; Xia et al. 2021).

The effect of personality on safety performance—with 60% to 80% of accidents attributed to human fallibility (Cooper 1998)—has prompted organizations to consider that *error-prone* individuals contribute to workplace accidents (Wallace 2004). Early scholars also assert the existence of a stable, dispositional variable, often referred to as “accident proneness” that has caused a limited number of individuals to be responsible for a disproportionately large number of accidents (Greenwood & Woods, 1919; Newbold, 1926). It is also widely suggested that workplace errors have a personality base, and some individuals have a higher probability of incurring an accident because certain attitudes accumulated over time influence decisions and contribute to unsafe acts (Shappell and Wiegmann 1997; Khdair et al. 2012; Beus et al. 2015; Klockner and Hicks 2015).

Personality variables interact with cognitive functions in the form of boredom proneness, unstable emotional patterns and risk-taking, thereby hampering the successful execution of vigilance tasks (Klockner and Hicks 2015; Hedayati et al. 2021). Some researchers (e.g. Daneman and Carpenter 1980; Cowan et al. 2006) also posit that individual differences in processing and storage capacity of the working memory may contribute to the variability in visual search performance by individuals engaged under similar work conditions. People also differ in how they deploy attention in their physical environments and their ability to deal safely and effectively with the complexity of certain work tasks (McIntyre and Graziano 2016; Xia et al. 2021). In the current study, differences in personality dimensions will be examined with the Big Five traits, alternatively referred to as the five-factor model.

3.3.9 The Big Five Personality Model

The Big Five personality model, referred to as the Five-Factor model of personality, has emerged as a valid and reasonably generalizable taxonomy for understanding the range of trait differences observed among individuals (McCrae and John 1992; Jensen and Patel 2011). An advantage of the five-factor model is its systematic approach in the study of personality and its relations to various skills and behaviors such as memory skills (Matthews and Deary 1998), hazard identification (Aroke et al. 2020), accident involvement (Gao et al. 2020), and compliance with institutional norms and rules (Arthur and Graziano 1996). To measure the Big-Five, adjective-based procedures and phrase-based questionnaires are utilized as explicit measures of personality that require a self-report by respondents (Grumm and Collani 2007). The model conceptualizes personality traits in five basic dimensions of personality, namely: extraversion, agreeableness, conscientiousness, neuroticism and openness to experience.

3.3.9.1 *Extraversion*

Extraversion refers to the degree to which an individual actively engages in the social environment (Klockner and Hicks 2015). Extraverted individuals are described as outgoing, social, gregarious, talkative, active, and assertive, whereas introverted individuals tend to be reserved and independent with a desire to remain in solitude (Costa and McCrae 1992; Ashton et al. 2002; Thoms and Venkataraman 2002).

Several empirical studies have supported a positive relationship between extraversion and accident involvement (e.g. Fine 1963; Thorrisen 2013; Zhang et al. 2020). Much of the support for extraversion as a predictor of unsafe behavior has derived from traffic violations (e.g. Tao et al. 2017; Linkov et al. 2019) and risk-taking behavior on construction sites (e.g. Gao et al. 2020; Zhang et al. 2020), where extraverts are significantly more accident– involved. High sensation seekers have a greater tendency to take risks when driving due to the need for novelty and thrills which increases their accident liability (Jonah, 1997). Moreover, because extraversion is associated with behavioral exploration and a desire to compete with and surpass others to increase their perceived status, this attitude may trigger aggression and serve as a motivational force for unsafe behavior

(Nielsen and Knardahl 2015). In addition, the lower level of vigilance of extraverts makes them perform poorly in attention-demanding tasks and therefore, injury-prone (Eysenck, 1962). High levels of extraversion are also detrimental to safe performance because the sensation-seeking aspect of this trait may lead individuals to engage in unsafe activities (Golimbet et al. 2007). In the construction context, extraverts are likely to work unsafely by ignoring safety rules or cutting corners to obtain a competitive advantage over their coworkers (Xia et al. 2021). Therefore, it was anticipated that this personality trait would be associated with a low hazard identification performance and may be more susceptible to the interference effect of cognitive and attention tasks.

3.3.9.2 ***Agreeableness***

Agreeableness examines one's interpersonal orientation and the degree to which an individual is amenable and easy to get along with (Cooper 2003; Goldberg et al. 2006). It includes elements of trust, tact, compliance, cooperation, courtesy, modesty, sympathy, tolerance and altruism (Hough 1992; Borkenau and Ostendorf 2008). Agreeable individuals are motivated to attain higher goals of communion, and thereby strive to retain and foster positive and meaningful relationships with others (Barrick et al. 2013). Individuals low on this trait encompass belligerence, hostility, aggression and lack of personal affection, all of which are associated with accident involvement (Clark and Robertson 2005). Low agreeableness may be considered a valid predictor of work accidents and deviant behavior such as disciplinary problems and organizational rule-breaking (Salgado 2002). Since most construction activities require collaborative efforts in which task completion and safety may be compromised by the actions of a single person, agreeable individuals are less likely to demonstrate unsafe behavior because doing so could jeopardize group well-being and damage interpersonal relationships (Gao et al. 2020; Xia et al. 2021). To this end, this study speculated that the personality trait of agreeableness would be positively associated with vigilance and hazard identification.

3.3.9.3 *Conscientiousness*

Conscientious people tend to be goal-directed, strong-willed, scrupulous, reliable and determined (Costa and McCrae 1992b). The facets of conscientiousness include self-efficacy, orderliness, dutifulness, achievement-striving, self-discipline, cautiousness, competence, order, perseverance, and deliberation (Clarke and Robertson 2005; Wolff and Kim 2012). To pursue higher goals of achievement, conscientious individuals try to successfully complete work tasks punctually, carefully, and efficiently (Liao and Lee 2009; Barrick et al. 2013). On the other hand, individuals low in conscientiousness are characterized by a lack of forward planning and absence of a systematic approach to decision making, suggesting that such people try to meet only immediate demands, do not care about prospective results, lack a sense of goals, violate organizational rules and perform tasks poorly, all significantly associated with accident involvement (Wallace and Vodanovich 2003; Clarke and Robertson 2005).

Previous empirical studies (e.g. Zhang et al. 2020; Swift et al. 2020) have reported a tendency for conscientiousness to correlate well across criterion measures of safety performance because individuals high on this trait tend to avoid risk-taking, follow safety rules and engage in goal-directed behavior (Hough 1992; Klockner and Hicks 2015). Correspondingly, the current study predicted that conscientiousness will be associated with superior hazard identification performance because the conscientiousness trait may influence vigilance when performing cognitive tasks. A study by Matthews (1999) also provides support for this speculation, with the observation that conscientiousness individuals thrive in settings requiring sustained and organized effort, in contrast to those low on the trait who are more vulnerable to cognitive errors that are predictive of workplace accidents.

3.3.9.4 *Neuroticism*

Neuroticism refers to the degree of emotional stability and measures whether an individual easily experiences psychological distress, unrealistic thoughts and excessive expectations (Costa and McCrea 1992). Neurotic people are characterized as emotionally unstable, unable to adjust, pessimistic, self-conscious, anxious, temperamental and insecure (Goldberg et al., 2006; Klockner and Hicks 2015). People high in the neuroticism trait tend to be distracted from work and error-prone because they immerse themselves in anxiety rather than the task at hand (Christian et al. 2009; Liao and Lee 2009). Conversely, individuals with high levels of emotional stability (low neuroticism) are calm, relaxed, secure, resilient and confident, and seldom feel anxious, depressed, or act impulsively to pursue risk (McCrae and John 1992; Wolff and Kim 2012).

Previous meta-analyses (e.g. Eysenck 1962; Salgado 2002) have suggested that neurotic employees have an increased accident liability because they are usually preoccupied with their own anxieties and worries which disrupt concentration from ongoing tasks (Hansen 1989; Clarke and Robertson 2005). They also respond negatively to environmental stressors that decrease cognitive and performance capacities, such as reaction times and judgment, thereby increasing the probability of errors (Steffy et al. 1986; Lee et al. 2003). Due to the foregoing, it was speculated that neuroticism would be associated with poor search performance under memory-demanding tasks.

3.3.9.5 *Openness*

Openness to experience measures the inclination to seek new experiences, and reflects a broad range of characteristics such as unconventional values, aesthetic sensitivity, and need for variety (Zhao and Seibert 2006; Besser and Shackelford 2007). Individuals high in the openness to experience trait are curious, broad-minded, imaginative, daring, risk-seeking, and open to trying new techniques (Goldberg 1990; Abdullah and Marican 2016). Contrarily, low levels of openness to experience are associated with a preference for familiarity, simplicity and closure, with a tendency to be less adventurous and conventional (Zweig and Webster 2004). Due to the motivation to attain higher goals of autonomy and control, highly open individuals may be prone to rule violations, particularly when working in environments where safety compliance is critical (McCrae and John 1992). Construction workers with this trait tend to be dissatisfied with traditional or routine environments and may behave unsafely as a result of their impulsiveness and willfulness (Zhang et al. 2020). The curious and exploratory nature of individuals with high scores on the openness dimension causes a reduced ability to focus on the task at hand, and may contribute to instances of errors and cognitive failure (Clark and Robertson 2005; Klockner and Hicks 2015). As a result, this study posited that open individuals would record a poor visual search performance when performing cognitive tasks.

3.4 Gap in knowledge

Human error has been noted as inherent in cognitive functions and predominate as the cause of failure in several workplace accidents, and cannot be eliminated except by disengaging the service of humans (Rasmussen 1997; Amalberti 2013). Studies in psychology have asserted that certain behaviors are the result of an interplay of personal dispositions and situational conditions which may interact in complex ways to influence active gaze control and attention allocation when viewing complex scenes (Heckhausen and Heckhausen, 2006; Niu et al. 2012). Since all errors have their basis as an individual failing, understanding the human factors underlying major hazard identification errors is of key importance to construction safety management.

Many studies acknowledge that the limited capacity of working memory affects performance during cognitive tasks. Due to the importance of vigilance on worker safety, the influence of working memory on human cognition has been at the core of discussions in the fields of cognitive engineering (Gutzwiller and Clegg 2013); transportation safety (Lambert et al. 2010), accident analysis (Borowsky et al. 2016), bioscience (Olivers 2008), psychology (Theeuwes et al. 2011), Neuroscience (Fischer et al. 2003) psychophysics (Souza and Oberauer 2017) and construction safety (Hasanzadeh et al. 2017; Liao et al. 2021; Liko et al. 2020) in recent years. This investigation was most notable in research by Hasanzadeh and colleagues (2017), who discovered that changes in memory load influenced visual search strategies and awareness of hazards in complex scenes. In their study, analysis of hazard-detection performance and attentional distributions showed that the degree of inspection and information-processing varied significantly under low and high working memory load conditions as participants switched their attention away from the visual attention task and focused on the secondary cognitive exercise when under higher memory loads.

Several studies in psychology have examined the influence of working memory on attention and job performance (e.g., Conway et al. 2001; Kane et al. 2001; Engle 2002; Cowan 2014). For example, Engle (2002) observed that a high working memory load may adversely impact task execution due to the likelihood of selecting an inadequate response when the brain attempts to process multidimensional information concurrently. Similarly, Conway et al. (2001) observed that people may find it challenging to hear their names in an auditory stream with a high working memory load that blocks out vital information and impairs cognitive processing especially during multitasking situations. Due to the correlation between attention and working memory capacity, a low working memory load may improve attentional focus to facilitate safety performance. To ratify this assertion, a study by Gugerty and Tirre (2000) observed that working memory loads impacted the ability of drivers to detect surrounding vehicles and react appropriately to potential risks in the environment. Some studies also discovered a link between high working memory capacity and imprudent driving, increased crashes and poor safety performance (Mäntylä et al. 2009; Ross et al. 2015; Pope et al. 2016; Starkey et al. 2016). Similar to the outcome of driving studies, an aviation study (Carretta et al. 1996) asserted that cognitive factors such as working memory and impaired attention are reliable predictors of pilots' situational awareness.

Concurrently, a body of literature have explored the links between personality traits and accident involvement (e.g. Arthur and Graziano 1996; Cellar et al. 2001; Clarke and Robertson 2008; Mallia et al. 2015; Jusoh et al. 2015; Gao et al. 2020). For example, Rauthmann and colleagues (2012) studied the impact of personality traits on visual behavior and the outcome indicated that three personality traits (extraversion, neuroticism, and openness) were valuable predictors of visual attention. In a related study, Wilbers et al. (2015) examined the relationship between individual differences in personality traits and gaze behavior and found a negative correlation between extraversion and fixation durations independent of stimulus type.

Hasanzadeh et al. (2019) investigated the impact of personality dimensions on the selective attention of workers exposed to fall hazards in a laboratory eye-tracking experiment. The study discovered that individuals who are introverted, conscientious and open to experience are less prone to injury, as these participants distributed their limited attentional resources more broadly to identify the fall hazards within the construction images. Similarly, Gao et al. (2020) observed a positive correlation between conscientiousness and agreeableness and safety behavior, in contrast to extraversion and neuroticism.

Combined, many of these studies mainly focused on the influence of working memory load on components of sustained attention (e.g. Fougnie and Marois 2006; Scanlon et al. 2007; Theeuwes et al. 2011; Souza and Oberauer 2017; Chen et al. 2018; Brady et al. 2019) or concentrated on the role of personality on injury-proneness (e.g. Thoms and Venkataraman 2002; Cellar et al. 2004;

Scott and Wiegand 2005; Landay et al. 2020) independently using piecemeal approaches. Although these investigations have broadened existing knowledge in various domains about the importance of working memory in guiding attention, while also elucidating the role of personality factors in safety performance and accident involvement, it seems insufficient to consider only potential main effects of working memory on visual attention or the impact of personality traits on accident liability. Rather, it would be beneficial to expound the specific interactions that may exist between attention allocation, personality variables and hazard recognition at a cognitive level. Such research would reveal currently unknown cognitive and individual factors responsible for human errors and indicate directions in which construction safety research might be expanded or modified. Thus, considering the cost of human errors in the construction safety domain, it is of concern that no previous research has investigated the relationship between cognitive overload, vigilance, individual differences and safety performance. Since individual differences in working memory capacity influences information processing and the rate at which individuals may orient toward hazards especially during multitasking situations, empirically investigating the extent to which personality traits may modulate visual attention when working memory is actively employed in other tasks has significant implications for safety management.

To address this important research gap, the current study will investigate the complex interactions that exist between working memory load, visual attention, personality traits and hazard identification by manipulating the demand on working memory and visual attention within cognitive and attention tasks using a well-informed and systematic approach that combines statistical analysis and non-invasive eye tracking technology. This research will also identify, predict and analyze the risk of human error by monitoring participants' real time eye movement patterns. Since eye tracking can reveal objective and quantifiable information about the quality, predictability and consistency of underlying process of the human brain when carrying out cognitively demanding tasks (McCarley and Kramer 2008), the technique will be utilized to investigate how construction workers generally perceive, attend, and recollect visual information to make safety decisions while maintaining information in memory and appraising complex environments in avoidance of hazards. Because individual differences in working memory capacity—the ability to maintain information while constraining attention to only relevant spatial locations in the face of distractions or proactive interference—are predictive of performance on complex cognitive tasks (Bleckley et al. 2003; Bleckley et al. 2015), one may anticipate a difference in the way certain personality dimensions will allocate limited attentional resources and select goal-relevant information while ignoring potential distraction when performing visual attention tasks (e.g. hazard identification) and cognitive-demanding tasks (information processing or memorization). In the interest of ensuring the safety of construction workers, it is hoped that developing a better understanding of workers' cognitive impairments due to memory overload that impacts their situational awareness and reduces their concentration when performing multiple tasks will go a long way to reduce human errors and injury liability in distracting and constantly-evolving surroundings.

3.5 Research Methodology

3.5.1 Participants

A total of 38 (30 male, 8 female*)* undergraduate students were recruited to undergo individual 30-minute experimental sessions. Participants were students of Civil Engineering in George Mason University and the University of Nebraska-Lincoln, with an average of two years of work experience in the residential and commercial sectors of the construction industry (87% had work experience less than 5 years and 13% had more than 5 years of experience), while 18% had received the Occupational Safety and Health Administration (OSHA) 10Hr/30Hr training. All participants had normal or corrected-to-normal vision and were oblivious of the purpose of the experiment. The tests were conducted in the Safety, Risk Management, and Decision-Making (SARMAD) laboratory at George Mason University and at the Center of Brain, Biology, and Behavior at the University of Nebraska-Lincoln. All procedures were approved by the George Mason University and University of Nebraska–Lincoln Institutional Review Boards.

3.5.2 Experimental Modeling

The experiment assessed the extent to which low and high memory load conditions impacted the visual search strategy of workers and the degree to which they oriented toward hazards. 35 high-quality construction scenario images obtained from residential and commercial construction sites across the United States were selected from a pool of 150 images and utilized for the experiment. Prior to developing the experiment, key areas of interest (AOI) comprising safety hazards such as fall-protection systems, fall-to-lower-level, housekeeping, ladder, electrocution, struck-by and caught-in-between, the ignorance of which was likely to lead to a safety incident were identified and defined in each construction image by certified safety professionals with over 10 years of work experience. The current study focused on the identification of *fall protection system* and *fall-to-lower-level* hazards because falls are the leading cause of deaths in the construction industry and accountable for over 33% of all construction worker deaths (Jahangiri et al. 2019; BLS, 2020). *Fall protection systems* included all scenarios of non-use or improper lanyard use and inadequate provision of fall protection equipment where necessary. Similarly, hazards categorized as *fall-to-lower-level* included instances of floor openings, missing guardrails, individuals working close to an unprotected roof or building edge, unguarded roof, and improperly installed scaffolding and skylights.

In total, 231 AOIs were identified in all 35 construction scenario images which formed the basis by which hazard identification performance was assessed under both low and high working-memory load situations.

Participants were required to identify construction safety hazards in scenario images as a primary, attention-demanding task. Concurrently, they held a string of numbers in memory that were presented prior to displaying the images which had to be recollected at the end of each trial as a secondary, cognitive task. During the experimental sessions, participants verbally communicated hazards identified in the images on-screen while responses were recorded by the research team concurrently. Notes taken during the experiment in conjunction with audio recordings were employed to match hazards identified by the participants with those outlined by the safety managers. Subsequently, the hazard identification (HI) index was derived by dividing the number of fall hazards identified by the total number of fall-related hazards within each scenario image (Eq. 1). The average performance of workers was calculated based on the average of their HI-Index across the 35 scenario images. Figure 3.2 gives an overview of the experimental design of the study.

$$\text{HI Index for each image} = \frac{\text{Number of fall hazards identified by worker}}{\text{Total number of fall}-\text{related hazards}} \qquad \text{Eq. 1}$$

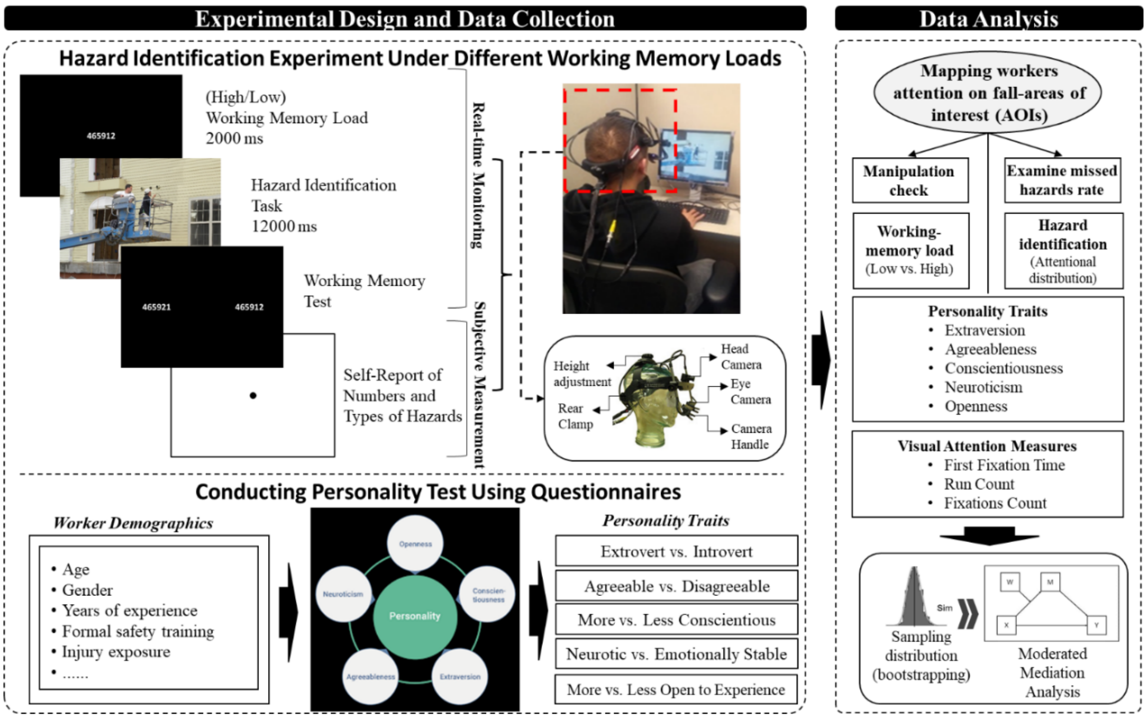


Figure 3.2. Experimental design to investigate the effect of working memory load on hazard identification

The study utilized the *Forward-Digit-Span* test to evaluate the working memory capacity of the subjects. The Forward- (or Backward) Digit-Span is one of the earliest and most frequently used neuropsychological tests to assess working memory capacity by administering cognitive tasks where working memory load is manipulated, and subjects are required to recall digit strings in forward (or reverse) order (Richardson, 2007). At the onset of the trial, a random 3- (low load) or 6- digit (high load) string of numbers that was displayed in white font on a black background appeared on the screen. Participants had to memorize these numbers within three seconds before each hazard-scenario image appeared. Thereafter, a construction image was presented, and subjects were required to search exhaustively for safety hazards within 12 seconds. On completion of the hazard identification task, the correct string of numbers presented at the onset of the trial was displayed alongside an incorrect alternative, with two strings placed out of order. Conclusively, participants verbally reported the hazards to the research team and were duly recorded before another image was displayed to commence the next trial. There was a total of 18 trials administered under the high working-memory load and 17 trials under the low-load conditions.

3.5.3 Eye metrics

The eye movements of participants were monitored in real-time using the SR Research EyeLink II eye tracker, a video-based eye-tracking system that consists of three miniature cameras mounted on a comfortable padded headband. One head-tracking camera detects infrared markers in the visual environment, while two eye cameras focus on the left and right eyes, respectively. This system operates with a high spatial resolution and a sampling rate of 500 Hz.

Eye metrics— describing visual attention allocation patterns—were extracted for each participant using the Eyelink Data Viewer software. To describe participants' visual attention allocation patterns, three eye metrics were employed: Fixation count *(the count of periods of relative eye stability over an AOI during which visual information is processed)*; run count *(the total number of runs, where a run is two consecutive fixations within the same AOI);* and TTFF *(the amount of time that elapses before a participant focuses on an AOI initially)* were utilized as proxies for attention and retrieved for statistical analysis. Employing these metrics to study visual and cognitive performance during vigilance tasks can provide valuable information on scanning behavior and inferences about where processing priority is allocated in a scene, since construction workers often orient their attention to locations where salient information may be obtained.

3.5.4 Analytic strategy: Multilevel modeling (MLM)

The current study hypothesized that i) visual attention will mediate the impact of working memory load on hazard identification performance, and ii) the influence of working memory load on visual attention and hazard identification performance will vary according to personality dimensions. The hypotheses are summarized below:

- *Hypothesis I: Visual attention will mediate the impact of working memory load on hazard identification performance.*
- *Hypothesis II: Personality traits will play a moderating role in the association between working memory load and hazard identification performance.*

To test the research hypotheses, the authors applied an MLM technique (Fig 3.3). A mediation framework involves a three-variable system in which an independent variable affects an intermediate or mediating variable, which, in turn, affects an outcome variable (Baron and Kenny 1986; MacKinnon et al. 2020). Moderated mediation, on the other hand, is employed to investigate mediating processes that vary across levels of a moderator (Kim and Hong 2020). The multilevel modeling is a flexible technique which allows the simultaneous examination of mediated and moderated effects of variables measured at both individual and group levels, as well as possible cross-level interactions in datasets nested within clusters (Raudenbush and Bryk 2002; Konradt et al. 2009; Zitzmann and Helm 2021). This technique allows researchers empirically test interesting research hypotheses about multilevel moderated mediation processes that are not easily clarified using conventional statistical procedures (Mathieu et al. 2008). Primarily, multilevel data tend to result from nested data structures (e.g., students nested within classrooms, individuals nested within teams or employees nested within workgroups). Consequently, repeated measurements are also viewed as a nested data structure where multiple observations are nested within groups (Peugh 2010; Lachowicz et al. 2015). In the current study, this modeling approach will facilitate the analysis and interpretation of the relationships between variables at more than one level of analysis.

For example, an individual-level (L1) variable (e.g. construction workers' personality traits) can be related to variables at the group (L2) level (e.g. low and high working memory loads) respectively.

Drawing on the benefits of this state-of-the-art technique that has been widely applied in various fields, including multivariate behavioral research (e.g. Kim and Hong 2020), statistical science (e.g. Zhang et al. 2009), structural equation modeling (e.g. Zitzmann and Helm 2021) and experimental psychology (e.g. Hu et al. 2020), the study employed the MLM technique to investigate its research hypotheses. Because the sample in the current study consisted of individuals (Level 1) nested within low and high working memory groups (Level 2), a 2-2-2 multilevel modeling approach was adopted to more accurately examine different effects of interest, including mediation and moderation.

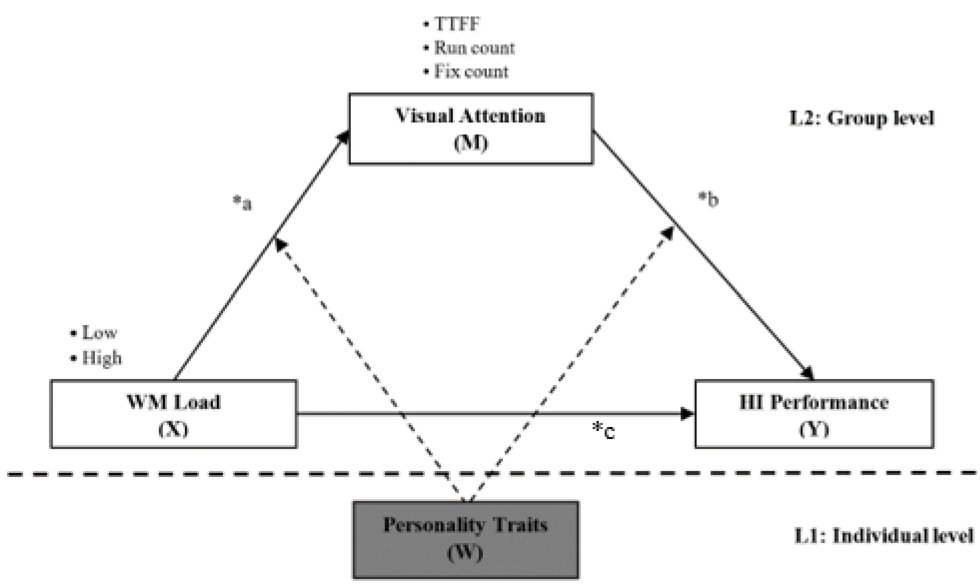


Figure 3.3. A multilevel model showing personality traits as moderators in the association between working memory load and visual attention (*Paths a, b, c)

A group level (L2) multilevel mediation model was designed with an individual level (L1) moderator. Visual attention indicators were included in the model as mediators of the relationship between working memory load and hazard recognition. To investigate other factors that may impact hazard identification in combination with working memory load and visual attention, the authors included personality traits as moderating variables. Working memory load was measured as the Level 2 predictor (X), TTFF (M1), run count (M2) and fixation count (M3) as Level 2 mediators, personality traits of extraversion (W1), agreeableness (W2), conscientiousness (W3), neuroticism (W4) and openness to experience (W5) as level 1 moderators, and hazard identification (Y) as the Level 2 outcome. To build the MLM model, the authors regressed the mediator variables (i.e. visual attention indicators) on the predictor variable (i.e. working memory load), and then regressed the outcome variable (i.e. hazard identification performance) on both the predictor and mediator variables, while accounting for the personality variables as moderators in the model. Both *within* and *between* effects of the moderators were examined. The *within* effect assessed the influence of visual attention on hazard identification across low and high working memory load trials, while the *between* effects evaluated the effect of personality on visual attention between participants. Taken together, the integrated multilevel moderated mediation model examined (1) whether visual attention (indicated here via eye metrics) mediates the effect of working memory load on hazard identification (with time-to-first fixation, run count and fixation count serving as proxies for attention), and (2) the influence of personality traits as moderators of the relationship between working memory load and hazard identification.

3.6 Results

3.6.1 Memory Test Performance

To ascertain the impact of working memory load on participants' ability to recognize hazards, hazard identification scores were compared for low and high working memory load conditions. Verbal reports obtained from participants during the hazard identification experiment revealed that working-memory load influenced the ease at which hazards were recognized. The outcome showed that the mean hazard identification scores were higher under the low load conditions (81%) in contrast to the high memory load alternative (70%). This result suggests that working memory load impacts safety performance as indicated by the differential results obtained in both low and high memory manipulations.

Furthermore, the HI scores for each subject under low and high working memory loads were calculated for fall-to-lower-level and fall protection-related hazards (Fig. 3.4). The outcome shows that participants missed more hazards during the high load trials than they did during the low load alternative. During the visual attention task of identifying fall-to-lower-level hazards, participants performed 3.4 times poorer under high working memory loads compared with the low load conditions. Similarly, fall protection hazard identification performance deteriorated 1.2 times under the high working memory condition. Therefore, high working memory load severely impacted the ability to identify active and potential hazards within the construction scenario images. Expectedly, a high working memory left fewer cognitive resources to attend to multiple tasks, signaling the need for workers to avoid needless distractions that may adversely affect attention and the successful performance of safety-related tasks. A summary of missed fall-to-lower-level and fall protection-related hazards is presented in Table 3.1.

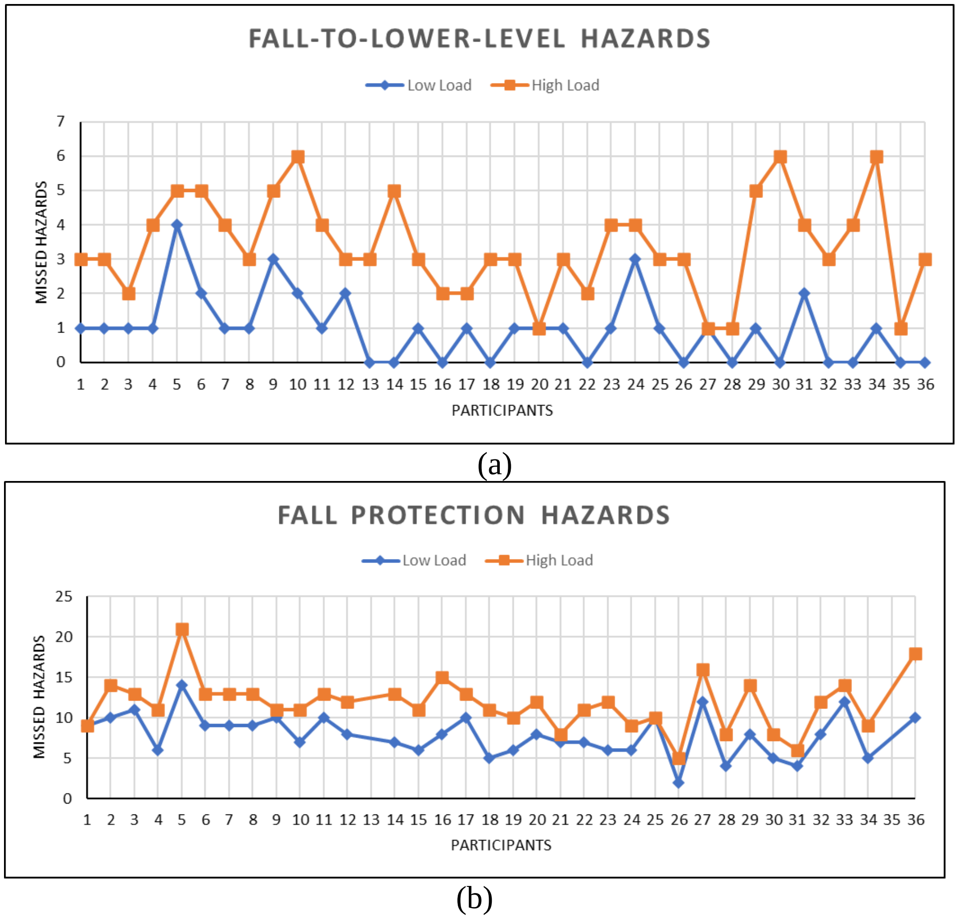


Figure 3.4. Graphical presentation of missed fall hazards during low and high working-memory load trials (a) Fall-to-lower-level (b) Fall protection hazards

Table 3.1. Average percentages of missed hazards under low and high working memory loads

Types of missed hazards	Low Memory Load	High Memory Load
Fall-to-lower-level hazards	4.1%	14.1%
Fall protection-related hazards	35.6%	41.4%

Subjects participated in a total of 35 experimental trials under two working memory loads conditions. The statistical model was tested using SPSS MLMED macro adapted from Rockwood

(2017). In the current study, 10, 000 bootstrap samples were generated using random sampling with replacement from the data set. In addition, the 95% confidence interval (95% CI) was used to estimate the conditional indirect effects of working memory (WM) load on visual attention and hazard identification (HI) performance in the presence of significant interactions with the moderators. In the context of a relatively modest sample size, the study considered interactions and conditional effects with a p-value of less than 0.10 and examined them as trending toward significance. Results of the multilevel moderated mediation analysis are provided for each visual attention indicator below (Table 3.2).

Table 3.2: Summary of significant interactions, direct effect and conditional indirect effects among predictor, mediator, moderator and outcome variables.

Metric	Moderator	Outcome	Variable	Effect	β	*t*-value	*p-value*	L-CI	U-CI
TTFF	Agreeableness	TTFF	WM Load	Within	-2991.360	-3.035	0.005***	-4994.380	-988.335
			Interaction		78.345	2.515	0.017**	15.025	141.665
		Hazard ID	TTFF	Within	-0.151		0.012**	-0.283	-0.046
	Conscientiousness	TTFF	WM Load	Within	-3281.870	-2.897	0.007***	-5584.530	-979.208
			Interaction		85.704	2.441	0.020**	14.356	157.052
		Hazard ID	TTFF	Within	-0.165		0.015**	-0.314	-0.049
	Openness	TTFF	Openness	Between	-40.789	-2.000	0.053*	-82.234	0.655
	All Moderators	Hazard ID	WM Load	Within	-0.131	-12.916	0.000****	-0.152	-0.111
			TTFF		-0.000	4.670	0.000****	0.000	0.000
RUN COUNT	Agreeableness	Run Count	WM Load	Within	-1.380	-6.364	0.000****	-1.820	-0.939
			Interaction		0.025	3.685	0.001***	0.011	0.039
		Hazard ID	Run count	Within	-0.173		0.030**	-0.339	-0.027
	Conscientiousness	Run Count	WM Load	Within	-1.269	-4.718	0.000****	-1.815	-0.722
			Interaction		0.021	2.551	0.015**	0.004	0.038
		Hazard ID	Run count	Within	-0.159		0.039**	-0.326	-0.023
	Neuroticism	Run count	Neuroticism	Between	-0.029	-2.048	0.048**	-0.057	-0.001
		Hazard ID	Run count	Within	-0.092		0.049**	-0.196	-0.015
	All Moderators	Hazard ID	WM Load	Within	-0.084	-2.549	0.016**	-0.151	-0.017
			Run count		0.126	2.342	0.025**	0.017	0.235
FIXATION COUNT	Agreeableness	Fix count	WM Load	Within	-2.243	-4.210	0.000****	-3.326	-1.161
			Interaction		0.030	1.753	0.089*	-0.005	0.064

	Hazard ID	Fix count	Within	-0.115		0.074*	-0.257	-0.006
Conscientiousness	Fix count	WM Load	Within	-2.829	-4.871	0.000****	-4.010	-1.649
		Interaction		0.047	2.620	0.013**	0.011	0.084
	Hazard ID	Fix count	Within	-0.144		0.066*	-0.312	-0.004
Neuroticism	Hazard ID	Fix count	Within	-0.068		0.094*	-0.161	-0.001
Openness	Fix count	Openness	Between	0.030	1.723	0.094*	-0.009	0.114
All Moderators	Hazard ID	WM Load	Within	-0.091	-2.619	0.013**	-0.161	-0.020
		Fix count		0.051	2.028	0.050*	0.000	0.102

$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$; $^{****}p < 0.001$.

Examination of the *direct* effect of WM load on HI performance when controlling for the mediator revealed a negative association between WM load and hazard identification (B = -.131, CI = -.152, -.111), indicating that a high WM load correlated with low scores on hazard identification. Although with a negligible effect size, the results revealed a significantly mediated "b path" as there was a negative association between TTFF and HI (*B* = -.000, *CI* =.000, .000), suggesting that lower scores on TTFF was associated with higher scores on HI.

With regard to the moderating influence of the personality dimensions, the results showed evidence of moderation of the "a path" from predictor (WM) to mediator (TTFF) by the ***agreeableness*** personality dimension, as there was a significant interaction (*p* = 0.017) between WM load and agreeableness. This outcome suggests that the effect of WM load on TTFF varied as a function of the agreeableness personality trait (*B* = -2991.36, *CI* = -4994.38, -988.34). The results also observed that the conditional *within* effect of TTFF was significant (*B* = -.151, *CI* = -.283, -.046), suggesting that the visual attentional indicator of TTFF was negatively associated with HI across low and high working memory load trials for the agreeableness personality dimension.

Similarly, the results revealed moderation of the "a path" from predictor (WM) to mediator (TTFF) by the ***conscientiousness*** personality dimension, as there was a significant interaction (*p* = 0.020) between WM load and conscientiousness, suggesting that the effect of WM load on TTFF varied as a function of the conscientiousness personality trait (*B* = -.3281.87, *CI* = -5584.53, -979.21). An inspection of the conditional *within* effect of TTFF (*B* = -.165, *CI* = -.313, -.048) identified that the visual attentional indicator of TTFF was negatively associated with HI across WM load trials for the conscientious personality dimension.

Moreover, the *between* effect of ***openness*** showed a trend toward statistical significance (p = 0.053), indicating that this personality may be associated with TTFF between individuals.

3.6.2 Run Count

An inspection of the *direct* effect of WM load on HI performance when controlling for the mediator revealed that WM load was negatively associated with hazard identification (B = -.084, CI = -.151, -.017), indicating that a high WM load correlated with low scores on hazard identification. The results also disclosed a significantly mediated "b path" due to the observed positive association between run count and HI (B =.126, CI =.017, .235), suggesting that higher scores on run count was associated with higher scores on HI.

Results of the analysis showed evidence of moderation of the "a path" from predictor (WM) to mediator (run count) by the ***agreeableness*** personality dimension, due to a significant interaction (p = 0.001) between WM load and agreeableness. This outcome suggests that the effect of WM load on run count varied as a function of the agreeableness personality trait (B = -.1.380, CI = -1.820, -.939). Examination of the conditional *within* effect of run count was also statistically significant (p = 0.030, B = -.173, CI = -.339, -.027), implying that run count was negatively associated with HI across low and high working memory load trials for the agreeableness personality dimension.

Similarly, there was evidence of moderation of the "a path" from predictor (WM) to mediator (run count) by the ***conscientiousness*** personality dimension due to a significant interaction (p = 0.015) between WM load and conscientiousness, indicating that the effect of WM load on run count varied as a function of the conscientiousness personality trait (B = -1.269, CI = -1.815, -.722). The conditional *within* effect of run count was statistically significant (*B* = -.159, *CI* = -.326, -.023), conveying that the visual attentional indicator of run count was negatively associated with HI across low and high working memory load trials for the conscientiousness personality dimension.

For the ***neuroticism*** personality dimension, the *between* effect was significant (*p* = 0.048), suggesting that this personality was associated with run count between individuals. Likewise, the conditional *within* effect of run count was statistically significant (*p* = 0.046, *B* = -.092, *CI* = -.196, -.015), implying that the visual attentional indicator of run count was associated with HI across low and high working memory load trials for the neuroticism personality dimension.

3.6.3 Fixation Count

Examination of the *direct* effect of WM load on HI performance disclosed a negative association between WM load with hazard identification (*B* = -.091, *CI* = -.161, -.020), indicating that a high WM load correlated with low scores on hazard identification. The results also detected a strong trend toward a significantly mediated "b path" due to a positive association between fixation count and HI (*B* =.051, *CI* = -.000, .102) at a modest statistical significance (*p*= 0.050), suggesting that high scores on fixation count may be positively associated with high scores on HI.

The output of statistical analysis revealed possible moderation of the "a path" from predictor (WM) to mediator (fixation count) by the ***agreeableness*** personality dimension, due to a trend toward significant interaction (*p* = 0.089) between WM load and agreeableness. Thus, the effect of WM load on fixation count may vary as a function of the agreeableness personality trait (*B* = -2.243, *CI* = -3.324, -1.161). Likewise, the conditional *within* effect of fixation count showed a trend towards statistical significance (*p* = 0.074, *B* = -.115, *CI* = -.257, -.006), suggesting that the visual attentional indicator of fixation count may be associated with HI across low and high working memory load trials for the agreeableness personality dimension.

Furthermore, the “a path” from predictor (WM) to mediator (fixation count) was moderated by the ***conscientiousness*** personality dimension, due to a statistically significant interaction (p = 0.013) between WM load and conscientiousness (B =-2.829, CI = -4.010, -1.649), and indicating that the effect of WM load on fixation count varied significantly as a function of the conscientiousness personality trait. The results also observed that the conditional *within* effect of fixation count showed a trend toward statistical significance (p = 0.066, B = -.144, CI = -.312, -.004), connoting that the visual attentional indicator of fixation count may be associated with HI across low and high working memory load trials for the conscientiousness personality dimension.

Moreover, results showed that the conditional *within* effect of fixation count revealed a trend toward statistical significance (p = 0.094, B = -.068, CI = -.161, -.001), suggesting that the visual attentional indicator of fixation count may be associated with HI across low and high working memory load trials for the ***neuroticism*** personality dimension. Correspondingly, the *between* effect of ***openness*** showed a trend toward statistical significance (p = 0.094), implying that this personality trait may be associated with fixation count between individuals.

3.7 Discussion

A multilevel moderated mediation model was applied to investigate the mediating influence of visual attention in the association between working memory load and hazard identification. The model also examined possible moderating effects by personality traits.

3.7.1 Hypothesis I: Mediating role of visual attention

3.7.1.1 *Working memory*

Generally, the results demonstrated that a low working memory load was associated with high scores on hazard identification, when controlling for the influence of the mediators and moderators, suggesting that a high memory load significantly impaired hazard recognition. A high working memory load negatively impacted the attentional distribution and search effectiveness of the participants such that they detected hazards at a considerably low rate compared to working under a low working memory burden. The increased memory burden limited participants' cognitive resources to retain information in memory while attempting to identify safety risks in the images, thereby constraining the ability to distribute attention in a balanced way to identify both glaring and concealed hazards. On the other hand, a reduced working memory load facilitated the identification of safety hazards, as individual were equipped with extra attentional reserve to view the scenes thoroughly and return their attention frequently to key areas of interest to attain high hazard identification scores.

Since a low working memory load is crucial for reducing distraction by maintaining the prioritization of relevant information in the brain, working memory plays a key role in hazard anticipation and detection (de Fockert et al 2001; Borowsky et al. 2016). Particularly, visual search is impaired when working memory interferes with visual attention, leading to a slow reaction time to the safety target (Dombrowe et al. 2010). A secondary task may also interact with working memory to adversely impact visual task performance and ultimately lower the rate of hazard detection, especially when workers have to handle multiple tasks in complex environments. The observation echoes the findings of previous studies (e.g. de Fockert et al 2001; Shipstead et al. 2012; Gutzwiller and Clegg 2013) which noted that a high memory load influenced the successful allocation of visual attention and filtering of distractions in the environment, leading to greater interference effects on perception and safety performance during selective attention tasks. Similarly, a recent study (Ramey et al. 2019) found that reduced demand on working memory brought about precise eye movements and direction of gaze toward target objects during visual search, leading to conscious recollection and increased search efficiency. Due to the foregoing, holding more information than necessary in memory could adversely impact safety performance and attention to hazards even when these elements are within the visual field of view, thereby causing a construction worker to lose track of the identify, location and trajectory of a hazard and increase the potential for human errors and ultimately near-misses or severe injuries.

3.7.1.2 Attention

The outcome of the study showed that a low TTFF, high run count and high fixation count predicted hazard identification, controlling for the moderators. Thus, hypothesis 1—which speculated that visual attention would mediate the impact of working memory load on hazard identification performance—is confirmed.

Fixations occur when the pupil is stationary, indicating an individual's focus of attention on a particular location or stimulus for visual processing and information absorption (Holmqvist et al. 2011; Gene´-Sampedro et al. 2021). Fixation count also signals how many attentional resources a person has allocated to an object (Goldberg and Kotval 1999). Similarly, run count, which reveal the number of visits to each AOI (with a visit being a single fixation or series of fixations on an AOI without fixating anywhere else outside of that AOI: Li et al. 2019) is an important metric that demonstrates the efficiency of searching for important safety hazards within an AOI among competing regions within a scene (Hasanzadeh et al. 2017). Therefore, because hazard recognition involves the most efficient utility of limited cognitive resources, it was not unusual to observe that individuals who committed high levels of attention via increased fixation counts to perceive more detail of the scene, recorded a quick entry time into the AOIs relative to the onset of the trial, and distributed their attention more broadly across the images through increased visit counts on safety-critical areas demonstrated a remarkable hazard identification performance.

3.7.2 Hypothesis II: Moderating role of personality traits

Similarly, the multilevel analysis revealed that certain personality dimensions moderated the association between working memory load and visual attention, thus confirming the second hypothesis. The relevant moderating personality dimensions are discussed below:

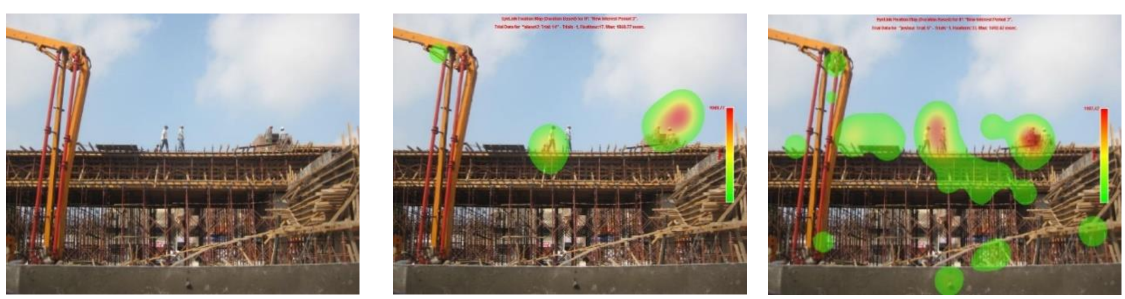
3.7.2.1 *Agreeableness*

The results showed that a low working memory load was associated with increased run count, increased fixation count, and ultimately high hazard identification performance for participants with the agreeable personality trait. This group of participants also recorded a low TTFF under a high working memory load.

The findings appear to be in concert with the outcome of previous studies (e.g. Cellar et al. 2001; Clarke and Robertson 2005; Landay et al. 2020) which discovered that the agreeableness personality dimension tend to be negatively correlated with workplace accident involvement. Notably, teams of highly agreeable individuals—possessing high interpersonal skills and effective cooperation with others— may exhibit a safe performance in risky activities due to an innate desire not to jeopardize the safety of a group or compromise interpersonal relationships (Barrick et al. 2013; Beus et al 2015). An early study of driving behavior (Deffenbacher et al. 1994) also observed that interpersonal violations on the road such as aggressive behavior toward other road users may be associated with a high negative affect and emotional arousal that may influence perception and information processing, ultimately increasing the risk of accidents. In the current study, the frequency at which subjects high in agreeableness returned their focus to hazardous area in the visual field of view, in addition to their ability to retain—and recall—considerable information in memory suggests that highly agreeable individuals may be more attentive to hazards even when working under high-memory-load conditions (Fig. 3.5).

(a) (b) (c)

(a) (b) (c)



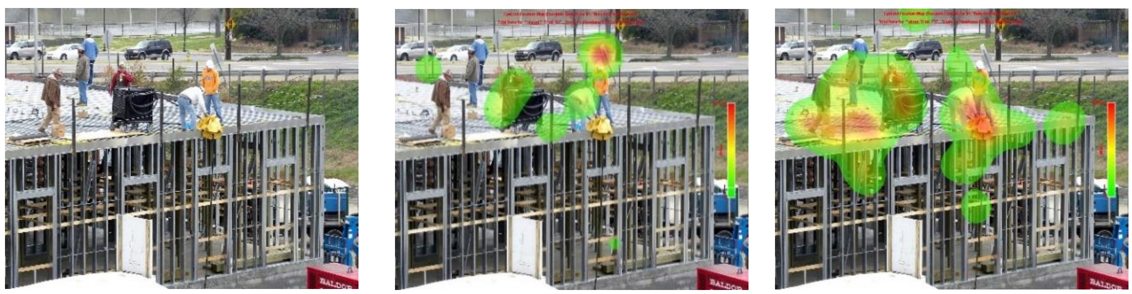
(a) (b) (c)

Figure 3.5: Attentional distribution (heat maps) (images courtesy of David Ausmus, with permission a):original picture; (b) attentional distribution of a participant who scored low in agreeableness under a low working memory load, and (c) attentional distribution of a participant who scored high in agreeableness under a high working memory load

3.7.2.2 *Conscientiousness*

The results showed that a low working memory load was associated with increased run count, increased fixation count, and ultimately high hazard identification performance for participants with the conscientiousness personality trait. In congruence with the observation of previous studies, conscientiousness has shown consistent relations with positive occupational variables, including job performance (Thoms et al. 1996; Mount and Barrick 1998), safety behavior (Gao et al. 2020), safety compliance (Xia et al. 2021) and attentional scope (Liao and Lee 2009). Most notably, workers with high scores on the conscientiousness trait demonstrate superior performance on cognitive and attentionally-demanding tasks and domains such as academic or workplace settings, distinguished by a pronounced capacity to maintain goal focus and attend to narrow visual details (Clarke and Robertson 2005; Swift et al. 2020). This finding dovetails with the outcome of a recent study (Hasanzadeh et al. 2019) which discovered a positive correlation between conscientiousness and the frequency at which workers high on this personality dimension returned their attention to hazardous locations more frequently across construction site images in search of fall hazards. In the present study, conscientious workers accumulated more fixations on the AOIs and returned their attention to hazardous areas more frequently to examine the images more thoroughly, utilizing their limited attentional and cognitive resources efficiently under a high working memory load. Invariably, this finding provides empirical evidence that less conscientious individuals may become more vulnerable to cognitive failures under memory-demanding tasks which may increase the potential for human error on dynamic jobsites (Fig 3.6).

(a) (b) (c)



(a) (b) (c)

(a) (b) (c)

Figure 3.6: Attentional distributions (heat maps) (images courtesy of David Ausmus, with permission): original picture; (b) attentional distribution of a participant who scored low in conscientiousness under a low working memory load, and (c) attentional distribution of a participant who scored high in conscientiousness under a high working memory load

The personality traits of extraversion, neuroticism and openness to experience showed no moderating influence in the associations between memory load and hazard identification performance in the multilevel model analysis.

3.8 Implications

This study offers potential benefits for academia and practice. The approach can be utilized to monitor visual attention as a primary task while assessing the impact of cognitive overload as a secondary activity concurrently to understand the influence of working memory load on impaired attention during multitasking situations, and the effect of such cognitive overload on a worker's ineptitude to comprehend a hazardous situation. The study outcome also clarifies the extent to which: i) attention may be impacted under differential working memory loads during the identification of fall safety hazards, and ii) personality traits may be pivotal factors that strengthen—or weaken—the effect of working memory on safety outcomes by accentuating the influence of low and high working memory loads on workers' attentional allocation and visual search strategy across hazardous scenes. Correspondingly, the study sheds more light regarding ways future construction management studies may leverage empirical data to harness multi-dimensional factors when assessing the effect of cognitive overload and personal characteristics (e.g. personality traits) on safety performance in construction-safety discussions.

In addition, synthesizing information about workers' unique traits with real-time data on attention, working memory and cognitive perception enables the evaluation of the impact of these variables on decision-making processes in risky situations. Thus, investigating the effect of distractions, task difficulty and a high cognitive load on attention explains why a worker may be unable to detect a hazard in a dynamic construction site when holding more information than necessary in memory. A better comprehension of the relationships between these safety variables will establish a basis for the early detection of workers who may be injury-prone or likely to be involved in avoidable accidents due to cognitive overload and/or unique traits. As it turns out, certain human errors may be reduced through careful selection of employees during task assignment that takes into account the cognitive limitations of workers as well as their individual capabilities. While personality traits acquired over time may be difficult to alter in the workplace, safety managers may find this outcome useful in assigning workers to tasks based on a combination of their cognitive abilities and personality variables to reduce the risk of injury among such workers.

3.9 Limitations

Despite the potential benefits of this study in advancing construction safety research, caution should be exercised about generalizing the findings due to certain limitations. First, static images were utilized for the experiment in a controlled laboratory environment. Future studies may replicate the experiment in a live construction environment using a mobile eye tracker to observe how distractions may impact attention and cognitive reasoning when identifying hazards in complex surroundings. Second, participants of this research were students with limited experience in the field of construction. While these individuals enabled the investigation of the impact of working memory load on hazard identification performance without experiential bias, future studies may target professional construction workers to determine whether the outcome of the research may vary when more experienced individuals participate in a related study. Third, the overall score in fall safety hazard recognition for each participant was employed in calculating the hazard identification index utilized for statistical analysis. Future research should consider investigating a broader category of safety hazards such as struck-by, housekeeping and electrocution hazards to examine the impact of working memory load on the recognition of various hazard types. Lastly, although the study offers potential contribution to the construction safety domain on the impact of working memory load on hazard identification performance, future studies may explore the impact of other variables such as stress, fatigue and time pressure on working memory and hazard identification.

3.10 Conclusions

The idea for this study grew out of the belief that holding more information than necessary in memory may have dire safety consequences for construction workers who have multiple distractions to contend with in dynamic environments. In parallel, since people do, in fact, have long term personality traits that influence their working memory and safe behavior in the work environment, the current study explored the mediating effect of visual attention in the association between working memory load and hazard identification, and the influence of personality traits as moderators of this association. This study contributes to the body of knowledge by revealing the underlying mechanism through which individual differences in attention and memory may exhibit important empirical relationships with hazard identification when employees work under differential cognitive loads. Moreover, investigating the cause of human error at the level of the individual facilitated a worker-centric analysis of dispositional, cognitive and task-related factors that may influence safety performance and increase the potential for error in complex surroundings.

Generally, the results revealed that participants were about 3.4 times more likely to miss out on the identification of fall-to-lower-level hazards and 1.2 times more prone to ignore or overlook important fall protection hazards under high working memory load conditions. Identifying hazards became challenging under a high working memory load as workers overly focused on attempting to recall the relatively longer number strings in the secondary task, thereby missing salient safety hazards in the scenario images. In contrast, it was relatively easier for the participants to identify fall-related hazards and the associated risks when the demand on their cognitive resources was relatively reduced under the low memory alternative. These findings highlight the importance of maintaining a reduced working memory load for a safer performance and the need to reduce distractions in dangerous construction environments, especially as workers have to process a variety of safety information or perform multiple tasks concurrently. Furthermore, it was observed that certain personality traits buffered the relation between working memory load and hazard identification. Specifically, the agreeableness and conscientiousness personality dimensions significantly influenced the visual attention and search strategies of workers exposed to fall hazards. Under a high working memory load, workers who were agreeable and conscientious distributed their limited attentional resources in a balanced way to identify fall-to-lower-level and fall protection hazards within the construction scenario images, signaling effective hazard identification skills under cognitive and attention-demanding situations.

The findings broaden existing understanding of the human factors at play when incidents occur as workers confront safety risks during multitasking situations on complex work sites. By putting the results of this study in consideration when selecting workers and assigning them to cognitive tasks, the potential for accidents may be reduced among vulnerable workers whose attention may become impaired when handling multiple tasks in dynamic environments.

CHAPTER 4: THE IMPACT OF TIME PRESSURE ON WORKER SAFETY: A SIMULATED ROOFING TASK

4.1 Abstract

The current study investigated the impact of time pressure on attention to safety hazards and susceptibility to hand injuries and slip, trip and fall (STF) incidents during a simulated roofing task. Thirty-seven participants installed 27 pieces of 40 ft2 shingles standing on a low-sloped roof model 4ft wide, 6ft long and 3ft high in two experimental conditions (1) a baseline study without time pressure and (ii) a second manipulation with a 7-minute time limit while they were recorded with a video camera and empirical measures of attention continuously monitored using eye tracking technology. The results revealed that construction workers may be at a heightened risk of STF and hand injury hazards as a result of a time pressure-induced reduction in attention to the STF and hand injury areas of interest (AOIs). In addition, time pressure resulted in a trade-off between safety and productivity as participants strived to balance the costs (slips, trips, falls and hand injuries) and benefits (productivity bonus and time-saving) associated with the task. This research is a proof of concept to construction managers on the need to prevent tight work schedules that induce time pressure and promote risk-taking, impact hazard awareness and increase workers' susceptibility to fall and hand injury hazards.

4.2 Introduction

Working under time pressure and in a stressful environment has become a routine phenomenon on many construction sites as it can be frequently observed that the actual schedule deviates from planned performances. When such differences arise, site managers often accelerate the project by aggressively scheduling activities to maintain the planned sequence or recover from a lapsed schedule (CII 1989; Nepal et al. 2006). However, the desire to complete tasks as quickly as possible is one of the reasons for increased risk-taking behavior, causing workers to compromise safety for production in response to pressure to meet up with the schedule requirements (Li et al. 2021). Increased pressure to perform may also heighten emotional stress levels, allowing fewer cognitive deliberations that may impair attention and increase the propensity to make risky choices (Ordonez and Benson 1997; El Hajia et al. 2019). In the face of such pressures, safety and production demands compete for workers' limited attention, often conflicting with those protecting workers from hazards in the work environment (McLain and Jarrell 2007). As a result, workers frequently make distressing choices about where to allocate available attention and effort, leading to a reduced scrutiny of safety-related decisions and possible unfavorable outcome (Han et al. 2014; Leung et al. 2015).

Although there is a common belief that increasing time pressure will reduce the attentiveness of workers towards hazards, there is no study that has tested this relationship. To address this knowledge gap, this research investigated the impact of time pressure on the visual attention of roofers towards safety hazards while installing shingles on a sloped roof. The research team decided to focus on roofing trade since it is a hazardous profession more than nine times as risky as the average occupation and more than three times dangerous as the average construction trade (Moore and Wagner 2014; Lan and Galy 2017). In addition, roofers record the highest incidence of fatal falls with a fatality rate more than 10 times the all-worker rate as a result of multiple factors in roof construction environments such as working on elevated, inclined surfaces, restrictions to awkward postures and lack of visual references that affect their balance control and increase the risk of falling (Hsiao and Simeonov 2001; BLS 2018). Also, among the different hazards that roofers are exposed to, the research decided to focus on slip, trip, and falls as one of the most fatal (Nasarwanji and Sun 2019) and hand injuries as one of the most frequent (Marom et al. 2019) hazards. The study of time pressure and visual attention leads to an important research question: Does time pressure have an impact on construction workers' attentiveness to fall and hand injury hazards on a construction site? This question will drive the search for critical factors that may increase the risk of a fall hazard or hand injury when working on elevated platforms under restrictive conditions. Accordingly, this study will investigate this research question by continuously monitoring the visual attention of construction workers with eye tracking technology as they carry out a simulated roofing activity under two experimental conditions: i) a baseline study with no time limit, and ii) a time pressure manipulation requiring task completion within a time limit.

This study provides empirical evidence regarding the negative impact of time pressure on the attentional distribution of workers and their ability to identify safety hazards. Considering the increased risk of injuries due to time pressure, project and safety managers should provide further safety precautions to compensate for the degraded cognitive states of workers or implement appropriate scheduling strategies and develop realistic project plans in order to prevent tight work schedules that erode safety, promote risk-taking, impact hazard awareness and increase workers' susceptibility to STFs and hand injuries.

4.3 Background

4.3.1 Roofing incidents

Among all construction trades, residential roofing is one of the most hazardous (Lan and Galy 2017). It is more than nine times as risky as the average occupation and more than three times dangerous as the average construction trade (Moore and Wagner 2014; Lan and Galy 2017). Roofers record the highest incidence of fatal falls with a fatality rate more than 10 times the all-worker rate (BLS 2018; Brown et al. 2020) as a result of working at high elevations and exposure to the danger of falling off ladders or the unprotected edges of a roof. Asides the risk of a fall to lower level, residential roofers perform a variety of tasks for extended periods on elevated and inclined work surfaces, making them prone to a variety of safety hazards, including slip hazards from a shingle glide (Earnest and Branche 2016), loss of balance from carrying bulky materials across uneven surfaces (Fredericks et al. 2005), restricted stepping control (Gao et al. 2008), poor grip between footwear and roof surface (Simeonov 2016), visual impairment affected by elevation (Chander et al. 2021), loss of sensation in the arm (Fu et al. 2007), hand injuries (Lipscomb et al. 2015) and musculoskeletal disorders (Breloff et al. 2020) from climbing and walking at different inclinations.

STFs are the leading cause of occupational fatalities and the single largest contributor (over 33%) to workplace injuries and fatalities. In parallel, the hand is the most frequently injured body part in the workplace because of its numerous interactions with the environment and the fine motor skills it provides. As a result, the importance of investigating the likelihood of STFs and hand injuries cannot be overemphasized. Roofing is an inherently dangerous activity that exposes workers to a variety of safety hazards (particularly STFs and hand injuries). When working on restricted and elevated platforms, roofers are tasked with the burden of identifying safety hazards and responding appropriately to them. However, workers' perception and comprehension of sources of risks may be severely impacted when working under time pressure, which can have dire consequences on their safety.

In the construction safety arena, several investigations have been carried out to examine the influence of a plethora of safety variables, such as risk perception (Habibnezhad et al. 2016), safety knowledge (Hasanzadeh et al. 2017), and cognitive overload (Liko et al. 2020) on hazard identification performance. However, no study has empirically investigated the extent to which time pressure affects visual attention to safety hazards (particularly STFs and hand-related risks) and increases workers' susceptibility to injury. Considering that workers recognize safety hazards through visual search, this study will employ eye tracking technology (the most direct, continuous and objective measure of attention) to continuously monitor participants' visual attention to STF and hand injury hazards in real time when carrying out a simulated roofing activity under time pressure. Assessing the risk of falls and hand injuries is a critical step in the process of implementing injury prevention measures to reduce the dangers associated with the roofing trade.

4.3.2 Slips, trips and falls (STFs)

STFs have been internationally recognized as the leading cause of occupational fatalities and long-term disabling injuries on construction sites (Yang et al. 2004; Nenonen 2013; Williams 2017). Approximately one in every three construction fatalities is due to a fall from an elevation (Radomsky et al. 2001; Dong et. al., 2014; Winn et al. 2014) and out of over 13,000 fatal incidents reported between 2003 and 2015, more than 34% resulted from falls (Bureau of Labor Statistics 2018). Additionally, STFs are the single largest contributor to workplace injury costs to employers, accounting for over 33% of the total nonfatal workers' compensation cost in the United States, including decreased productivity, delay in construction schedule and increased economic burden (Earnest and Branche 2016; Nasarwanji and Sun 2019). STFs account for a considerable portion of sprains, fractures and other musculoskeletal disorders as workers lose their balance on roofs, inclines, stairs, ladders, scaffolding and other uneven surfaces while transferring from one place to another (Lipscomb et al. 2006; Lim et al. 2016; Mangharam et al. 2016). This experience is usually disruptive and painful, requiring lengthy periods of rehabilitation and enormous financial burdens on workers and their families. Thus, the prevention of STFs is of utmost importance to safeguard construction workers and reduce direct and indirect costs from resultant injuries.

STFs involve unintended human movement as a result of a low friction, slipperiness, unstable gait patterns and a poor grip at the interface between the footwear and the underfoot surface (Gao et al., 2008; Nenonen 2013). Particularly, loss of balance— the body's inability to control its center of mass or maintain an upright posture in the presence of recurring perturbations— is one of the triggering events for STF incidents in roof construction (Shumway-Cook and Woollacott 1995; Simonov 2003; Sugama and Seo 2021). Particularly, falls from elevated surfaces are triggered by a loss of balance within the human body or an unstable environment which has an adverse effect on postural stability and causes disruptions to workers' gait movements (Lin et al. 2009; Zampogna et al. 2020). Multiple factors in roof construction environments— such as a steep slope, height, and lack of visual references—may affect workers' balance control and increase their risk of falling (Hsiao and Simeonov 2001). Another contributory factor to STF incidents includes time pressure to complete work tasks (Courtney et al., 2001; Han et al. 2014) which induces stress and unstable gait patterns that increase the potential for a fall.

4.3.3 Hand injuries

Aside STFs, hand injuries frequently occur in the workplace specially among roofers. The hand is an active and exposed body structure important in almost every daily activity and one of the main points of the human interface used to explore the immediate environment (Pollard et al. 2014). Given the numerous interactions the hand has with the environment and the fine motor skills it provides (including gripping, grasping, and pinching), it is not entirely surprising that the hand is the leading body part injured at work, affecting an estimated 1,080,000 workers annually in the United States (Center for Disease Control 1998; Sorock et al. 2001). Particularly, acute hand injury (e.g., laceration, crush or fracture) is a common occurrence at work, accounting for approximately 10%-30% of all patients admitted to the hospital emergency departments and up to 20% of all injuries treated (de Jong et al. 2014; Marom et al. 2019). Hand and finger injuries account for almost 30 percent of occupational injuries across all industries, over one million occupational injuries in the United States annually, and over 90% of all workplace limb amputations, leading to more serious consequences than any other organ in terms of social and financial hardships and economic losses (Oleske and Hahn, 1992; Sorock et al.2004; Liang et al., 2004). In addition, of the 286,810 non-fatal occupational injuries to upper extremities in 2018 involving days away from work in private industries, 123,990 involved hands (over 43 percent), according to the U.S. Bureau of Labor Statistics (OHS 2020). When cuts and lacerations of the fingers and hands are combined, the number of days-away-from-work cases (approximately 110 000 annually), is second only to back strain and sprain frequency according to US Bureau of Labor Statistics data (Courtney and Webster 1999).

Various hand-related disorders have been identified in the literature, including hand-arm vibration syndrome (HAVS). HAVS is a complex, potentially disabling condition comprising one or more specific neurological, vascular, and musculoskeletal features, associated with intensive hand use and exposure to hand-held vibrating tools, such as chipping and grinding pneumatic tools, chain saws and strimmers, jackleg drills, and electrically driven rotating tools (Taylor 1988; Heaver et al. 2011), with symptoms including tingling, prickling, sensory loss and decreased dexterity (Falkiner 2003; Shavit et al. 2020). Although injuries to the hand and fingers are unlikely to be life-threatening, they are prevalent among construction industry workers and can result in physical deterioration, lack of productivity, and permanent impairments (Peters et al. 1999; de Putter et al. 2012; Lipscomb et al. 2013).

Likewise, nail injuries—involving puncture wounds to the hands and fingers—are among the most common in wood frame construction, accounting for 14% of injuries among residential carpenters

(Lipscomb et al. 2003b). Nail guns (including nailers, pneumatic hammers, pneumatic nailers or air-powered nailers) fire up to nine nails per second (Gaylord 1994) at velocities as high as 1,400 ft. per second (Hoffman 1997). This machinery imparts a large amount of energy to a small projectile and can cause serious injuries to workers (ranging from a slight scratch to a fractured bone) if not properly aimed, is shot before the operator is ready or inadvertently strikes a worker (Baggs et al. 2001).

Some researchers have investigated the potential for acute hand injury incidents in the workplace. About two decades ago, Sorock and team (2001) utilized a case-crossover design to assess the change in risk of an acute event (such as an injury) related to transient exposure (such as working with unusual work materials) and observed that the relative risk was significantly elevated for a task performed using an unusual work method, or when workers were distracted or felt rushed. Glove use was also associated with a reduced risk of an acute hand injury.

In the health sector, Pili et al. (2003) investigated the frequency of needle stick and sharp injuries among healthcare workers of an academic hospital and discovered that the hand was involved in 82% of such injuries. Furthermore, DavasAksan et al. (2012) defined the risk factors for occupational hand injuries while exploring the relationship between the most frequently reported machines and the fingers injured, based on the records of a microsurgery hospital. The study reported that powered woodcutters, presses, planning and milling machines, and machine belts were the most frequent machines involved in injuries. Furthermore, the research found that 60.9% of agricultural machines, 52.7% of metal working machines, 54.7% of transmission machinery, and 42.8% of wood and assimilated machines affected the right hand, and the most frequent injuries were open wound (46.3%) and traumatic amputation (53.2%) of the wrist and hand.

An in-depth analysis of the root causes of injuries in the mining industry from 2002 to 2011 by Pollard and colleagues (2014) revealed that maintenance and repair were associated with a significant number of hand and finger injuries, with a range of severities averaging over 20 amputated fingers, 180 fractured hands and fingers, and 455 hand and finger lacerations per year. Many of these injuries were caused by hands being struck by or caught in tools and equipment.

Similarly, Nowrouzi-Kia et al. (2018) analyzed prevalent injuries in the global mining workforce and found that musculoskeletal injuries to the hand, in addition to slips and falls were the major lost-time injuries. In like manner, Marom et al. (2019) sought to determine time of return to work among male manual workers after a hand injury over a 12-month follow-up in a cohort study and observed that as much as 25% of participants did not return to work by the end of the 1-year follow-up period, and the median time-off-work was given as 92 days. Notably, decreased level of self-efficacy, higher workplace demands, level of pain, level of emotional response to trauma, reduced physical capability of the hand, and higher level of disability were significantly associated with delayed time of return.

Injuries of the hand have an enormous impact on hand function and quality of life (Sorock et al. 2001). They affect individuals in their productive ages and may result in long-term physical and functional disability that limits participation in occupational and day-to-day activities (DavasAksan et al. 2012). Investigations assessing the impact of amputations in worse cases (Whyte and Carroll 2002; Marom et al. 2019) show that these injuries cause economic and social distress, including pain, disfigurement, and in greater than one-fifth of the incidents, an inability for workers to return to their previous occupations. It is in light of these issues that visual attention needs to be directed toward. potential hand-related risks especially when under time pressure to deliver on tasks, in order to avoid acute traumatic hand distresses, including lacerations, crushes, fractures and tendon, nerve and vessels injuries and even loss of sensation to the arm and hands, particularly among roofers whose hands are frequently exposed and easily prone to injury during shingle installation.

4.3.4 Time pressure

4.3.4.1 *Time pressure and human performance*

The impact of time pressure on performance has been mixed in the literature. Although having negative effects on certain performance metrics, some researchers (e.g. Roskes et al. 2013) opine that time pressure does not always hurt performance. Rather, it can be applied in some situations for employees to work in a focused manner which can be activating, enhance enjoyment and improve the efficiency of operations. Accordingly, it has been suggested that there may be an optimal level of time-related stress, with very low and very high levels of pressure being detrimental to performance (Baer and Oldham 2006; Byron et al. 2010).

Notably, time pressure has been observed as a motivating potential in some studies. For instance, Chong et al. (2011) argue that teams do not necessarily perform worse under a high level of time pressure, asserting that high-performance teams can thrive in intense time-pressure situations. Their study investigated the impact of time pressure at the team level and found that team identification sustained team coordination, especially for teams facing hindrance time pressure. The investigators suggested that teams that possess strong identification could be positioned strategically in projects where time pressure is intense and stakes are high. The subjects in a study by Mäntylä et al. (2014) performed requirements review and software development tasks in which time pressure was associated with time saving, in addition to an increased efficiency in test case development and review per unit time. The study suggested the use of moderate time pressure to increase efficiency, but stressed the need to avoid excessive time pressure due to the creation of suboptimal performance. Baethge et al. (2018) tested whether time-exposure effects of time pressure as a stressor may be considered a challenge (under short-term exposure) or hindrance stressor (under long-term exposure) by examining the effect of time pressure on work engagement. Although short-term exposure to pressure was observed to be beneficial for a certain time, stable and long-term exposure to time pressure reduced work engagement. Thus, the study encouraged employers to avoid keeping time pressure permanently high in order to motivate employees, as a short-term increase in time pressure (e.g. before a deadline) may serve as a motivating factor.

Concurrently, time constraint has been observed to have deleterious effects on both decision-making processes and outcomes as documented by various researchers. for example, Wagenaar and Groeneweg (1987) found that human information processing errors occurred more frequently in the presence of high situational stress as a result of time pressure than would be expected by chance. The errors were observed to be almost exclusively related to a lack of attention in the context of environmental stressors, particularly poor visual conditions. In research to examine how the utilization of different attributes changes under time pressure, Svenson and Edland (1987) demonstrated that decisions and choices can be affected by time constraint with an effect strong enough to affect the majority of subjects, such that one type of alternative was preferred under time pressure and a different option was selected when the decision time was unlimited. Furthermore, Brown and Miller (2000) investigated the extent to which communication networks was affected by two situational variables, time pressure and task complexity. The outcome showed that time pressure did not influence the emergence of communication structure, suggesting that the effect of time pressure may differ depending on the complexity of the task. Caballer and colleagues (2005) analyzed the direct and combined effects of the communication media and time pressure in group work on the affective responses of team members to group processes and outcomes while performing intellective tasks. The results showed a direct effect of communication media on satisfaction with the process and a negative effect of time pressure on the satisfaction and commitment to group results. Using publicly available data from annual reports, Lambert and team (2017) found that time pressure imposed on the audits of registered firms negative impacted quality of earnings and audit completion by the accelerated deadline.

4.3.4.2 ***Time pressure and safety***

Because workers' cognitive abilities are affected by their physical and mental state as a result of work-related fatigue as well as the demanding environmental conditions onsite, workers' perception and comprehension of sources of risk and safety information may be impacted by time pressure (Williams 2017; Kim et al. 2021). Accordingly, stress levels are elevated—a consequence of completing a task in less time than normally required, which produces a change in physiological (e.g. increase in heart rate), psychological (e.g. anxiety and frustration) and behavioral (e.g. increases error rates, unsafe behavior) consequences (Hurrell 2005; Mazloumi et al. 2008).

A few attempts have been made to examine the impact of time pressure on safe behavior. In an early study, Seo (2005) observed that when workers experience production pressure in the form of excessive workload, required work-pace and time pressure, workers perceive a heightened risk and barrier to work engagement which propelled them to behave unsafely. Similarly, Han et al. (2014) examined the impact of production pressure on safety performance in construction operations and found that perceived production pressure affected productivity and resulted in a degradation of safety, eventually impacting both safety management and accident rates. Recently, Wong et al. (2020) explored the underlying reasons why construction workers avoid the use of personal protective equipment (PPE). In their study, participants reported that they often avoided PPE to minimize the delay and discomfort associated with its use especially when instructed by forepersons to work faster to meet production deadlines.

In a driving study, Rendon-Velez et al. (2016) investigated the effect of time pressure on measures of drivers' eye movement, pupil diameter, cardiovascular and respiratory activity, driving performance, vehicle control, limb movement, head position, and self-reported state. Analysis of participants' driving behavior revealed that under time pressure, subjects (1) drove significantly faster, an effect that was reflected in auxiliary measures such as maximum brake position, throttle activity, and lane keeping precision, (2) exhibited increased physiological activity, such as increased heart rate, increased respiration rate, increased pupil diameter, and reduced blink rate, and (3) adopted scenario-specific strategies for effective task completion, such as driving to the left of the lane during car following, and early visual lookout when approaching intersections.

4.3.5 Visual attention and hazard identification

Construction sites are inherently dangerous environments that expose workers to a variety of safety hazards and demand the entire human senses and attention for a safe performance (Lu et al. 2011; Pinheiro et al. 2016). In such complex settings, construction workers are tasked with identifying hazards and responding appropriately to them to prevent undesirable outcomes and uncontrolled risks (Rozenfeld et al. 2010; Li et al. 2019). In a dynamic environment, identifying relevant visual information—a complex and multidimensional cognitive process—and determining which information requires additional processing is important for workers' safety (Kaber et al. 2016; Hasanzadeh et al. 2017). Many accidents occur on construction sites because of a failure to notice hazards, misperceptions about their associated risks, and an inability to make timely decisions as a result of attention-related problems such as change blindness, inattentiveness and inherent human limitations (Habibnezhad et al. 2016).

Human errors (such as failure to identify a hazard) are often attributed to a worker's lack of situational awareness which leads to improper reactions and increases the likelihood of injury (Bentley 2009).

One major property that is associated with situation awareness is attention—the focus of consciousness on a particular stimulus while ignoring other distracting stimuli (James 1913; Wickens et al. 2013). To be situationally aware, one needs to pay attention to perceive and process the environment (Endsley 1995). However, the ability to detect and perceive hazards is constrained by limited human attentional resources in combination with the excessive attentional demands of a construction environment (Hasanzadeh et al. 2017).

Since workers experience increased visual and mental demands on jobsites because of the need to remain vigilant for potential hazards by dividing their attention in several directions across a variety of tasks performed concurrently, construction site accidents can be reduced if construction workers are able to promptly detect possible hazards by maintaining appropriate levels of situational awareness and taking preventive actions to reduce or eliminate the risk of injuries (Lu et al. 2011; Han et al. 2020).

4.3.6 Measuring visual attention with eye tracking technology

Because the ability to promptly recognize safety hazards on construction sites remains low (Hardison et al. 2017), it is necessary to understand how workers process visual information during hazard recognition tasks. To study attention, one needs a reliable means of measuring it (Hasanzadeh et al. 2017). Considerable evidence suggests that people often look directly at the stimuli they are currently attending to (Duchowski 2007). As such, a worker is likely to perceive and identify the hazard in the location of his or her focus of attention, consider protective actions and respond appropriately. One scientific way of studying attention is to observe eye-movement patterns because where one looks is highly correlated with where one's attention is focused (Hallett 1986).

Behavioral data on eye movements represent the most direct manifestation of visual attention and provide valuable information about an observer's attention and cognitive processing in hazardous situations (Duchowski 2007). Since construction workers recognize potential site hazards through their visual search (Han et al. 2020), eye tracking technology may be employed to assess how workers alternate between selective (focus on only one stimulus) and distributed attention (dividing attention between two or more objects), which reflects the amount and quality of information that a worker is able to perceive from the visual environment (Wickens et al. 2013).

Eye tracking is widely accepted as the most direct, continuous and objective measure of attention that works based on the tracking principles of human eye movements while perceiving a scene and processing visual information (Merino et al. 2018; Han et al. 2020). Tracking eye movements provides insights into attentional allocation, visual search strategies, and cognitive processes in real time, which serve as inputs to be organized and prioritized in the brain and executed as behavior (Murray et al. 2009; Kuzel et al. 2013). Through eye movement recording, researchers can understand the visual behavior of individuals, interpret their response to different image stimuli and assess hazard-identification abilities. As noted by Pernice and Nielsen (2009), observing where participants look, gleaning detailed insights about participants' perspectives, and drawing conclusions based on participants' point-of-view saliences are among the most important advantages of using eye-tracking technology.

4.3.7 Related work

Hazard identification has been studied in several domains involving human–machine interaction such as aviation (Ziv. 2016), transportation (Ma et al. 2020) and construction (Hasanzadeh et al. 2017). Having established that eye tracking technology provides deeper insights into visual behavior and cognitive processes, researchers have applied this technique to evaluate the impact of safety-related variables on hazard identification performance in order to optimize construction safety management measures. These variables include visual attention (Underwood et al. 2003); risk perception (Habibnezhad et al. 2016); safety knowledge (Hasanzadeh et al. 2017); focal attention location (Hardison et al. 2017); situational awareness (Hasanzadeh et al. 2018); motor disabilities (Merino et al. 2018); mental fatigue (Li et al. 2019); visual search strategies (Xu et al. 2019); cognitive overload

(Liko et al. 2020); hazard detection skills (Hasanzadeh et al. 2017; Chihming et al. 2020); work experience (Aroke et al. 2020); and visual engagement (Liang et al. 2021).

In a driving study, Underwood et al. (2003) recorded the eye fixations of novice and experienced drivers as they drove along rural, suburban and dual-carriageway roads. The research detected marked differences in the sequences of fixations between novice and experienced drivers on the types of roads, with experienced drivers showing greater sensitivity overall, while observing some stereotypical transitions in the visual attention of the novices.

In an aviation study, Ziv (2016) conducted a comprehensive literature review by grouping scholarly articles that employed eye-tracking technology according to prevalent themes, such as basic cockpit visual scanning, visual scanning in the automated cockpit, effects of new technology on visual scanning, nonnormal flight circumstances, differences between experts and novices, and mathematical models of visual scanning. The study observed that there exist specific gaze behaviors that are important when performing various flight tasks and monitoring automated processes that can be employed to differentiate between expert and novice pilots.

Likewise, using eye-tracking technology, Habibnezhad et al. (2016) investigated whether workers' risk perception impacts their visual search strategies when identifying hazards and found that people with high risk perception recorded a lower mean dwell-time percentage for all types of hazards, a lower mean dwell-time percentage for ladder hazards, and a higher first-fixation duration for struck-by-material hazards compared to individuals with a low risk perception.

Hasanzadeh et al. (2017) harnessed eye-tracking technology to evaluate the impact of workers' hazard-identification skills on their attentional distributions and visual search strategies. To achieve this objective, an experiment was designed in which the eye movements of 31 construction workers were tracked while they searched for hazards in 35 randomly ordered construction scenario images. The analyses indicated that hazard identification skills significantly impacted workers' visual search strategies, as workers with higher hazard-identification skills had lower dwell-time percentages on ladder-related hazards, higher fixation counts on fall-to-lower-level hazards, and higher fixation counts and run counts on fall-protection systems, struck-by, housekeeping, and all hazardous areas combined.

In a related study, Hasanzadeh et al. (2017) employed eye-tracking technology to measure the impact of safety knowledge in terms of training, work experience, and injury exposure on construction workers' attentional allocation. The study observed that work experience and injury exposure significantly impacted the visual search strategies and attentional allocation of participants, but found no statistically significant difference in the hazard identification abilities of workers with and without the OSHA 10-hour safety training certification.

Hardison et al. (2017) investigated the extent to which the proportion of focused and distributed attention during hazard recognition tasks relates to the proportion of safety hazards identified. Using binocular eye tracking glasses, the research team compared the proportion of focused and distributed attention to hazard recognition performance scores for 18 subjects across three photographs in quasi-experimental trials and found no correlation between the proportion of fixations on hazards and hazard recognition performance.

Furthermore, Hasanzadeh and colleagues (2018) examined the differences in attentional allocation between workers with low and high situation awareness levels while exposed to tripping hazards on a real construction site while their eye movements were tracked as direct measures of attention via a wearable mobile eye tracker. The research team discovered that subjects allocated attention unequally to all hazardous areas of interest, with the differences in attentional distribution modulated by the level of situation awareness.

In like manner, Merino et. al (2018) conducted an eye tracking experiment to analyze the difficulties in visual identification of buildings by observing the focus of visual attention of individuals with motor disabilities. The researchers discovered that the lack of visual information caused difficulties for individuals to locate and identify the correct route for the offset inside a building. The researchers also asserted that the use of the assistive technology reduced subjectivity in decision-making related to the development of accessible environments for workers with motor disabilities.

Li et al. (2019) utilized wearable eye trackers to evaluate the impact of mental fatigue on the visual attention allocation and hazard detection abilities of construction equipment operators and observed that hazard detection abilities decreased when the level of mental fatigue increased, which was reflected by significant increases in reaction time for hazards and the number of misdetections.

Moreover, Xu et al. (2019) conducted an experiment aimed at improving construction site safety inspection by comparing the search strategies of participants who successfully recognized hazards to those who were unable to, and observed that outstanding participants followed similar hazard search patterns, concentrating on specific hazardous areas rather than unimportant distractors. These individuals employed a logical and serial search pattern by observing a sub-area fully before systematically shifting attention to another location.

In another driving study, Ma et al. (2020) conducted an on-road driving eye tracking experiment to investigate the visual attention fixation and transition characteristics of drivers when under different cognitive workloads. The study observed that under a mild cognitive workload, drivers' sight trajectory was mainly focused on the distant front area but transition trajectory shifted to the junction near the front and far sides as workload level increased.

In the construction safety arena, Aroke and team (2020) combined eye-tracking technology with mediation analysis to investigate the extent to which the influence of work experience on the identification of fall hazards may be mediated by visual attention and discovered that attention mediated the relationship between work experience and hazard identification, suggesting that visual attention is the mechanism through which experienced workers are able to identify active and potential fall hazards in dynamic environments in contrast to novices.

In a closely-related study, Liko et. al. (2020) assessed the impact of working memory load on the detection of fall hazards as participants conducted a primary visual search task of identifying safety hazards in 35 construction-scenario images while memorizing a three- (low load) and six- (high load) digit string of numbers as a secondary cognitive task that was recalled at the end of the visual search. The researchers observed that workers performed poorly in the visual search task under a high working memory load, stressing the importance of working memory in the ability of workers to comprehend hazardous situations when performing memory-demanding tasks.

Similarly, Han et al. (2020) investigated the search patterns and attention resource allocation of workers under different site conditions that could affect subjects' cognitive load and computed metrics related to participants' fixation, visual search track, and attention map to evaluate the impact of cognitive load on hazard detection. The findings revealed that messy sites with disorganized items increased participants' cognitive load and impaired their ability to detect hazards.

More so, Chihming et al. (2020) employed eye tracking technology to accurately understand workers' cognition of construction hazards and discovered that participants exhibited superior hazard recognition abilities for common and obvious slip, trip and fall hazards in contrast to electrical hazards.

Although these studies have demonstrated the applicability of eye tracking technology in understanding the importance of safety variables (including visual attention) on hazard detection ability and safety performance, an in-depth quantitative research that focuses on measuring and evaluating the influence of time pressure on construction workers' attention to STF and hand injury hazards is lacking in construction safety literature. To this end, the current study will address this important research gap by employing eye tracking to continuously track the eye movements of participants during a simulated roofing activity and observe their visual attention to STF and hand injury hazards when working under time pressure.

4.4 Gaps in knowledge

From the foregoing, several researchers have successfully documented the influence of time pressure on various performance criteria including work engagement, time-saving, time-related stress, decision making, team effectiveness and safe behavior. Synchronously, a number of studies have investigated the prevalence of acute hand injuries in various occupational domains, in addition to the frequency of occurrence in the work environment, the root causes and risk factors associated with hand injuries and their impact on timely return to work. Considered as a whole, one can say that there were several literature reviews on time pressure and hand injuries in the past, but the extent to which visual attention to safety hazards may deteriorate as a result of time pressure has been largely ignored in the body of knowledge.

Although it is highly acknowledged that time pressure is an important variable in accident occurrence, there is little recognition within published literature of its impact on hazard identification in the construction workplace. Among construction trades, roofers are particularly at a high risk of injury and fatality because of a disproportionate exposure to STF and hand injury hazards (Mistikoglu et al. 2015). With such high fatal and nonfatal injuries reported in occupational populations, there is a need to enlighten construction safety arenas on the existence of certain factors that can aggravate the risk of STFs and hand injuries among residential roofers. The visual focus of attention of construction workers is a critical cue for recognizing entity interactions and enables the interpretation of workers' intentions, the prediction of movements, and the comprehension of the jobsite (Cai et al. 2020; Lengyel et al. 2021). Considering the danger associated with this high-risk occupation and how a lapse in the visual attention may contribute to falls and other safety incidents, a major scrutiny needs to be made on the mechanisms by which individuals may prioritize attention to safety hazards and the extent to which their focus may be impacted under time pressure. In particular, if construction workers hardly look at safety-critical areas in the work environment, this could mean that they may miss, ignore or perceive certain hazards to be unimportant when under time pressure, which may significantly reduce the potential of navigating their tasks safely. The resultant unsafe behavior may put millions of construction workers in harm's way, especially increasing their susceptibility to STF hazards, other roofing-related incidents (such as hand injuries) and lifelong bodily impairments. As a result, the underlying motivation of this paper is that it is essential to systematically investigate the impact of time pressure on attention to safety hazards during a simulated roofing task using eye-tracking technology. This effort can provide valuable insights into the direction that the construction industry must operate to tackle the issue of time pressure and safety performance.

Accordingly, the combination of time pressure and visual attention in this research poses a very important research question: Does time pressure have an impact on construction workers' attentiveness to fall and hand injury hazards on a construction site? This question drives the search for critical factors that may protect construction workers (especially residential roofers) against fall hazards and hand injuries when working on elevated platforms under restrictive conditions.

This study will address this research gap by continuously monitoring the visual attention of construction workers with eye-tracking technology in a simulated roofing activity under two experimental conditions: i) a baseline study with no deadline, and ii) a time pressure manipulation requiring task completion within a time limit. Because time pressure taxes cognitive resources and undermines information processing, the study predicts that creating tight work schedules that induce pressure for task completion may severely impact the visual attention of construction workers to safety hazards and increase their susceptibility to safety incidents. Therefore, the main null hypothesis of this study is:

- *Null hypothesis: Time pressure has no impact on construction workers' attentiveness to hazards (i.e. STFs and hand injuries) on a construction site*.

4.5 Research Methodology

The research investigated significant changes in attention to safety hazards when workers performed a roofing task within their natural abilities (baseline experiment) and when they worked with a time limit (time pressure manipulation). Additionally, participants were recorded with a video camera to examine whether time pressure increased workers' susceptibility to safety incidents and impacted their risk-taking behavior. An overview of the research is described in subsequent sections.

4.5.1 Data collection

4.5.1.1 *Participants*

In total, 37 undergraduate students from the Civil Engineering program at George Mason University with varied experience in construction were recruited to participate in a simulated roofing task. Years of experience varied as follows: less than 1 year (62%), 1-5 years (30%) and more than 5 years (8%). Eight percent of the participants had received the Occupational Safety and Health Administration (OSHA) 10-h/30-h training, while 19% acquired onsite/informal safety training. No form of training was reported among 73% of the students. Regarding injury exposure, a total of 84% of the participants reported no previous exposure to an injury while 16% had been injured on the job. Similarly, 35% of the students recorded that they had witnessed other workers get injured in the workplace, while 65% responded otherwise. To observe the safety performance of subjects without the disguise of natural behavior acquired from years of work experience, construction students were preferred to professional roofers to achieve the aims of the study without experimental bias. All participants had normal or corrected-to-normal vision and were ignorant of the study objectives. All research procedures were approved by the Institutional Review Board (IRB) at George Mason University.

4.5.2 Experimental design

Human subjects participated in activities to assess their attention to hazards and safe conduct when completing a potentially hazardous task while their eye metrics were collected using the Tobii Pro Glasses II mobile eye tracker (Fig. 4.1). This device gives objective insights into visual attention and cognitive engagement by showing exactly what a person is looking at in real time as they move freely in a real-world setting. The Tobii Pro Glasses 2 eye tracking system includes the Tobii Pro Glasses wearable eye tracker (also referred to as the head unit), a wearable recording unit that records and stores eye tracking data, sounds and scene camera video on a removable SD memory card, and the Tobii Glasses Controller Software. The eye tracking device facilitates pupil size estimation and eye-tracking precision with minimized gaze data loss and includes a scene camera that captures a full HD video of what a participant is viewing, eye tracking sensors that record eye orientation and infrared illuminators that brighten the eyes to support the eye tracking sensors.

The experiment required the installation of asphalt shingles in two separate tasks: the first without a time limit, and the second, with an incentive to complete the task within a limited time (simulating time pressure).

4.4.3 Roofing task

Participants installed 27 pieces of 40 ft^2 shingles standing on a low-sloped roof model 4ft wide, 6ft long and 3ft high in two experimental conditions. Shingles were asphalt type with class-A fire rating. Xfasten double-sided woodworking tape was utilized to hold the shingles firmly on the roof. Personal protective equipment (PPE) such as safety harness, knee protectors and safety gloves were provided to reduce the risk of injury. At the initial experimental run (baseline), subjects completed the task within their natural speed and no time limit was enforced. However, a 7-minute time limit was imposed in the second experiment. Within this time, participants were required to install as many shingles as they could. Several pre-test installations were carried out to determine the appropriate time-limit for the roofing activity in the second experimental manipulation. On the basis of these trials, it was determined that 7 minutes would allow at least half of the participants (equivalent to entry level roofers) sufficient time to perform the task and still impose a time pressure on all participants. A 15-dollar gift card was provided as an incentive to complete the task on time if at least 32 ft^2 of shingles were installed within the allotted time. The entire experiment took approximately 30 minutes.

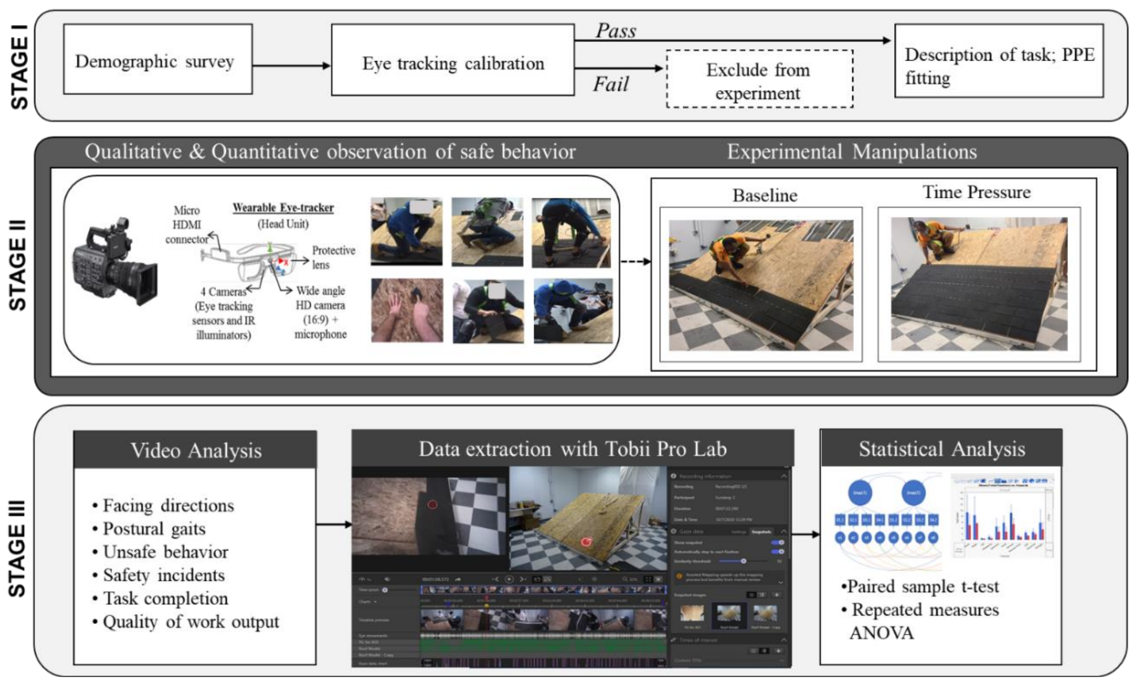


Figure 4.1: Experimental design to examine the influence of time pressure on attention to safety hazards

4.5.4 Areas of interest (AOIs)

Eye-tracking experiments utilize AOIs to study visual attention and analyze eye gaze data. AOIs are regions of stimuli segmented to concentrate the analysis of visual attention to certain safety-critical areas by linking eye metrics to those areas within a scene (Lengyel et al. 2021; Llanes-Jurado et al. 2021). To assess attention to construction safety hazards, for instance, multiple AOIs may be defined around materials, tools and equipment that pose potential danger to workers which require utmost vigilance to stay safe. Potentially hazardous AOIs were defined on the roof to assess the extent to which time pressure influenced participants' attention to likely sources of danger and how time limit impacted the safe conduct of the task.

The STF-related AOIs included: i) safety harness anchor point; ii) roof edges; iii) safety harness; iv) safety footwear; and v) shingles. Similarly hazardous AOIs which could increase the potential for hand injuries comprised: i) nails hinged on the roof; ii) hammer; and iii) hands.

Utilizing the Tobii Pro Lab Analyzer edition version 1.152, eye gaze data harnessed from the Tobii Pro recording unit were mapped onto snapshots of the roof image using manual mapping. Manual mapping was employed due to the dynamic nature of the experiment. The assisted mapping alternative is employed for experiments conducted in environments with reduced variability and facilitates automatic mapping of fixation points by the software.

4.5.5 Eye movement metrics

During a visual search, the eyes alternate between fixations (when they are aimed at a fixed point in the visual field), and rapid movements called saccades (Noton and Stark 1971; Bisley 2011). Both eye behaviors reveal shifts in the allocation of visual attention and are cyclic in nature because each saccade leads to a new fixation on a different point in the visual field. Fixations are periods when the eyes are relatively still, holding the central foveal vision in place so that the visual system can process information in more detail, lasting approximately 200-300 milliseconds (Granka et al. 2008; Tobi Pro 2021). Fixations are generally associated with attention, visual processing, and information absorption and used to assess an observer's focus of interest, in addition to gauging cognitive difficulty (Vickers 2007). Saccades, on the other hand, are rapid eye movements from one fixation to another which typically last about 30 to 80 milliseconds (Boch et al. 1984). They are the fastest eye movements that indicate the focal orientation of the eyes as they shift from one point of interest to another, with no visual information recognized during these movements (Bridgeman et al. 1994). This research measured attentiveness to hazards using four fixation-related metrics—time-to-first-fixation (TTFF), total fixation duration (TFD), dwell time and run count—to test the research hypothesis and examine participants' visual attention allocation as they conducted a simulated roofing task

TTFF measures the elapsed time until the first fixation occurs in the target AOI (Hollingworth and Bahle 2019). The amount of time taken to identify some safety-related areas of interest (AOIs) within a stimulus is predicted to be negatively affected by time pressure (via an increase in time) because of a reduced ability to promptly fixate on hazardous areas because of a focus to complete the task within the specified limit.

The TFD computes the total time an individual fixates on an AOI. Since this metric indicates the degree of cognitive difficulty and attention resources allocated to an AOI as a result of in-depth processing (Fraser et al. 2017), it was hypothesized that there will be a decrease in the TFD or a reduced time taken to examine the work area for safety hazards as a result of time pressure.

Dwell time records the elapsed time between the start of the first fixation on an AOI until the end of the last fixation on the AOI. It was also anticipated that the dwell time—which signifies the general looking behavior and attention to AOIs (Tobi Pro 2021)—will be negatively impacted by time pressure, as it is unlikely that participants will distribute their attention more broadly to monitor hazardous areas that may affect their safety when constrained by time.

Run count indicates the number of visits to a specific AOI over the course of the experiment. A visit is defined as the time between the start of the first fixation on the AOI until the end of the last fixation on the AOI, excluding the entry and exit saccades (Tobi Pro 2021). Since the run count gives an indication of the informativeness of a region of interest (Ares et al. 2013), time pressure is projected to bring about a decrease in this eye metric due to the burden of completing the task on time.

Utilizing these metrics to study visual performance during task execution will provide valuable information on attention to safety hazards and show how time pressure may impact how individuals prioritize certain areas in the visual field of view than other locations, as workers potentially compromise their safety in response to time pressure. The main null hypothesis was tested four times for all eye tracking metrics to investigate whether time pressure will impact the visual attention of construction workers and increase their susceptibility to STFs and hand injuries.

4.5.6 Data analysis

4.5.6.1 *Paired Sample T-test*

Since the effect of time pressure on visual attention to safety hazards was observed in two experimental manipulations, the paired sample t-test was employed to examine whether attention to the STF and hand injury AOIs varied significantly from the baseline to the time pressure manipulation. The paired sample t-test (also known as the dependent sample or repeated-measures t-test) is a statistical procedure for comparing the equality of the means of two matched or highly correlated groups repeatedly observed at different points in time to assess the predominance of a treatment (Ramosaj 2020). In this test, each subject is measured at two different time points or for two related conditions—usually before and after treatment— resulting in paired observations, after which the statistical difference between both population means in the matched sample design is investigated. Using the attentional indicators on STF and hand jury AOIs in the baseline and time pressure experiment as the first and second pairs respectively, the results of a paired-sample t-test (Norušis 2002) will indicate whether or not there is a significant increase (or decrease) in attention to safety hazards when the time pressure increased from the first experiment to the second.

4.5.6.2 *Repeat Measure Analysis of Variance (RM-ANOVA)*

The results were further analyzed to investigate whether there was a significant effect of the type of hazard (STF or hand injury-related) or time (baseline or time pressure) on visual attention (i.e., eye tracking metrics), or whether an interaction between both variables (hazard type and time) will exist to influence participants' attention.

When observations are repeatedly assessed over time (as in this study), an RM- ANOVA is performed to investigate the effect of experimental conditions on the outcome of interest at each time point (Gueorguieva and Krystal. 2004; Langenberg et al. 2020). The technique assumes a common set of time periods among all individual units and a balanced array of data (Krueger and Tian 2004). Accordingly, the RM-ANOVA was employed to examine whether: 1) hazard type and time interact to influence attention; 2) there is a main effect of hazard type on visual attention; and 3) there is a main effect of time on visual attention.

4.5.7 Analytic strategy

The *Wilks' Lambda* (Wilks, 1932, 1935; Todorov and Filzmoser 2010)— a commonly used tool of inference about the mean vectors of several multivariate normal populations and also known as the *likelihood ratio test*—was applied for the interpretation of results. The cut off value of statistical significance was set at 0.05.

The *Levene*'s test for homogeneity of variances was also employed in the study. Valid use of the ANOVA procedure is contingent on the assumptions of normality, homogeneity of population variances (HOV) and independence of observations (Kim and Cribbie 2018). As a result, researchers examine whether or not the HOV assumption has been satisfied with the Levene's test. The homogeneity of variance assumption stipulates that groups have similar variances or reactions to the treatment received. Violation of this assumption may infer that test results may be attributable to other factors other than the treatments received by the groups. Thus, Levene's test for homogeneity—essentially an analysis of variance (ANOVA) done to examine deviations of the sample scores from the group means or assess variance inequality across groups—is one of the widely acknowledged tests in terms of statistical power, and is quite robust to departures from normality (Levene, 1960; Conover et al. 1981). The assumption for homogeneity of variance for the safety hazards in this study was violated if the p-value was less than 0.05 (Starkweather 2010). Thereafter, a pairwise comparison was performed via the *Tukey's honestly significant difference (HSD)* post hoc test to assess where there was a difference in attention across the safety hazards.

The *Bonferroni* adjustment was utilized to surmount the challenges associated with multiple comparisons. When statistical tests are performed multiple times to investigate pairwise associations, the likelihood of committing a family-wise type 1 error rate is artificially increased, requiring adjustment of individual significance levels (Vialatte and Cichocki 2008). To avoid spurious positives, the alpha value is usually lowered to account for the number of comparisons performed (Weisstein 2021). Thus, the Bonferroni correction is an adjustment made to the p-values when several statistical tests are performed simultaneously on a single data set to avoid potential inflation of the alpha level. The Bonferroni correction reduces the problems associated with multiple comparisons by dividing the significance level (usually 0.05) by the number of comparisons, and setting the result as the critical p-value for statistical significance for an overall risk no larger than 0.05 of falsely detecting a difference (Garamszegi 2006; Napierala 2012).

4.6 Results

4.6.1 Paired sample t-test

4.6.1.1 *STF hazards*

Time-to-first-fixation (TTFF)

The results of the paired sample t-test showed that the mean TTFF on all STF AOIs [footwear (p = 0.470), harness anchor point (p = 0.123), edges (p = 0.390), harness (p = 0.859) and shingles (p = 0.416)] did not significantly change from the baseline to the time pressure manipulation (Table 4.1).

Total fixation duration (TFD)

The mean TFD on the majority of STF AOIs [footwear (p = 0.002), edges (p = 0.020), harness (p = 0.018) and shingles (p = 0.022)] changed significantly from the baseline to the time pressure manipulation (Table 4.1). However, TFD on an STF AOI [harness anchor point (p = 0.178)] did not significantly vary in both experiments.

Dwell time

While the mean dwell time on an STF AOI [footwear (p = 0.030)] changed significantly from the baseline to the time pressure manipulation (Table 1), dwell time on other STF AOIs [harness anchor point (p = 0.797), edges (p = 0.705), harness (p = 0.694) and shingles (p = 0.069)] did not significantly differ in both experiments.

Runt count

The run count on most STF AOIs [footwear (*p* = 0.000), edges (*p* = 0.004), harness (*p* = 0.000) and shingles (*p* = 0.005)] varied significantly from the baseline to the time pressure manipulation (Table 4.1), but was not the case for an STF AOI [harness anchor point (*p* = 0.073)].

4.6.1.2 *Hand injury hazards*

Time-to-first-fixation (TTFF)

The results of the paired sample t-test showed that the mean TTFF to hand injury AOIs [nails (*p* = 0.574), hammer (*p* = 0.534), hand (*p* = 0.917)] did not significantly change from the baseline to the time pressure manipulation (Table 4.1).

Total fixation duration (TFD)

The mean TFD on all hand injury AOIs [hammer (*p* = 0.003), hand (*p* = 0.008), nail (*p* = 0.043)] changed significantly from the baseline to the time pressure manipulation (Table 4.1).

Dwell time

While the mean dwell time on a hand injury AOI [hand (*p* = 0.043))] changed significantly from the baseline to the time pressure manipulation (Table 4.1), dwell time on other hand injury AOIs [nails (*p* = 0.499) and hammer (*p* = 0.167)] did not significantly differ in both experiments.

Runt count

The run count on most hand injury AOIs [hammer (*p* = 0.000) and hand (*p* = 0.000)] varied significantly from the baseline to the time pressure manipulation (Table 4.1), but was not the case for one hand injury [nail (*p* = 0.073)] AOI.

4.6.2 RM-ANOVA

The result of the RM-ANOVA revealed a main effect of hazard type on TTFF (F = 9.392, p = 0.000), TFD (F = 5.081, p = 0.000), dwell time (F = 8.289, p = 0.000) and run count (F = 11.00, p = 0.000). Likewise, there was a main effect of time on dwell time (F = 4.361, p = 0.042) and run count (F = 5.043, p = 0.029), in contrast to TTFF (F = 0.326, p = 0.571) and TFD (F = 3.640, p = 0.062).

These main effects were not qualified by an interaction between hazard type and time for all four eye metrics observed: TTFF (F = 0.380, p = 0.925), TFD (F = 1.235, p = 0.304), dwell time (F = 1.692, p = 0.253) and run count (F = 1.805, p = 0.105).

4.6.2.1 *STF hazards*

Time-to-first-fixation

Levene's test showed no violation of the equality of variance assumption for all STF AOIs [harness anchor (F = 0.980, p = 0.327), edges (F = 2.602, p = 0.113), footwear (F = 0.012, p = 0.915), harness (F = 1.753, p = 0.192) and shingles (F = 1.399, p = 0.243)].

Post hoc analyses using Tukey's HSD (Table 4.2) revealed that on average, the mean TTFF was lowest on the STF AOIs (harness; M= 7.726 and edges; M= 8.408) and highest on an STF AOI (harness anchor; M= 68.436).

Total fixation duration

Levene's test indicated no violation of the equal variance assumption for most STF AOIs [harness anchor (F = 0.984, p = 0.326), edges (F = 2.607, p = 0.113), harness (F = 3.252, p = 0.080) and shingles (F = 3.918, p = 0.056)]. However, unequal variances were observed for one STF AOI [footwear (F = 8.647, p = 0.006)].

Post hoc analyses using Tukey's HSD (Table 4.2) showed that on average, the mean TFD was lowest on an STF AOI (harness anchor; *M*= 1.128), but highest on two STF AOIs [edges (*M*= 9.197) and harness (*M*= 9.604)].

Dwell time

Levene's test indicated no violation of the equal variance assumption for all STF AOIs [harness anchor (F = 2.003, p = 0.163), edges (F = 0.069, p = 0.794), footwear (F = 3.854, p = 0.055), harness (F = 1.142, p = 0.290) and shingles (F = 1.762, p = 0.190)].

Post hoc analyses using Tukey's HSD (Table 4.2) demonstrated that on average, the mean dwell time was lowest on an STF AOI [harness anchor (*M*= 0.003)], but highest on two STF AOIs [edges (*M*= 0.009) and harness (*M*= 0.031)].

Run Count

Levene's test indicated no violation of the equal variance assumption for two STF AOIs [harness anchor (F = 0.198, p = 0.658) and edges (F = 3.802, p = 0.057]. However, unequal variances were observed for some STF AOIs [footwear (F = 9.056, p = 0.004), harness (F = 4.666, p = 0.036) and shingles (F = 10.934, p = 0.002)].

Post hoc analyses using Tukey's HSD (Table 4.2) showed that on average, the mean run count was lowest on one STF AOI (harness anchor; *M*= 4.172), but highest on two STF AOIs [footwear (*M*=27.695) and harness (*M*= 28.367)].

4.6.2.2 *Hand injury hazards*

Time-to-first-fixation

Levene's test showed no violation of the equality of variance assumption for all hand injury AOIs [nails (F = 0.711, p = 0.403), hammers (F = 0.058, p = 0.811) and hand (F = 0.027, p = 0.869)].

Post hoc analyses using Tukey's HSD (Table 4.2) revealed that on average, the mean TTFF was highest on a hand injury AOI [nails (*M*= 42.917)].

Total fixation duration

Levene's test indicated no violation of the equal variance assumption for one hand injury AOI [nail (F = 0.992, p = 0.324)]. However, unequal variances were observed for two hand injury AOIs [hammers (F = 5.776, p = 0.022) and hand (F = 7.836, p = 0.008)].

Post hoc analyses using Tukey's HSD (Table 4.2) showed that on average, the mean TFD was lowest on one hand injury AOI [nails (*M*= 2.183)], but highest on no hand injury AOI.

Dwell time

Levene's test indicated no violation of the equal variance assumption for all hand injury AOIs [nails (F = 0.019, p = 0.891), hammer (F = 0.094, p = 0.760) and hand (F = 1.385, p = 0.245)].

Post hoc analyses using Tukey's HSD (Table 4.2) demonstrated that on average, the mean dwell time was lowest on a hand injury AOI [nails (*M*= 0.006)], but highest on no hand injury AOI.

Run Count

Levene's test indicated no violation of the equal variance assumption for one hand injury AOI [nail (F = 1.714, p = 0.197)]. However, unequal variances were observed for other hand injury AOIs [hammers (F = 12.044, p = 0.001) and hand (F = 11.997, p = 0.001)].

Post hoc analyses using Tukey's HSD (Table 4.2) showed that on average, the mean run count was lowest on a hand injury AOI [nails (*M*= 7.077)], but highest on no hand injury AOIs.

Table 4.1: Results of paired t-test in baseline and time pressure manipulations

	Time-to-first-fixation			Total fixation duration			Dwell time			Run count		
	Mean (seconds)			Mean (seconds)			Mean (seconds)			Mean (seconds)		
Hazards	**BL**	**TP**	**P-value**	**BL**	**TP**	**P-value**	**BL**	**TP**	**P-value**	**BL**	**TP**	**P-value**
Harness anchor	78.53	58.34	0.123	1.33	0.930	0.178	0.003	0.003	0.797	4.76	3.58	0.073
Nails	35.47	50.36	0.574	2.79	1.580	0.043*	0.006	0.005	0.499	8.28	5.88	0.073
Edges	10.54	6.28	0.390	11.29	7.110	0.020*	0.027	0.026	0.705	30.60	21.46	0.004**
Footwear	14.77	13.17	0.470	11.80	6.040	0.002**	0.030	0.021	0.030*	34.64	20.75	0.001**
Hammer	18.55	21.04	0.534	5.65	3.190	0.003**	0.012	0.010	0.167	19.08	11.50	0.001**
Hand	13.98	13.79	0.917	7.56	3.380	0.008**	0.015	0.011	0.043*	22.16	11.92	0.001**
Harness	7.55	7.90	0.859	12.06	7.150	0.018*	0.028	0.026	0.694	35.40	21.33	0.001**
Shingles	14.24	13.86	0.416	7.64	4.520	0.022*	0.016	0.013	0.069	24.28	15.04	0.005**

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table 4.2: Pairwise comparisons of eye tracking metrics on safety hazards

		Time-to-first-fixation		Total fix. duration		Dwell time		Run count	
AOIs	**AOIs**	**Mean**	**P-value[a]**	**Mean**	**P-value[a]**	**Mean**	**P-value[a]**	**Mean**	**P-value[a]**
Harness anchor		68.436		1.128		0.003		4.172	
	Nails	42.917	-	2.183	0.005**	0.006	0.016*	7.077	0.003**
	Edges	8.408	0.000***	9.197	0.000***	0.029	0.000***	26.029	0.000***
	Footwear	13.968	0.001**	8.920	0.000***	0.028	0.000***	27.695	0.000***
	Hammer	19.795	0.007**	4.418	0.000***	0.011	0.000***	15.290	0.000***
	Hand	13.884	0.000***	5.471	0.000***	0.015	0.000***	17.038	0.000***
	Harness	7.726	0.001**	9.604	0.000***	0.031	0.000***	28.367	0.000***
	Shingles	13.853	0.001**	6.081	0.000***	0.017	0.000***	19.661	0.000***
Nails		42.917		2.182		0.006		7.070	
	Harn. anchor	68.436	-	1.128	0.005**	0.003	0.016*	4.172	0.003**
	Edges	8.408	0.001**	9.197	0.000***	0.029	0.000***	26.029	0.000***
	Footwear	13.968	0.002**	8.920	0.000***	0.028	0.000***	27.695	0.000***
	Hammer	19.795		4.418	0.001**	0.011	0.003**	15.290	0.000***
	Hand	13.884	0.019*	5.471	0.000***	0.015	0.000***	17.038	0.000***
	Harness	7.726	0.000***	9.604	0.000***	0.031	0.000***	28.367	0.000***
	Shingles	13.853	0.009**	6.081	0.000***	0.017	0.000**	19.661	0.000***
Edges		8.408		9.197		0.029		26.029	
	Harn. anchor	68.436	0.000***	1.128	0.000***	0.003	0.000***	4.172	0.000***
	Nails	42.917	0.001**	2.183	0.000***	0.006	0.000***	7.077	0.000***
	Hammer	19.795	-	4.418	0.000***	0.011	0.000***	15.290	0.000***
	Hand	13.884	-	5.471	0.000***	0.015	0.000***	17.038	0.000***

	Shingles	13.853	-	6.081	0.001**	0.017	0.000***	19.661	0.000***
Footwear		13.968		8.920		0.028		27.695	
	Harn. anchor	68.436	0.001**	1.128	0.000***	0.003	0.000***	4.172	0.000***
	Nails	42.917	0.002**	2.183	0.000***	0.006	0.000***	7.077	0.000***
	Hammer	19.795	-	4.418	0.000***	0.011	0.000***	15.290	0.000***
	Hand	13.884	-	5.471	0.000***	0.015	0.000***	17.038	0.000***
	Shingles	13.853	-	6.081	0.002**	0.017	0.000***	19.661	0.000***
Hammer		19.795		4.418		0.011		15.290	
	Harn. anchor	68.436	0.007**	1.128	0.000***	0.003	0.000***	4.172	0.000***
	Nails	42.917	-	2.183	0.001**	0.006	0.002**	7.077	0.000***
	Edges	8.408	-	9.197	0.000***	0.029	0.000***	26.029	0.000***
	Footwear	13.968	-	8.920	0.000***	0.028	0.000***	27.695	0.000***
	Harness	7.726	0.002**	9.604	0.000***	0.031	0.000***	28.367	0.000***
	Shingles	13.853	-	6.081	0.021**	0.017	0.022**	19.661	0.004**
Hand		13.884		5.471		0.015		17.038	
	Harn. anchor	68.436	0.000***	1.128	0.000***	0.003	0.000***	4.172	0.000***
	Nails	42.917	0.019*	2.183	0.000***	0.006	0.000***	7.077	0.000***
	Edges	8.408	-	9.197	0.000***	0.029	0.000***	26.029	0.000***
	Footwear	13.968	-	8.920	0.000***	0.028	0.000***	27.695	0.000***
	Harness	7.726	-	9.604	0.000***	0.031	0.000***	19.661	0.000***
Harness		7.726		9.604		0.031		28.367	
	Harn. anchor	68.436	0.000***	1.128	0.000***	0.003	0.000***	4.172	0.000***
	Nails	42.917	0.000***	2.183	0.000***	0.006	0.000***	7.077	0.000***
	Hammer	19.795	0.002**	4.418	0.000***	0.011	0.000***	15.290	0.000***
	Hand	13.884	-	5.471	0.000***	0.015	0.000***	17.038	0.000***
	Shingles	13.853	-	6.081	0.001**	0.017	0.000***	19.661	0.000***
Shingles		13.853		6.081		0.017		19.661	
	Harn. anchor	68.436	0.001**	1.128	0.000***	0.003	0.000***	4.172	0.000***
	Nails	42.917	0.009**	2.183	0.000***	0.006	0.001***	7.077	0.000***
	Edges	8.408	-	9.197	0.001**	0.029	0.000***	26.029	0.000***
	Footwear	13.968	-	8.920	0.002**	0.028	0.000***	27.695	0.000***
	Hammer	19.795	-	4.418	0.021*	0.011	0.022**	15.290	0.004**
	Harness	7.726	-	9.604	0.001**	0.031	0.000***	28.367	0.000***

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

[a] Bonferroni adjustment for multiple comparison

4.7 Discussion

The results of statistical analysis revealed that TTFF (time taken to view the safety AOIs from the onset of the trial) on STF (edges, shingles, footwear and harness anchor) and hand injury (hands) AOIs reduced from the baseline to the time pressure manipulation. On the other hand, there was an increase in time taken to initially fixate on an STF (harness) and hand injury (nails and hammer) AOIs as a result of time pressure, suggesting increased proneness to fall hazards and hand injuries. Similarly, the findings lend support to the research hypothesis of a reduction in visual attention (as evidenced by a reduced TFD, dwell time and run count) on all STF and hand injury AOIs from the baseline to the time pressure manipulation. Pairwise comparison of the safety hazards showed that on average, participants paid more attention to the STF AOIs (edges, footwear and harness) and the least attention to the majority of the hand injury AOI (nails and hammer) and an STF AOI (harness anchor), highlighting increased proneness to both STF and hand injuries when performing a high-risk activity (such as roofing construction) under time pressure.

As observed by Kelly and Karau (1999), time pressure is likely to restrict the amount of information considered or the thoroughness with which information is evaluated beyond functional levels, which may negatively impact visual attention and overall safety performance. In addition, time pressure creates extra cognitive demands on individuals and limits the amount of information that can be processed when making safety decisions (Payne et al. 1996). Moreover, having to complete a task in a short amount of time could lead to high mental workload, anxiety and frustration, which may alter the cognitive processing of a task (Rendon-Velez et al. 2016). Particularly in the construction safety domain, emotional stress can induce feelings of exhaustion, which may cause workers to ignore safety rules and increase the risk of injury (Elfering et al. 2006). Keinan et al. (1999) identified two primary reasons for the detrimental effects of time pressure on cognitive performance. First, the experience of time pressure elicits stress and arousal, which distracts individuals from the task at hand. Time stress causes high levels of arousal which leads individuals to focus on an increasingly narrow range of task-relevant cues (Svenson and Edland 1987; Kruglanski and Webster 1996) in a manner that influences visual attention and information processing in the work environment. Second, working within a time limit leads to a heightened need to monitor task progress and the amount of time remaining, which consumes a significant amount of mental resources needed for effective task performance (Karau and Kelly 1992; Hancock and Szalma 2008). Moreover, Maule and Hockey (1993) explained that psychological stress increases when people are forced to make decisions within a limited time frame, but attempt to adapt to the increased cognitive demands associated with time pressure. As a result, workers may accelerate information processing to meet an impending deadline or become selective by focusing on the most important information or eliminate important safety information from consideration to cope with the time-restricting situation (Maule and Mackie 1990; Payne et al. 1996).

The negative impact of time pressure on the visual attention to hazards in the current study even at the expense of safety is not entirely surprising, given the near-consistent observation of significant negative correlations between time pressure and safety performance in extant literature. For example, Svenson and Edland (1987) observed that when the time available for a given task is initially unrestricted but decreased gradually, the situation leads to increased focusing and mobilization of resources to perform the task. However, the researchers noted that further restriction of the time available induces feelings of pressure that transforms into time stress when the experience becomes more intense as time-to-completion decreases. Similarly, Goliszek (1992) discovered that time pressure causes emotional stress as a result of prolonged exposure to stressful conditions, such that workers get emotionally drained, chronically fatigued, and lose the ability to devote themselves to their job duties. Furthermore, a study by Gilliland and Schmitt (1993) that noted that time constraints limit the depth (amount of information accessed) and latency (amount of time spent looking at each piece of information) of information search in a process-tracing decision task. In the safety domain, Hofmann and Stetzer (1996) examined the factors that influence the frequency of reported unsafe behaviors in industrial accidents and found that a strong pressure within the organization to complete work tasks as quickly as possible was associated with unsafe behavior.

Taken together, the findings in the current study demonstrate that construction workers may be at a heightened risk of STF and hand injury hazards due to the potential danger of allocating reduced attentional resources to safety-critical areas as participants prioritized task completion and compromised a measure of attention to safety hazards when pressed to complete tasks in a shorter time than they normally would.

4.7.1 Impact of time pressure on STFs

During the experiment, it was observed that some participants encountered a slip on the roof as a result of a relatively low friction and loose grip of participants' footwear on the roof, aggravated by the time limit imposed in the second run. Foot slippage is the most widespread unforeseen event that causes falls on the same level, and a contributing factor to falls from heights and falls to a lower level (Irzmańska 2015). Time pressure also impacted the balance of participants especially as they completed a task that subjected them to perturbations and destabilizing factors on a sloped roof with mostly ill-fitting, worn-out or slippery footwear which affected their gait, traction and stability.

Furthermore, it appeared that participants had a major concern about encountering a fall, evidenced by the marked attention paid to the STF AOIs (reduced TTFF and a high TFD, dwell time, and run count on the edges, footwear and harness). However, the authors noticed that pressure to complete the task within the time limit culminated in the experience of a fall, trip or near-skid incident during the time pressure manipulation, while some participants were prompted to work near the unprotected edge of the roof and placed their legs off the roof edge.

Notably, it was of concern that the least attention was paid to the harness anchor for the entire duration of the experiment. The personal fall arrest system—consisting of a full body harness, a shock absorbing lanyard or self-retracting lifeline, and anchorage—is a proven means of protecting workers designed to arrest the worker safely during a fall (Arnold 2016; ; Heidari et al. 2021; Rey-Merchan et al. 2021). However, participants in this study paid the least attention to the anchor point of the safety harness. The importance of visual attention to the safety harness and its anchor cannot be overemphasized because a high number of fatalities emanates from absence or misuse of the harness and inaccurate placement of anchor points, such as not tying off to an appropriate structure (Hinze.and Olbina 2008; Perry et al. 2015). Heidari and his team (2021) also emphasize that adequate visual attention should be paid to the selection of anchor points to avoid the use of nonstructural elements, swing hazards, suspension trauma and excessive rope slack, and to ascertain that maximum arresting force is applied to a worker during a fall. Against this backdrop, proper safety education should provoke construction workers to regularly monitor these devices to ensure their safety during a roofing task. To buttress its importance, the Occupational Safety and Health Administration (2015) mandates the use of a safety harness when working on roofs and in close proximity to an unprotected edge 6 feet or more above the lower level. In spite of the legal requirement of its use and workers' cognizance of their exposure to a fall, it was disturbing to observe a significant decline in the visual attention of workers on this part of the STF AOI. Some individuals simply twirled the lanyard around their bodies as it got in the way of completing the task faster, paying minimal attention to the harness-lanyard-anchor connection and underestimating the safety risks involved.

4.7.2 Impact of time pressure on hand injuries

The current study discovered that the least attention was paid to all hand injury AOIs (hand, hammer and nails), suggesting increased susceptibility to hand injuries when roofers are pressed to deliver on tasks within a time limit. Being the most frequently injured body part, the potential for hand injuries in the workplace has been studied by various scholars. To identify risk factors for acute occupational traumatic hand injuries, Sorock et al. (2001) conducted a case-crossover study of transient exposures (such as being rushed), and found that specific transient factors in the work environment may increase or decrease the risk of occupational hand trauma. These factors include equipment considerations such as utilizing a tool or work piece in an unusual condition; work practice such as performing an unusual task or executing a task using an unusual work method; worker-related factors like being distracted or rushed, and personal protective equipment such as glove use. In a related study (Abudayyeh et al. 2003), contractors were asked to rank the relative frequency of injury and illness on a scale from 1 to 6, with 1 being the most frequent. Of the 10 electrical contractors who participated in the study, seven assigned the hand/fingers a relative ranking of 1, making it by far the body part most frequently affected. They also reported drills, hammers, saws, pliers, and knives as the tools mostly involved in injuries to the hands or fingers, with cuts identified as the most common type of hand injuries resulting from the use of these tools. Sorock and team (2004) also identified factors associated with hand and finger injuries, including worker characteristics (e.g. experience level), workplace conditions (e.g. poor tool design), transient work practices (e.g. being in a hurry), and worker capabilities (e.g. fatigue or not paying full attention to the task). In this study, time pressure impacted attention to most of the hand injury AOIs (nails hinged on the roof and hammer) and various unsafe behavior—including crawling with the hammer and stepping on nails hinged on the roof—were noticed among the participants during the time pressure manipulation.

4.7.3 Safety-Productivity divide

Although time pressure impacted workers' visual attention to safety hazards, the study observed that productivity increased from the baseline (installing 3 shingles per minute) to the time pressure manipulation (4 shingles per minute). This increased productivity achieved at the detriment of safety may be explained by the safety-production conflict.

Construction projects are expected to simultaneously achieve multiple performance goals in productivity and performance, while incorporating best practices in safety and health for overall operational success (Lawani et al. 2009; Karakhan and Gambatese 2018). As a result, management typically requires employees to work both safely and productively. While both factors are closely related, they may be in apparent conflict with each other (Memarian and Mitropoulos 2016). Literature in occupational safety have conceptualized the "safety-production conflict" as the perceived inability to achieve safety and production simultaneously (Mitropoulos et al. 2005; McLain and Jarrell 2007). In other words, when safety and productivity goals compete for workers' attention due to pressure resulting from productivity, safety often deteriorates while productivity becomes a priority due to the need for accelerated production and the culminating financial incentives (Nepal et al. 2006; Mitropoulos and Cupido 2009). In such situations, construction workers tend to put more effort into their work tasks which makes them less alert to safety and increases the propensity for injury incidents (Goldenhar et al. 2003; Mohammadi et al. 2018). Moreover, the complexity of the construction industry and the ever increasing drive for higher productivity can result in a degradation of safety as work demands usually strain workers' ability to safely meet management's production expectations, directly impacting safety management and accident rates (van der Molen et al. 2005;

McLain and Jarrell 2007). Consequently, because of pressures on cost, schedule, and productivity, workers may violate safety rules and engage in unsafe behavior, with the belief that such conduct will empower them to be more productive (Alper and Karsh 2009; Usmen and Vilnitis 2015). Particularly, workers cut safety corners when they face pressures to perform and will forgo safe work practices when they feel the need to perform quickly. For example, some studies (e.g. Han et al. 2014; Guo et al. 2015) observed that workers take risks in the face of production pressure and tend to avoid safety equipment to improve productivity due to its discomfort. These unsafe practices often become the norm as managers and supervisors invest less time and energy in safety and may encourage workers to take shortcuts to meet production schedules to keep up with the already delayed schedule goals especially when such conducts aid workers to complete the task more quickly and efficiently (Mullen 2004; Mohammadi et al. 2018).

Empirical research (e.g. Hofmann and Stetzer 1996; Usmen and Vilnitis 2015) have documented their findings regarding the safety-production divide which causes workers to focus more narrowly on performance rather than safety goals because the former is likely to be more salient. Embrey (1992) identified production-safety tradeoffs, time pressure, communication-coordination systems and safety culture as key organizational factors that influence safety performance. Along similar lines, Hofmann and Stetzer (1996) observed that as work overload increased, workers adopted more risky short cuts at the detriment of their safety. In a study that observed residential roofers, Usmen and Vilnitis (2015) discovered that productivity dramatically decreased when fall arrest systems were used because workers lost ample time adjusting their lanyards on steep roofs which resulted in a loss of productivity . Similarly, Nordlöf and team (2015) examined safety culture and risk-taking behavior by exploring workers' experiences and perceptions on safety and risk. The workers asserted that a trade-off existed between productivity and safety, where production targets and production pressures were perceived to be prioritized over safety procedures with practical obstacles to working safely.

Recently, Hasanzadeh and de la Garza (2020) examined whether reduced task demands as a result of safer conditions caused fall risks to be underestimated, encouraged increased productivity, and impacted risk-taking behaviors. In doing so, changes in participants' productivity, risk perception, risk-taking behavior and safety performance were examined when they were provided with various levels of safety interventions. The study found that the reduced perceived risk and the desire for increased productivity skewed risk analysis and strongly biased workers toward presuming invulnerability when safety interventions were in place.

In line with the findings above, participants in the current study focused on performance, that is, installing at least 32ft2 of shingles within the 7-minute time limit rather than on their safety. It was worrisome that participants underestimated the risks involved in the roofing activity because of the security offered by the fall arrest and other safety equipment, that they geared all efforts to increase their productivity in the second experiment (time pressure manipulation) to justify behaviors that were unsafe.

4.7.4 Risk compensation

An equally important factor that impacts workers' safety behavior is their risk-seeking propensity. This concept measures a worker's subjective judgment of a safety risk and willingness to engage in activities with known elements of physical danger (Westaby and Lee 2003; Lavino and Neumann 2010). When a worker perceives risks by collecting various kinds of information to assess the gravity of danger, the worker establishes their safety attitude based on the perceived risks. Then, the s/he may decide whether or not to engage in unsafe behavior based on the established attitude (Shin et al. 2014). People tend to overestimate their ability to control or prevent accidents, which leads to an underestimation of risks and propels workers to behave unsafely intentionally (Lichtenstein et al. 1978). As such, negative attitudes like the tendency to underestimate the possibility of hazards and take shortcuts to get the job done poses a great threat to safety on work sites (Mohammadi et al. 2018). Especially, because sustaining a work-related injury may not be immediate but progress over repeated exposure to the dangerous situation, workers who do not experience instantaneous harm are more likely to have a reduced perception of risks and engage in unsafe work behavior (Canter 1980; Bjorkman 1984). By the same token, individuals are likely to have a greater judgment of risk if the negative effect of the actions (that is, accident-involvement or near-misses) are immediate, as opposed to delayed. In addition, workers with a high sensation-seeking tendency may underestimate the danger associated with a task and increase the proneness of bodily injuries and near-misses (Westaby and Lee 2003). Furthermore, optimistic bias, or the belief that one is less susceptible to risks is associated with engagement in unsafe behavior (Vaughn 1993). As a result, individuals may justify the adoption of unsafe work practices and continue their involvement in dangerous activities due to the overly optimistic belief that they are immune to the risks associated with the behavior.

In parallel, workers may choose a course of action that exposes them to hazards and increase the likelihood of injury involvement because of risk compensation. According to the risk compensation paradigm, risky behaviors simultaneously induce both costs and benefits. While costs reflect the undesired outcomes of risky behavior, including injuries or fatalities, benefits produce positive outcomes such as excitement and time-saving (Mullen 2004; Zuckerman 2007). The risk compensation theory represents the concept that individuals have a risk tolerance level when engaging in an activity and may alter their behaviors to achieve their preferred balance between the risks and benefits associated with the activity (Peltzman 1975; Wilde 1982).

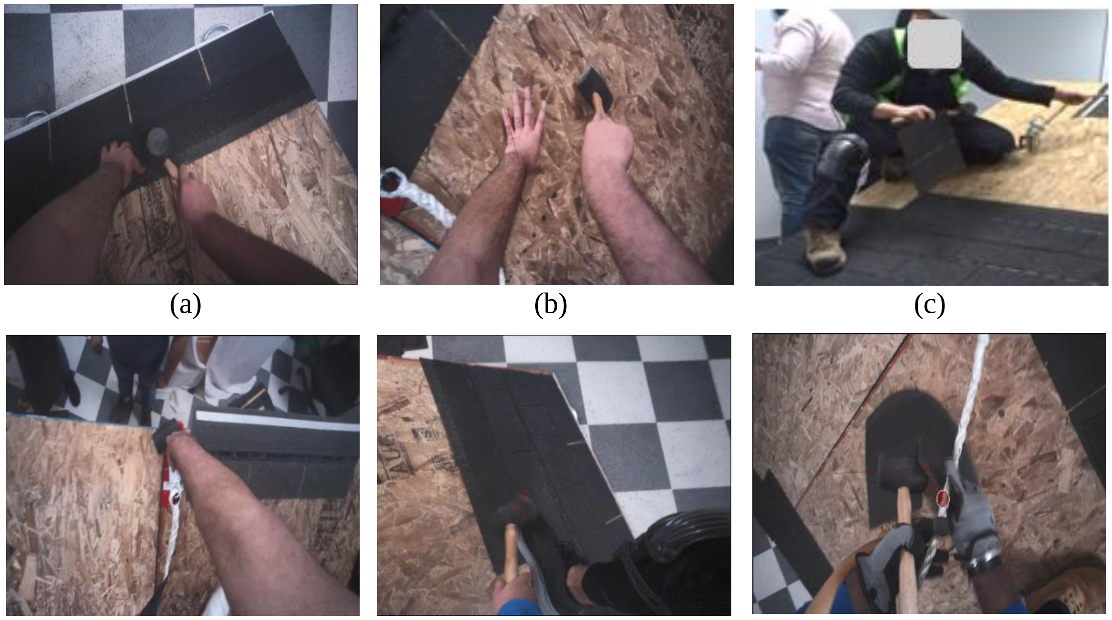
A study by Hasanzadeh and colleagues (2020) lends some credence to the risk-compensatory attitude of construction workers. In their study, a mixed-reality roofing simulation was utilized to examine the extent to which an individual's risk propensity may influence their risk-compensatory behavior under three levels of safety intervention (i.e., no intervention, injury-reducing intervention, and injury-preventing intervention). The results demonstrated that risk propensity moderated the relationship between providing safety interventions and risk-taking behaviors, as participants with a high sensation-seeking propensity took significantly more risks when protected with a safety intervention due to a decline in the perceived level of risk.

Due to the foregoing, pay and reward systems is a major factor that influences the risk taking penchant of workers. Hence, productivity bonus systems should be carefully thought out so that workers are not encouraged to adopt unsafe behavior and ignore safety hazards that may put them in harm's way. In contrast to safety bonuses which encourage operatives to work more safely, productivity bonuses motivate workers to be more productive and may cause safety precautions to be overlooked, leading to increased risk taking due to the need to accelerate the pace of construction to the detriment of careful working (Langford et al. 2000; LaBelle 2005). As a result, safety and productivity must go hand in hand and reward systems that compensate workers for following safety rules and adopting safe work practices while achieving the desired level of productivity should be adopted on construction projects.

In the current study, participants compared the negative aspects of the roofing task (such as the risk of hand injury, falling off the edge of the roof and tripping over the lanyard) to the positive features (promised reward and time-saving to complete the task within the imposed limit), and were motivated to adopt unsafe behaviors (Fig. 4.2) because the associated costs were perceived to be less than the beneficial outcomes.

Because participants wanted to complete the task within the imposed time limit, there were several instances where they compromised their safety in order to increase their work-rate, finish the task faster and receive their compensation. Notably in the time pressure manipulation, participants paid little attention to the harness anchor to ensure that they were securely tied off as they casually utilized the lanyard as a handhold in situations where they almost fell off the roof and tripped over a casually-held shingle that got under the feet and constituted a slip hazard due to poor coordination of the hammer, shingle and hands (Fig. 4.3). As the time to complete the activity became more constrained, participants repeatedly leaned over the roof or sat too close to the roof edge and tripped on the lanyard as it got in the way of completing the roofing activity on-time due to repeated adjustments. In a few instances, participants were observed crawling with the hammer to hurriedly grab the shingles from the pick-up area and where unmindful of the nails that were hinged on the roof and in close proximity to the shingle depository, such that they narrowly missed injury to their hands and fingers in several instances during the time pressure manipulation. Taken together, most of the participants secured the benefits of the activity as they were able to channel their energy in a highly stressful situation to increase productivity, complete the task in a shorter duration, and obtain the reward of their efforts. However, the benefits were obtained at the cost of repeated slips, trips, falls and hand injury near-misses, as they underestimated the associated risks in the roofing task and jeopardized their safety through increased risk-taking and unsafe behavior.

This study therefore illustrates how the provision of productivity bonuses may become counterproductive because of the risk compensation bias experienced by workers. This outcome suggests that efforts to fast-track construction schedules by imposing a time limit for the completion of work tasks within the shortest time possible and providing incentives to achieve same may have a detrimental effect on safety, as workers may be prompted to adjust their risk-taking behaviors to obtain the reward associated with accelerated task completion.



(a) (b) (c)

(d) (e) (f)

Figure 4.2: Unsafe behavior: (a) Hammer too close to edge; (b) Hammer misuse for support; (c) Sitting too close to roof edge; (d) Hammer for support at roof tip; (e) Hammer hit close to boots; and (f) Poor hand coordination

(a) (b) (c)

(d) (e) (f)

Figure 4.3: Safety-related incidents: (a) Fall off roof; (b) Slip hazard; (c) Nail puncture hazard; (d) Roof edge hazard; (e) Near-skid; and (f) Near-fall off roof

4.8 Conclusion

The current study utilized eye-tracking technology to investigate the impact of time pressure on the visual attention of workers to safety hazards and offers potential benefits to both academia and industry. For academia, an experiment that combines eye-tracking technology and statistical analysis in construction safety research will broaden existing understanding of the extent to which time pressure impacts visual attention to safety hazards and increase workers' susceptibility to STFs and hand injuries. The study outcome also yielded novel insights into the tradeoff between safety and productivity, by demonstrating how workers balance the risks in a task (e.g. hand injuries and STF hazards) and the potential reward or benefit (e.g. time saving and productivity bonus) when making safety decisions.

For the industry, this study illustrates how time pressure can induce negative effects on construction performance. Foreseeably, the outcome will enlighten supervisors on the need to implement appropriate scheduling strategies and develop realistic project plans that carefully integrate individual trades to the overall project schedule in order to prevent tight work schedules that may induce time pressure. Unrealistic timing of tasks leads to cutting of safety corners by workers to overcome schedule pressure which promotes risk-taking, impacts hazard awareness and increases their susceptibility to injury.

Furthermore, the outcome will empower safety practitioners and project managers to prioritize the performance of robust job hazard analysis—which is essentially focusing on job tasks as a way to identify hazards before they occur—when developing construction schedules. Considering that one out of every six construction workers can expect to be injured at an average cost of $18,000 (Hinze 1993), this study extends the frontiers of knowledge of the degree to which time pressure, in combination with other factors related to the worker, task, tools, and work environment may combine to erode the safety of workers and increase the liability of management for expensive compensations and litigation in the event of avoidable injuries and other unsafe outcomes. Moreover, a 9-year retrospective surveillance of work-related injuries related to the use of pneumatic nailers in Washington by Baggs and team (2001) found that 3,616 accepted state fund claims were associated with nail gun injuries, with a total cost of $692,548 per year and involved more than three days away from work, and over 60 percent of this cost was incurred from claimants in the wood frame building construction.

In addition, while it is beneficial to keep a motivated workforce, the promise—and payment—of productivity bonuses should be affected in a manner that improves both safety and productivity and does not induce workers to take shortcuts, adopt unsafe work practices or compromise their safety in order to meet up with production schedules.

Despite the potential contributions of this study to the construction safety arena, there are few limitations that deserve further research efforts. First, recruiting students with limited roofing experience limits the generalizability of the findings. Future studies may replicate this experiment with residential workers to observe the extent to which the outcome may align or differ from the results presented in this study. Second, although a moderate sample size required for statistical analysis was utilized in this study, future studies may utilize a more robust sample size in order to surmount the challenges associated with a modest sample. Third, this study simulated a roofing task under controlled experimental conditions in a laboratory. An interesting exercise to overcome this limitation is to carry out this exercise on a live construction project in order to observe the extent to which the dynamics of visual attention allocation may change in a complex construction environment with multiple safety hazards.

In spite of these limitations, this research is a proof of the concept that time pressure can seriously degrade the visual attention of workers to safety hazards and increase their susceptibility to slips, trips, falls and hand injuries. Residential roofers are disproportionately exposed to a myriad of safety hazards. Therefore, in the interest of their safety, organizations may improve their safety practices by implementing appropriate scheduling strategies that avoid tight work schedules that may severely impair attention to safety hazards or adversely impact overall construction performance.

CHAPTER 5: CONCLUSION

5.1 Research Summary

The limited attention capability of workers hinders in-depth situational awareness and risk analysis that undermine workers' safety as they concurrently execute tasks, identify and attend to known hazards, and respond appropriately to new hazards to prevent undesirable outcomes. Since one of the root causes of human error that leads to occupational accidents is a worker's inattention when searching for potential or active hazards, the current study employed a worker-centric approach to identify precursors of human error by implementing multiple eye-tracking experiments in the laboratory using safety variables, including worker characteristics (e.g., work experience, safety training and injury exposure), individual differences (e.g., personality traits), attentional indicators (eye movements), well-established cognitive manipulations (e.g., working-memory load) and attention-restricting workplace factors (e.g., time pressure) to predict— and subsequently mitigate—the human errors that lead to accidents in dynamic environments.

In the first objective, this project investigated why construction workers fail to comprehend hazardous situations under various conditions by utilizing an integrated moderated mediation model in combination with eye tracking technology to systematically (1) understand the role of attention (indicated here via eye movements) as a mediator of the effect of worker characteristics on hazard-identification, and (2) explore the moderating impact of personality traits underlying this link.

As a second objective, this study explored the extent to which low and high working memory load conditions impact the visual search strategy of workers and the speed at which they orient toward hazards. Put differently, the research sought to investigate how construction workers generally perceive, attend, and recollect visual information to make safety decisions while maintaining information in memory and appraising complex environments in avoidance of hazards. Furthermore, considering that time-restrictive conditions may cause human errors that adversely impact safety decisions, this project investigated the impact of time pressure on workers' attention to safety hazards when they performed a simulated roofing task in two experimental conditions: (1) a baseline study without time pressure and (ii) a second run with a 7-minute time limit as a third objective.

The results provided empirical evidence that individuals with greater work experience and safety training were better at hazard identification independent of visual attention and regardless of personality. More so, individual differences in conscientiousness and openness to experience revealed significant direct associations with visual attention and superior hazard identification, signifying that personality traits are pivotal factors that accentuate the influence of worker characteristics on attentional allocation and visual search strategies across hazardous scenes. As such, the unique ways that individuals process information from the environment due to individual differences in personality may explain why some workers recognize or fail to identify hazards on jobsites.

In addition, the study outcome showed that the mean hazard identification scores were higher under low load conditions (81%) in contrast to the high memory load alternative (70%), suggesting that a high working memory load severely impacts safety performance as indicated by the differential results obtained in both experimental trials. Expectedly, a high working memory left fewer cognitive resources to attend to multiple tasks such that participants detected hazards at a considerably low rate compared to operating under a low working memory burden. The high memory weight also limited participants' cognitive resources to retain information in memory while attempting to identify safety risks in the images, thereby constraining the ability to distribute attention in a balanced way to identify both glaring and concealed hazards. On the other hand, a reduced working memory load facilitated the identification of safety hazards as individuals were equipped with extra attentional reserve to view the scenes thoroughly and return their attention frequently to key areas of interest to attain high hazard identification scores.

Likewise, hazard identification performance deteriorated 3.4 and 1.2 times more under high working memory load conditions compared with the low load alternative when participants identified fall-to-lower-level and fall protection hazards respectively. This result provides empirical insights into the potential magnitude of overlooking important fall protection hazards under high working memory load conditions and emphasizes the importance of maintaining a reduced working memory load and the need to limit distractions in dangerous construction environments, especially as workers have to process a variety of safety information or perform multiple tasks concurrently. Similarly, multilevel data analyses demonstrated that the agreeableness and conscientiousness personality dimensions moderated the association between working memory load and hazard identification, such that workers with high scores on both traits distributed their limited attentional resources in a balanced way to identify both active and potential hazards under a high working memory load. This finding suggests that conscientious and agreeable workers are likely to be more attentive to hazards when performing multiple tasks in cognitive and attention-demanding situations.

Regarding the simulated roofing task, the study observed that construction workers may be at a heightened risk of STF hazards as a result of a time pressure-induced reduction in attention to the fall-related AOIs of the harness, harness anchor, edges, footwear, and shingles, in addition to hand injuries from hammer and nails. This outcome highlights the potential danger of allocating reduced attentional resources to safety-critical areas when workers are pressed to complete their tasks in a shorter time than they normally would.

Moreover, the imposed time limit impacted the balance of participants and subjected them to perturbations and destabilizing factors on a sloped roof which affected their gait, traction and stability. Particularly, more participants were observed working near the unprotected edge of the roof and placing their legs off the roof edge in the second round of experiments. Asides the risk of STF hazards, time pressure impacted attention to nail- and hammer-related hazards after the baseline experiment, such that a significantly reduced attention to the hand injury AOIs (hammer, hand and nails) was observed over time, together with various unsafe behavior—including crawling with the hammer and stepping on nails hinged on the roof.

Taken together, this research is a proof of concept that time pressure can significantly degrade the visual attention of workers to safety hazards and increase their susceptibility to STFs and hand injuries.

5.2 Contributions and Implications for Construction Safety

This study offers a new theoretical perspective based on empirical evidence regarding the impact of individual differences on the hazard-identification performance of construction workers and provides an example of ways future construction management studies may harness multi-dimensional factors when assessing the effect of different demographic and psychographic traits in construction safety discussions and the impact of these variables on decision-making processes in risky situations.

By employing the moderated mediation technique, this research provides empirical evidence for the potentially pivotal role of worker characteristics and dispositional traits with regard to hazard identification performance on jobsites by explaining how the impact of worker characteristics on hazard identification skills can be strengthened or weakened by personality traits and showing that personality dimensions may not only influence workers' hazard identification performance but also affect how workers distribute their attention when exposed to various hazardous situations. The approach also enables the incorporation of cognitive and attention tasks to understand the influence of working memory load on impaired attention during multitasking situations, and the effect of such cognitive overload on a worker's ineptitude to comprehend a hazardous situation. Thus, investigating the effect of distractions, task difficulty and a high cognitive load on attention explains why a worker may be unable to detect a hazard on a dynamic construction site when holding more information than necessary in memory.

A better comprehension of the relationships between these safety variables will establish a basis for the early detection of workers who may be injury-prone. Besides, additional safety interventions tailored to unique characteristics may be designed for these workers in order to improve their hazard identification skills and reduce the risk of accidents on construction sites.

Furthermore, studying the link between working memory, visual attention and personality dimensions may be utilized as safety screening tools that would assist organizations to scrutinize employees, develop selection schemes and assign workers to suitable tasks based on a combination of their cognitive abilities and personality variables to reduce the risk of injury among vulnerable workers whose attention may become impaired when handling multiple tasks in dynamic environments. Although certain personality dimensions displayed superior hazard identification performance in various attention and cognitive tasks, the study dissuades a discrimination among workers who exhibit personality traits that are positively correlated with modest visual search strategies and working memory capacities. However, additional safety interventions may be designed for at-risk workers, while bolstering their unique strengths in the work environment.

Additionally, this study will enlighten project managers on the negative consequences of time pressure and the need to develop realistic project plans especially when formulating construction schedules in order to prevent tight work schedules that may induce workers to cut safety corners and increase risk taking behavior, which ultimately limits hazard awareness and heightens the likelihood of STFs and hand injuries during roofing construction. Foreseeably, safety practitioners and project managers will be encouraged to prioritize the performance of a robust job hazard analysis—which is essentially focusing on job tasks as a way to identify hazards before they occur—when developing construction schedules to understand the extent to which time pressure, in combination with other factors related to the worker, task, tools, and work environment may combine to erode the safety of workers and increase the liability of management for expensive compensations in the event of avoidable injuries and other unsafe outcomes. Residential roofers are disproportionately exposed to a myriad of safety hazards. In the interest of their safety, organizations may improve their safety practices by investing in more efficient crew sizes and equipment in lieu of having workers complete dangerous tasks under time pressure which may severely impair attention to safety hazards and visual processing of the work environment.

5.3 Limitations and Areas for Future Research

Despite the potential benefits of this study to advancing research and practice, there are few limitations that deserve further research efforts. First, the overall score in fall-related hazard recognition was employed in calculating the hazard identification index utilized for statistical analysis. Future research should consider investigating a broader range of safety hazards, such as struck-by, housekeeping, caught-in-between, and electrocution hazards to examine the impact of safety variables on the recognition of various hazard types. Second, since eye movements can be utilized as an indicator of meta-cognitive processes such as visual attention and situational awareness, future studies may employ this technology to track the gaze patterns of workers in real-time and further examine the effect other attention-limiting variables such as stress, fatigue, task complexity, workload and complacency on safety performance, and consequently, on the potential for injury incidents in a construction environment Third, this research focused on how individual workers distribute their limited attention to detect safety hazards. Future studies may expound on this project by studying groups of individuals working in a crew utilizing other behavioral theories (such as psychoanalytic, learning and sociocultural) to investigate how various personalities may complement each other in workgroups to impact safety performance. In addition, other personality-measuring scales such as *sensation-seeking, locus of control* and the *cognitive appraisal of risky events* may be employed to evaluate the influence of psychological factors on safety-related decision making. Fourth, the present study monitored the attention of workers using eye tracking technology. Although this technique facilitated the study of visual attention in real time, future research may utilize other wearable sensors such as the functional near-infrared spectroscopy (fNIRS) and electroencephalogram (EEG) to investigate the cognitive processes that may signal human error and put workers at risk of various safety hazards.

REFERENCES

Abbassinia, M., Kalatpour, O., Motamedzadeh, M., Soltanian, A., and Mohammadfam, I. (2020). “The application of lean production in reducing human error and improving response in emergencies: A case study in a petrochemical industry”. *Iranian Journal of Ergonomics, 8*(2): 39-49.

Abdelhamid, T. and Everett, G. (2002). “Physiological Demands During Construction Work.” *Journal of Construction Engineering and Management,* 128(5): 427-438.

Abdelgawad, M. and Fayek, A. (2012). “Comprehensive Hybrid Framework for Risk Analysis in the Construction Industry Using Combined Failure Mode and Effect Analysis, Fault Trees, Event Trees, and Fuzzy Logic”. *Journal of Construction Engineering and Management,* 10.1061/(ASCE)CO.1943-7862.0000471, 642-651.

Abdullah, A. and Marican, S. (2016). “The Effects of Big-Five Personality Traits on Deviant Behavior”. *Procedia- Social and Behavioral Sciences,* 29: 19-25.

Ahn, J., Bae, J. and Lee, S. (2019). “A Human Error Detection System in Nuclear Power Plant Operations”. Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technologies, pp. 115-121.

Alexander, D., Hallowell, M. and Gambatese, J. (2017). “Precursors of Construction Fatalities: Iterative Experiment to Test the Predictive Validity of Human Judgment”. *Journal of Construction Engineering and Management*, 143(7): 1-12.

Allen, M. (1997). “The problem of multicollinearity.” In Understanding regression analysis, 176–180. Boston: Springer.

Alper, S. and Karsh, B. (2009). “A systematic review of safety violations in industry”. Accident Analysis and Prevention, 41 (4): 739–754.

Alwasel, A., Abdel-Rahman, E., Haas, C. and Lee, S. (2017). “Experience, Productivity, and Musculoskeletal Injury among Masonry Worker”. *Journal of Construction Engineering and Management*., 143(6): 1-13.

Alwasel, A., Abdel-Rahman, E., Haas, C. and Lee, S. (2017). “Experience, Productivity, and Musculoskeletal Injury among Masonry Worker”. *Journal of Construction Engineering and Management*., 143(6): 1-13.

Amalberti, R. (2013). “Navigating Safety”. *Springer Briefs in Applied Sciences and Technology*, pp. 19-52.

Amalberti, R. and Wioland, L. (2020) "Human error in aviation." In *Aviation safety*, CRC Press; pp. 91-108.

Antwi-Afari, M., Li, H., Seo, J. and Wong, A. (2018). “Automated detection and classification of construction workers' loss of balance events using wearable insole pressure sensors”. *Automation in Construction*, 96: 189-199.

Ares, G., Giménez, A., Bruzzone, F., Vidal, L., Antúnez, L. and Maiche, A. (2013). Consumer visual processing of food labels: Results from an eye-tracking study. *Journal of Sensory Studies*, *28*(2): 138-153.

Arezes, P. M., and Miguel, A. S. (2008). “Risk perception and safety behavior: A study in an occupational environment.” *Safety Science*, 46(6), 900–907.

Arifuddin, R., Latief, R. and Suraji, A. (2020). “An investigation of fall accident in a high-rise building project”. IOP Conf. Series: Earth and Environmental Science, 419: 1-7.

Arnold, A. (2016). “An assessment of the asphalt shingle roofing process for residential buildings”. *Procedia Engineering*, 145: 760 – 765.

Arthur, W. and Graziano, W. (1996). “The Five-Factor Model, Conscientiousness, and Driving Accident Involvement”, *Journal of Personality,* 593-618.

Aroke, O., Esmaeili, B., Hasanzadeh, S., Dodd, M. and Brock, R. (2020). “The Role of Work Experience on Hazard Identification: Assessing the Mediating Effect of Inattention Under Fall-Hazard Conditions”. *In Proceedings of ASCE 2020 Construction Research Congress (CRC) Conference,* Tempe, Arizona, pp. 509-519.

Arrington, C., Kulesz, P., Francis, D., Fletcher, J. and Barnes, M. (2014). “The Contribution of Attentional Control and Working Memory to Reading Comprehension and Decoding”. *Scientific Studies of Reading*, 18:325–346.

Arthur, W. and Doverspike, D. (2001). “Predicting Motor Vehicle Crash Involvement from a Personality Measure and a Driving Knowledge Test”. *Journal of Prevention & Intervention in the Community*, 22:1, 35-42.

Ashton, M., Lee, K. and Paunonen, S. (2002), “What is the central feature of extraversion? Social attention versus reward sensitivity”. *Journal of Personality and Social Psychology*, 83(1): 245-252.

Atkinson, R. C., and Shiffrin, R. M. (1968). “Human memory: a proposed system and its control processes.” In: Spence KW, Spence JT, eds. T*he Psychology of Learning and Motivation: Advances in Research and Theory, vol. 2.* New York Academic Press; 89–195.

Baddeley, A. (1986). “Working memory”. New York, NY: Clarendon/Oxford University Press.

Baddeley, A. (1992). “Working Memory: The Interface between Memory and Cognition”. *Journal of Cognitive Neuroscience,* 4(3): 1-8.

Baddeley, A. and Hitch, G. (1974). “Working memory”. In G. Bower (Ed.), Recent Advances in Learning and Motivation. New York: Academic Press

Baer, M. and Oldham, G. (2006). “The curvilinear relation between experienced creative time pressure and creativity: Moderating effects of openness to experience and support for creativity”. *Journal of Applied Psychology,* 91: 963-970.

Baethge, A., Vahle-Hinz, T., Schulte-Braucks, J. and van Dick, R. (2018). “A matter of time? Challenging and hindering effects of time pressure on work engagement”. *Work & Stress,* 32(3): 228-247.

Baggs, j., Cohen, M., Kalat, J. and Silverstein, B. (2001). “Pneumatic Nailer Injuries: A Report on Washington State 1990-1998”. *Occupational Safety,* pp. 33-38.

Bajcar, B. and Babiak, J. (2020). “Neuroticism and cyberchondria: The mediating role of intolerance of uncertainty and defensive pessimism”. *Personality and Individual Differences,* 162: 1-9.

Ballard, G., and Howell, G. (1998). “Shielding production: Essential step in production control.” *Journal of Construction Engineering and Management*, 124(1): 11–17.

Barlow, D., Sauer-Zavala, S., Carl, J., Bullis, J. and Ellar, K. (2014). ‘The Nature, Diagnosis, and Treatment of Neuroticism: Back to the Future’. *Clinical Psychological Science,* 2(3): 344 –365.

Barnir, A., Hutchins, H. and Watson, W. (2011). “Mediation and Moderated Mediation in the Relationship Among Role Models, Self-Efficacy, Entrepreneurial Career Intention, and Gender”. *Journal of Applied Social Psychology,* 41(2): 270–297.

Baron, R. M., & Kenny, D. A. (1986). “The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations”. *Journal of Personality and Social Psychology,* 51, 1173–1182.

Barrick, M. and Mount, M. (1991). "The Big Five Personality Dimensions and Job Performance: A meta-analysis". *Personnel Psychology*, 44:1-26.

Barrick, M., Mount, M. and Li, N. (2013). "The theory of purposeful work behavior: The role of personality, higher-order goals, and job characteristics". *Acad. Manage. Rev*. 38 (1): 132–153.

Bentley, T. (2009). "The role of latent and active failures in workplace slips, trips and falls: An information processing approach". *Applied Ergonomics*, 40(2): 175–180.

Berggren, N., and N. Derakshan. (2013). "Attentional Control Deficits in Trait Anxiety: Why You See Them and Why You Don't". *Biological Psychology* , 92 (3): 440–446.

Besser, A. and Shackelford, T. (2007). "Mediation of the effects of the big five personality dimensions on negative mood and confirmed affective expectations by perceived situational stress: A quasi-field study of vacationers". *Personality and Individual Differences*, 42: 1333–1346.

Beus, J., Dhanani, L. and McCord, M. (2015). "A meta-analysis of personality and workplace safety: Addressing unanswered questions." *Journal of Applied Psychology*, 100 (2): 481–498.

Bhandari, S., Hallowell, M., Boven, L., Welker, K., Golparvar-Fard, M. and Gruber, J. (2020). "Using Augmented Virtuality to Examine How Emotions Influence Construction-Hazard Identification, Risk Assessment, and Safety Decisions". *Journal of Construction Engineering and Management*, 146(2): 1-12.

Bhoir, S. A., Hasanzadeh, S., Esmaeili, B., Dodd, M. D., & Fardhosseini, M. S. (2015, June). Measuring construction workers' attention using eye-tracking technology. In *Proc., ICSC15: The Canadian Society for Civil Engineering 5th Int./11th Construction Specialty Conf.* Univ. of British Columbia, Vancouver, Canada.

Bisley, J. (2011). "The neural basis of visual attention". *Journal of Physiology*, 589(1): 49–57.

Bjorkman, M. (1984). "Decision making, risk taking and psychological time: Review of empirical findings and psychological theory". *Scandinavian Journal of Psychology*, 25: 31 – 49.

Bleckley, M., Durso, F., Crutchfield, J., Engle, R. and Khanna, M. (2003). "Individual differences in working memory capacity predict visual attention allocation". *Psychonomic Bulletin & Review*, 10 (4): 884-889.

Boch, R., Fischer, B. and Ramsperger, E. (1984). Express-saccades of the monkey: reaction times versus intensity, size, duration, and eccentricity of their targets. *Experimental Brain Research*, *55*(2), 223-231.

Boelen, P. and Klugkist, I. (2011). "Cognitive behavioral variables mediate the associations of neuroticism and attachment insecurity with Prolonged Grief Disorder severity". *Anxiety, Stress, and Coping*, 24(3): 291-307.

Bohm, J. and Harris, D (2010). "Risk Perception and Risk-Taking Behavior of Construction Site Dumper Drivers". *International Journal of Occupational Safety and Ergonomics*, 16:1, 55-67.

Bojko, A. (2009). "Informative or misleading? Heat maps deconstructed." *Human-computer interaction*. New trends, J. A. Jacko, ed., Springer, Berlin, 30–39.

Borkenau, P. and Ostendorf, F. (2008), NEO-Fu¨ nf-Faktoren Inventar nach Costa und McCrae. Manual (NEO Five Factor Inventory of Costa and McCrae. Manual), Hogrefe, Go¨ttingen.

Borowsky, A., Horrey, W., Liang, Y., Garabet, A., Simmons, L. and Fisher, D. (2016). "The effects of brief visual interruption tasks on drivers' ability to resume their visual search for a pre-cued hazard". *Accident Analysis and Prevention,* 93: 207-216.

Brady, T., Stormer, V., Shafer-Skelton, A., Williams, J., Chapman, A. and Schill, H. (2019). "Scaling up visual attention and visual working memory to the real world". *Psychology of Learning and Motivation,* 70: 29-69.

Breloff, S., Carey, R., Wade, C. and Waddell, D. (2020). "Inclination angles during cross-slope roof walking". *Safety Science,* 132: 1-7.Brown, S., Brooks, R. and Dong, X. (2020). "New Trends of Fatal Falls in the Construction Industry". *CPWR Center for Construction, Research and Training*, pp 1-6.

Bridgeman, B., Van der Heijden, A. and Velichkovsky, B. (1994). "A theory of visual stability across saccadic eye Movements". *Behavioral and Brain Sciences*, *17*(2), 247-258.

Bronner, R. (1982). "Decision making under time pressure". Lexington Books, Lexington, Mass.

Brooke, P. and Paige, R. (2003). "Fault trees for security system design and analysis". *Computers & Security*, *22*(3): 256-264.

Brown, T. and Miller, C. (2000). "Communication Networks in Task-Performing Groups: Effects of Task Complexity, Time Pressure and Interpersonal Dominance". *Small Group* Research, 31(2): 131-157.

Bunting, J., Branche, C., Trahan, C. and Goldenhar, L. (2017). " A national safety stand-down to reduce construction worker falls". *Journal of Safety Research*, 60: 103-111.

Bureau of Labor Statistics (2018). Economic News Release. Census of Fatal Occupational Injuries Summary. Available online: https://www.bls.gov/news.release/cfoi.nr0.htm

Bureau of Labor Statistics. (2018). "Injuries, illnesses, and fatalities. https://www. bls.gov/iif/ Assessed 7th sept, 2021.

Bureau of Labor Statistics. (2020). "OSHA's Fall Prevention Campaign". (https://www.osha.gov/stopfalls/index.html) (Feb. 2, 2021).

Burgess, G., Depue, B., Ruzic, L., Willcutt, E., Du, Y. And Banich M. (2010). "Attentional Control Activation Relates to Working Memory in Attention-Deficit/Hyperactivity Disorder". *Biological Psychiatry,* 67: 632-640.

Burke, M., Sarpy, S., Tesluk, P. and Smith-Crow, K. (2002). "General Safety Performance: A test of a grounded theoretical model". *Personnel Psychology,* 55: 429-457.

Bussier, M. and Chong, H. (2020). "Relationship between safety measures and human error in the construction industry: working at heights". *International Journal of Occupational Safety and Ergonomics,* pp. 1-10.

Butlewski, M., Kaczmarek, Misztal, A. and Sławińska, M. (2014). "Design methods of reducing human error in practice". *Journal of Safety and Reliability,* pp. 1-6.

Byron, K., Khazanchi, S. and Nazarian, D. (2010). "The relationship between stressors and creativity: A meta-analysis examining competing theoretical models". *Journal of Applied Psychology,* 95: 201-212.

Caballer, A., Gracia, F. and Peiro, J. (2005). "Affective responses to work process and outcomes in virtual teams Effects of communication media and time pressure". *Journal of Managerial Psychology,* 20(4): 245-260.

Cacciabue, P. and Vella, G. (2010). "Human factors engineering in healthcare systems: The problem of human error and accident management". *International Journal of Medical Informatics,* 79(4): 1-17.

Cai, J., Yang, L., Zhang, Y. and Cai, H. (2020). "Estimating the Visual Attention of Construction Workers from Head Pose Using Convolutional Neural Network-Based Multi-Task Learning". *Construction research Congress,* 1-9.

Camerota, F. (2020). "Fifteen years of wireless sensors for balance assessment in neurological disorders". *Sensors,* 20: 3247.

Canter, D. (1980). "Fires and human behavior". John Wiley & Sons.

Carretta, T., Perry, D. and Ree, M. (1996). "Prediction of situation awareness in F-15 pilots." *International Journal of Aviation Psychology,* 6: 21–41.

Carvalho, S., Pinto-Gouveia, J., Gillanders, D. and Castilh, P. (2019). “Pain and Depressive Symptoms: Exploring Cognitive Fusion and Self-Compassion in a Moderated Mediation Model”. *The Journal of Psychology,* 153(2): 173-186.

Caspi, A., Roberts, B. and Shiner, R. (2005). “Personality development: stability and change”. *Annual Review of Psychology*, 56 (1): 453–484.

Cellar, D., Nelosn, Z. and Yorke, C. (2000). “The Five Factor Model and Driving Behavior: Personality and Involvement in Vehicular Accidents”. *Psychological Reports,* 86: 454-456.

Cellar, D., Nelson, Z., Yorke, C. and Bauer, C. (2001). “The five-factor model and safety in the workplace: Investigating the relationships between personality and accident involvement”. *Journal of Prevention & Intervention in the Community,* 22(1): 43-52.

Cellar, D., Yorke, C., Nelson, Z. and Carroll, K. (2004). “Relationships Between Five Factor Personality Variables, Workplace Accidents and Self-Efficacy”. *Psychological Reports,* 94: 1437-1441.

Center for Disease Control (2001). “Nonfatal occupational injuries and illnesses treated in hospital emergency departments—United States, 1998. *MMWR,* 50(16):313–317.

Chan, A., Yang, Y. and Darko, A. (2018). “Construction Accidents in a Large-Scale Public Infrastructure Project: Severity and Prevention”. *Journal of Construction Engineering and Management*, 144(10): 1-13.

Chander, H., Shojaei, A., Deb, S., Arachchige, S., Hudson, C., Knight, A. and Carruth, D. (2021). “Impact of Virtual Reality–Generated Construction Environments at Different Heights on Postural Stability and Fall Risk”. *Workplace Health and Safety,* 69(1): 32-40.

Chang, Y., Friesner, D., Lee, I., Chu, T., Chen, H., Wu, W. and Teng, C. (2016). “Openness to experience, work experience and patient safety”. *Journal of Nursing Management,* 24: 1098–1108.

Chen, J., Wang, R., Lin, Z. and Guo, X. (2018). “Measuring the cognitive loads of construction safety sign designs during selective and sustained attention”. *Safety Science,* 105: 9-21.

Chihming, W., Zexin, J., Yuxin, L., Songqing, H. and Zhongwei, Y. (2020). “Investigation on the Eye-tracking Technology in Hazard Identification of Building Construction Engineering”. *2nd IEEE International Conference on Architecture, Construction, Environment and Hydraulics,* pp. 32-35.

Choi, S. (2008). “Postural balance and adaptations in transitioning sloped surfaces”. *International Journal of Construction Education and Research,* 4 (3): 189–199.

Chong, D., Van Eerde, W., Chai, K. and Rutte, C. (2011). “A Double-Edged Sword: The Effects of Challenge and Hindrance Time Pressure on New Product Development Teams”. *IEEE Transactions on Engineering Management,* 58(1): 71-86.

Choudhry, R. and Fang, D. (2008). “Why operatives engage in unsafe work behavior: Investigating factors on construction sites”. *Safety Science*, 46: 566–584.

Christian, M., Bradley, J., Wallace, J. and Burke, M. (2009). “Workplace Safety: A Meta-Analysis of the Roles of Person and Situation Factors”. *Journal of Applied* Psychology, 94(5): 1103–1127.

Chub, F., Fua, Y. and Liu, S. (2019). “Organization is also a “life form”: Organizational-level personality, job satisfaction, and safety performance of high-speed rail operators”. *Accident Analysis and Prevention*, 125: 217-223.

Clark, S. (2008). “An Examination of the Role of Personality in Work Accidents Using Meta-analysis”. *Applied Psychology: An International Review*, 57(1): 94–108.

Clarke, S. and Robertson, I. (2005). “A meta-analytic review of the Big Five personality factors and accident involvement in occupational and non-occupational settings”. *Journal of Occupational and Organizational Psychology*, 78: 355–376.

Cobb-Clark, D. and Schurer, S. (2012). “The stability of big-five personality traits”. *Economics Letters,* 115: 11–15.

Cohen (2013). “The Neuropsychology of Attention”. Second ed. Springer Science & Business Media.

Colville J. (1993). “The economic impact of hand injuries”. *Journal of Hand Surgeries*, 18: 395–398.

Conners, F. (2009). “Attentional control and the simple view of reading”. *Reading and Writing*, 22: 591–613.

Conover, W., Johnson, M. and Johnson, M. (1981). “A comparative study of tests for homogeneity of variances, with applications to the outer continental shelf bidding data”. *Technometrics*, 23: 351-361.

Construction Industry Institute (CII). (1989). “Concepts and methods of schedule compression”. Construction Industry Institute Publication No. 6-7, The University of Texas at Austin, Austin, Tex.

Conway, A., Cowan, N. and Bunting, M. (2001). “The cocktail party phenomenon revisited: the importance of working memory capacity*.” Psychonomic Bulletin & Review,* 8(2): 331-335.

Cooper, C. (1998). “The Changing Nature of Work”. *Community, Work and Family,* 1(3): 313–317.

Cooper, D. (2003). “Psychology, risk and safety”. *Professional Safety,* 48:39 – 46.

Costa, P. and McCrea, R. (1992). “Revised neo personality inventory (NEO PI-R) and neo five-factor inventory (NEO-FFI)”. Odessa, FL: Psychological Assessment Resources.

Costa, P. and McCrae, R. (1995). Persons, places and personality: career assessment using the revised NEO personality inventory. *Journal of Career Assessment*. 3(2): 123–139.

Courtney, T. and Webster W. (1999). “Disabling occupational morbidity in the United States. An alternative way of seeing the Bureau of Labor Statistics’ data”. *Journal of Occupational and Environmental Medicine,* 41:60–69.

Courtney, T., Sorock, G., Manning, D., Collins, J. and Holbein-Jenny, M. (2001). “Occupational slip, trip, and fall-related injuries–can the contribution of slipperiness be isolated?”. *Ergonomics,* 44: 1118–1137.

Cowan, N. (1988). “Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information processing system”. *Psychology Bulletin,* 104: 163–191.

Cowan, N. (2008). “What are the differences between long-term, short-term, and working memory?”. *Progress in Brain Research,* 169: 323-338.

Cowan, N., Fristoe, N., Elliot, E. and Brunner, R. and Saults, J. (2006). “Scope of attention, control of attention, and intelligence in children and adults”. *Memory and Cognition*, 34:1754–1768.

Craik, F. (2014). “Effects of Distraction on Memory and Cognition: A Commentary”. *Frontiers in Psychology,* 5(841): 1-5.

Cullen, J., Wright, L. and Alessandri, M. (2002). “The Personality Variable Openness to Experience as It Relates to Homophobia”. *Journal of Homosexuality,* 42(4): 119-134.

Dadkhah, D., Cen, D. and Dutta, at. (2021). “Determining the Risk of Slipping with Slip-Resistant Footwear”. *Springer Nature Switzerland,* 220: 631–637.

Daneman, M. and Carpenter, P. (1980). “Individual Differences in Working Memory and Reading”. *Journal of Verbal Learning and Verbal Behavior,* 19: 450-466.

DavasAksan, A., Durusoy, R., Bal, E., Kayalar, M., Ada, S. and Tanık, F. (2012). "Risk Factors for Occupational Hand Injuries: Relationship Between Agency and Finger". *American Journal of Industrial Medicine,* 55:465–473.

Davids, A. and Mahone, J. (1957). "Personality Dynamics and Accident Proneness in an Industrial Setting". *Journal of Applied Psychology*, 41(5): 1-4.

Deery, H. (1999). "Hazard and risk perception among young novice drivers". *Journal of Safety Research*, 30(4), 225–36.

Deffenbacher, J., Oetting, E. and Lynch, R. (1994). "Development of a driving anger scale". *Psychological Reports*, 74: 83–91.

de Fockert, J., Rees, G., Frith, C. and Lavie, N. (2001). "The Role of Working Memory in Visual Selective Attention". *Science*, 291 (5509): 1803-1806.

de Jong, J., Nguyen, J., Sonnema, A., Nguyen, E., Amadio, P. and Moran, S. (2014). "The incidence of acute traumatic tendon injuries in the hand and wrist: a 10-year population-based study. *Clinics in Orthopedic Surgery*, 6:196-202.

de Putter, C., Selles, R., Polinder, S., Panneman, M., Hovius, S. and van Beeck, E. (2012). "Economic impact of hand and wrist injuries: health-care costs and productivity costs in a population-based study". *The Journal of Bone and Joint Surgery,* 94(9):1-18.

Dember, W. and Warm, J. (1979). Psychology of perception (2nd ed.). New York: Holt, Rinehart and Winston.

Desimone, R. and Duncan, J. (1995). "Neural mechanisms of selective visual attention". *Annual Review of Neuroscience,* 18: 193-222.

Dhou K. (2019). "An innovative employment of virtual humans to explore the chess personalities of Garry Kasparov and other class-A players". In: *International conference on human-computer interaction, Orlando, FL,* 26–31 July 2019, pp. 306–319.

DiDomenico, A., McGorry, R. and Banks, J. (2011). "Effects of common working postures on balance control during the stabilization phase of transitioning to standing". *Ergonomics*, 54(11): 1053–1059.

Dodd, M. and Shumborski, S. (2009). "Examining the influence of action on spatial working memory: The importance of selection". *The Quarterly Journal of Experimental Psychology*, 62(6): 1236 – 1247.

Dodd, M. and Wilson, D. (2009). "Training attention: Interactions between central cues and reflexive attention". *Visual Cognition,* 17(5): 736-754.

Dombrowe, I., Olivers, C. and Donk, M. (2010). "The time course of working memory effects on visual attention". *Visual Cognition,* 18(8): 1089-1112.

Dong, X., Entzel, P., Men, Y., Chowdhury, R. and Schneider, S. (2004). "Effects of Safety and Health Training on Work-Related Injury Among Construction Laborers". *Journal of Occupational and Environmental Medicine,* 46(12): 1222-1228.

Dong, X., Wang, X., Largay, J., Platner, J., Stafford, E., Cain, C. and Choi, S. (2014). "Fatal Falls in the U.S. Residential Construction Industry". *American Journal of Industrial Medicine,* 57: 992-1000.

Drake, M., Morris, M. and Davis, T. (2017). "Neuroticism's susceptibility to distress: Moderated with mindfulness". *Personality and Individual Differences* 106: 248–252.

Duchowski, A. (2007). Eye tracking methodology: Theory and practice, 2nd Ed., Springer Science and Business Media, London.

Duncan, J., Ward, R. and Shapiro, K. (1994). "Direct measurement of attentional dwell time in human vision". *Nature,* 369: 313–315.

Dutta, A., Breloff, S., Dai, F., Sinsel, E., Warren, C., Carey, R. and Wu, J. (2020). "Effects of working posture and roof slope on activation of lower limb muscles during shingle installation". *Ergonomics,* 63(9): 1182–1193.

Dzeng, R., Lin, C. and Fang, Y. (2016). "Using eye-tracker to compare search patterns between experienced and novice workers for site hazard identification". *Safety Science,* 82:56-67.

Earnest, G. and Branche, C. (2016). "Knowledge Gaps and Emerging Issues for Fall Control in Construction". *Fall Prevention and Protection,* pp. 469-490.

Edwards, J. and Lambert, L. (2007). "Methods for Integrating Moderation and Mediation: A General Analytical Framework Using Moderated Path Analysis". *Psychological Methods,* 12(1): 1–22.

Ehsani, J., Li, K., Simons-Morton, B., Tree-McGrath, C., Pmerlus, J., O'Brien, F. and Klauer, S. (2015). 'Conscientious personality and young drivers' crash risk'. *Journal of Safety Research* 54: 83–87.

Einarsson, S. (1999). “Human error in high hazard systems: Do we treat the problem in an appropriate way?”. *Journal of Risk Research*, 2(2): 115-128.

Elfering, A., Grebner, S. and Tribolet-Hardy, F. (2013). “The long arm of time pressure at work: Cognitive failure and commuting near-accidents”. *European Journal of Work and Organizational Psychology*, 22(6): 737-749.

Elfering, A., Semmer, N. and Grebner, S. (2006). “Work stress and patient safety: Observer-rated work stressors as predictors of characteristics of safety-related events reported by young nurses”. *Ergonomics*, 49(5–6): 457–469.

El Hajia, A., Krawczyk, M., Sylwestrzak, M. And Zawojska, E. (2019). Time pressure and risk taking in auctions: A field experiment. *Journal of Behavioral and Experimental Economics*, 78: 68-79.

Embrey, D. (1992). “Incorporating management and organizational factors into probabilistic safety assessment”. *Reliability Engineering and System Safety*, 38: 199-208.

Endsley, M. (1995). “Toward a theory of situation awareness in dynamic systems”. *The Journal of the Human Factors and Ergonomics Society*, 37(1): 32–64.

Engle, R. (2002). “Working Memory Capacity as Executive Attention” *Current Directions in Psychological Science, 11*(1): 19– 23.

Engle, R. and Kane, M. (2004). “Executive attention, working memory capacity, and a two-factor theory of cognitive control”. In B. Ross (Ed.). The psychology of learning and motivation, NY: Elsevier. 44: 145–199.

Engle, R., Tuholski, S., Laughlin, J. and Conway, A. (1999). “Working memory, short-term memory, and general fluid intelligence: a latent-variable approach”. *Journal of Experimental Psychology: General*, 128: 309–331.

Esmaeili, B. (2012). *Identifying and quantifying construction safety risks at the attribute level*. (Doctoral dissertation, University of Colorado at Boulder).

Esmaeili, B., Hallowell, M. and Rajagopalan, B. (2015a). “Attribute-Based Safety Risk Assessment. I: Analysis at the Fundamental Level. *Journal of Construction Engineering and Management,* 10.1061/(ASCE)CO.1943-7862.0000980, 04015021.

Esmaeili, B., Hallowell, M. and Rajagopalan, B. (2015b). “Attribute-Based Safety Risk Assessment. II: Predicting Safety Outcomes Using Generalized Linear Models”. *Journal of Construction Engineering and Management*, 10.1061/(ASCE)CO.1943-7862.0000981, 04015022.

Eysenck, H. J. (1962). The structure of human personality. London: Methuen.

Falkiner, S. (2003). “Diagnosis and treatment for hand–arm vibration syndrome and its relationship to carpal tunnel syndrome”. *Australian Family Physician*, 32: 530–534.

Falkland, E. and Wiggins, M. (2019). “Cross-task cue utilization and situational awareness in simulated air traffic control”. *Applied Ergonomics*, 74: 24–30.

Fang, D., Zhao, C. and Zhang, M. (2016). “A Cognitive Model of Construction Workers’ Unsafe Behaviors”. *Journal of Construction Engineering and Management*, 142(9): 04016039-1-8.

Fang, Y. and Cho, Y. (2015). “Analyzing Construction Workers’ Recognition of Hazards by Estimating Visual Focus of Attention”. *The 6th International Conference on Construction Engineering and Project Management*, 248-251.

Fang, Y., Cho, Y.K., Durso, F. and Seo, J. (2018). “Assessment of operator's situation awareness for smart operation of mobile cranes”. *Automation in Construction*, 85: 65-75.

Farhadi, H., Nasir, N., Omar, F. and Nouri, A. (2015). “Understanding Employees’ Deviant Behavior: The Role of Agreeableness and Stress Related to Wor”’. *International Conference on Social Sciences & Humanities*, 2: 102-107.

Fielden, C., Kim, L. and MacCan, C. (2015). ‘Extraversion’. *International Encyclopedia of the Social & Behavioral Sciences*, 8(2): 623-627.

Fine, B. (1963). “Introversion-Extraversion and Motor Vehicle Driver Behavior”. *Perceptual and Motor Skills*, 12: 95-100.

Fischer, M. Castel, A., Dodd, M. and Pratt, J. (2003). “Perceiving numbers causes spatial shifts of attention”. *Nature Neuroscience*, 6(6): 555-556.

Fisher, C., Chengalur-Smith, I. and Ballou, D. (2003). “The Impact of Experience and Time on the Use of Data Quality Information in Decision Making”. *Information Systems Research*, 14: 170–188.

Fleming, M. A. (2009). Hazard recognition. By Design, *American Society of Safety Engineers, 8*(3), 11-15.

Fleming, P. and England, H. (2020). “Anchor-based Goals and Personality Effects on Hazard Identification in Risk Assessment”. *Journal of Risk Analysis and Crisis Response*, 10(3): 113–118.

Floyd, A. and Floyd, H. (2014). “Cultural Drift and the Occlusion of Electrical Safety”. *IEEE Transactions on Industry Applications*, 50(3): 1610-1618.

Fougnie, D. and Marois, R. (2006). “Distinct Capacity Limits for Attention and Working Memory Evidence From Attentive Tracking and Visual Working Memory Paradigms”. *Association for Psychological Science*, 17(6): 526-534.

Fougnie, D. Y. (2008). “The relationship between attention and working memory.” New research on short-term memory, *Nova Science Publishers*, pp. 1–45.

Fraser, K, Fors, K., Kokkinakis, D. and Nordlund, A. (2017). An analysis of eye-movements during reading for the detection of mild cognitive impairment. In *Proceedings of the 2017 Conference on Empirical Methods in Natural Language Processing*, pp. 1016-1026.

Fredericks, T., Abudayyeh, O., Choi, S., Wiersma, M. and Charles, M. (2005). “Occupational Injuries and Fatalities in the Roofing Contracting Industry”. *Journal of Construction Engineering and Management*, 131(11): 1233-1240.

Fu, Y., Wang, P., Wang, S., Liu, H. and Zhang, F. (2007). “Design and Development of a Portable Exoskeleton Based CPM Machine for Rehabilitation of Hand Injuries”. Proceedings of the 2007 IEEE International Conference on Robotics and Biomimetics, pp. 1476-1481.

Fukuda, K., Woodman and Vogel, E. (2016). “Individual Differences in Visual Working Memory Capacity: Contributions of Attentional Control to Storage”. *Elsevier*, 1-2.

Fulvio, .J and Postle, B. (2020). “Cognitive Control, Not Time, Determines the Status of Items in Working Memory”. *Journal of Cognition*, 3(1): 1–8.

Gao, C., Holme´r, I. and Abeysekera, J. (2008). “Slips and falls in a cold climate: Underfoot surface, footwear design and worker preferences for preventive measures”. *Applied Ergonomics,* 39: 385–391.

Gao, Y., González, V. and Yiu, T. (2020). “Exploring the Relationship between Construction Workers’ Personality Traits and Safety Behavior”. *Journal of Construction Engineering and Management*, 146(3): 1-13.

Garamszegi, L. (2006). “Comparing effect sizes across variables: generalization without the need for Bonferroni correction”. *Behavioral Ecology*, 682-687.

Garrett, J. and Teizer, J. (2009). “Human Factors Analysis Classification System Relating to Human Error Awareness Taxonomy in Construction Safety”. *Journal of Construction Engineering and Management*, 135(8): 754-763.

Gaylord, W. (1994). “Nail Guns: Speed Before Safety”. *Trial*, 30:46-52.

Gellatly, I. (1996). “Conscientiousness and Task Performance: Test of a Cognitive Process Mode"’. *Journal of Applied Psychology*, 81(5): 474-482.

Gene´-Sampedro, A., Alonso, F., Sa´nchez-Ramos, C. and Useche, S. (2021). “Comparing oculomotor efficiency and visual attention between drivers and non-drivers through the Adult Developmental Eye Movement (ADEM) test: A visual-verbal test”. *PLoS ONE,* 16(2): 1-20.

George, J. and Zhou, J. (2001). “When Openness to Experience and Conscientiousness Are Related to Creative Behavior: An Interactional Approach”. *Journal of Applied Psychology,* 86(3): 513-52.

Gilkey, D. (2021). “Slips, Trips, and Falls: A Call to Duty”. *World Safety Journal*, pp. 1-19.

Gilliland, S. and Schmitt, N. (1993). “Information redundancy and decision behavior: A process training investigation”. *Organizational Behavior and Human Decision Processes*, 54: 157–180.

Goh, Y. & Chua, D. (2009). “Case-Based Reasoning for Construction Hazard Identification: Case Representation and Retrieval”. *Journal of Construction Engineering and Management*, 10.1061/(ASCE)CO.1943-7862.0000093, 1181-1189.

Goldberg, L. (1992). “The development of markers for the Big-Five factor structure.” *Psychol. Assess.* 4 (1): 26–42.

Goldberg, J. H., & Kotval, X. P. (1999). Computer interface evaluation using eye movements: Methods and constructs. International Journal of Industrial Ergonomics, 24(6), 631–645.

Goldberg, L. (1990) An alternative description of personality: The Big-Five factor structure, *Journal of Personality and Social Psychology*, 59, 1216 – 1229.

Goldberg, L., Johnson, J., Eber, H., Hogan, R., Ashton, M. and Cloninger, C. (2006). “The International Personality Item Pool and the future of public-domain personality measures”. *Journal of Research in Personality,* 40: 84–96.

Goldenhar, L., Williams, L. and Swanson, N. (2003). “Modelling relationships between job stressors and injury and near-miss outcomes for construction labourers”. *Work Stress,* 17(3): 218–240.

Golimbet, V., Alfimova, M., Gritsenko, I. and Ebstein, R. (2007). “Relationship between dopamine system genes and extraversion and novelty seeking.” *Neurosci. Behav. Physiol*. 37(6): 601–606.

Goliszek, A. (1992). “60 second stress management”. New Horizon, London

Golkar, A., Johansson, E., Kasahara, M., Osika, W., Perski, A., & Savic, I. (2014). The influence of work-related chronic stress on the regulation of emotion and on functional connectivity in the brain. *PloS One*, 9(9): e104550.

González Palencia, J., Furubayashi, T. and Nakata, T. (2012). "Energy use and CO2 emissions reduction potential in passenger car fleet using zero emission vehicles and lightweight materials". *Energy*, 48(1), 548-565.

Granka, L., Feusner, M. and Lorigo, L. (2008). “Eye Monitoring in Online Search”. In: R. Hammoud, ed. Passive Eye Monitoring: Algorithms, Applications and Experiments, New York, NY: Springer, pp. 283-304.

Graziano, W., Habashi, M. and Tobin, R. (2007). “Agreeableness, Empathy, and Helping: A Person X Situation Perspective”. *Journal of Personality and Social Psychology*, 93(4): 583–599.

Grech, M., Horberry, T. and Smith, A. (2002). “Human Error in Maritime Operations: Analyses of Accident Reports Using the Leximancer Tool”. *Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting*, pp. 1718-1722.

Greenwood, M. and Woods, H. (1919). A report on the incidence of industrial accidents upon individuals with special reference to multiple accidents. In W. Haddon, E.A. Suchman, & D. Klein (Eds.), Accident proneness. New York: Harper and Row (1964).

Grumm, M. and Collani, G. (2007). “Measuring Big-Five personality dimensions with the implicit association test – Implicit personality traits or self-esteem?”. *Personality and Individual Differences,* 43: 2205–2217.

Gueorguieva, R. and Krystal, J. (2004). “Move Over ANOVA: Progress in Analyzing Repeated-Measures Data and Its Reflection in Papers Published in the Archives of General Psychiatry”. *Archives of General Psychiatry*, 61:1-8.

Gugerty, L. and Tirre, W. (2000). “Individual differences in situation awareness.” In M. R. Endsley & D. J. Garland (Eds.), *Situation awareness analysis and measurement* (pp. 249–276). Mahwah, NJ: Erlbaum.*Guilford Press,* New York, NY.

Guo, B., Yiu, T. and González, V. (2015). “Identifying behavior patterns of construction safety using system archetypes”. Accident Analysis and Prevention, 80: 125–141.

Guo, Z., Chen, R., Zhang, K., Pan, Y. and Wu, J. (2016). “The impairing effect of mental fatigue on visual sustained attention under monotonous multi-object visual attention task in long durations: an event-related potential based study”. *PLoS One,* 11(9): 1-10.

Gutzwiller, R. and Clegg, B. (2013). “The Role of Working Memory in Levels of Situation Awareness”. *Journal of Cognitive Engineering and Decision Making*, 7(2): 141–154.

Habibnezhad, M., Fardhosseini, S., Vahed, A., Esmaeili, B. and Dodd, M. (2016). “The Relationship between Construction Workers’ Risk Perception and Eye Movement in Hazard Identification”. *Construction Research Congress,* pp. 2984-2994.

Hallett, P. (1986). “*Eye movements and human visual perception*”. Handbook of perception and human performance, Vol. 1, Wiley, New York.

Haluik, A. (2016). “Risk Perception and Decision making in Hazard Analysis: Improving Safety for the Next Generation of Electrical Workers”. *IEEE,* 26: 122-129.

Haluik, A. (2016). “Risk Perception and Decision making in Hazard Analysis: Improving Safety for the Next Generation of Electrical Workers”. *IEEE,* 26: 122-129.

Han, S. and Kim, M. (2004). “Visual Search Does Not Remain Efficient When Executive Working Memory Is Working”. *Psychological Science,* 15(9): 623-628.

Han, S., Sab, F., Lee, S., Mohamed, Y. and Pena-Mora, F. (2014). “Toward an understanding of the impact of production pressure on safety performance in construction operations”. *Accident Analysis and Prevention,* 68:106-116.

Han, Y., Yin, Z., Zhang, J., Jin, R. and Yang, T. (2020). “Eye-Tracking Experimental Study Investigating the Influence Factors of Construction Safety Hazard Recognition”. *Journal of Construction Engineering and Management,* 146(8): 1-13.

Hancock, P. and Szalma, J. (Eds.). (2008). “Performance under stress”. Aldershot: Ashgate.

Hansen, C. (1989). “A Causal Model of the Relationship Among Accidents, Biodata, Personality, and Cognitive Factors”. *Journal of Applied Psychology,* 74(1): 81-90.

Hardison, D., Sears, M., Hallowell, M. and Goodrum, P. (2017). “Using Eye Tracking Technology to Evaluate Focal Attention Location and Its Relationship to Hazard Identification”. *Leadership in Sustainable Infrastructure,* 72: 1-9.

Harrel, W. (1990). “Perceived Risk of Occupational Injury: Control Over Pace of Work and Blue-Collar Versus White-Collar Work”. *Perceptual and Motor Skills*, 70: 1351-1359.

Hasanzadeh, S., Esmaeili, B. and Dodd, M. (2017). “Measuring the Impacts of Safety Knowledge on Construction Workers’ Attentional Allocation and Hazard Detection Using Remote Eye-Tracking Technology” . *Journal of Management in Engineering*, 33(5): 04017024-1-17.

Hasanzadeh, S., B. Esmaeili, and M. D. Dodd. (2017b). “Impact of construction workers’ hazard identification skills on their visual attention”. *Journal of Construction Engineering and Management*, 143 (10): 1-12.

Hasanzadeh, S., Esmaeili, B., and Dodd, M. (2017a). “Measuring the impact of working memory load on the safety performance of construction workers.” Computing in civil engineering, Seattle, 158–166.

Hasanzadeh, S., Esmaeili, B. and Dodd, M. (2018). “Examining the Relationship between Construction Workers’ Visual Attention and Situation Awareness under Fall and Tripping Hazard Conditions: Using Mobile Eye Tracking”. *Journal of Construction Engineering and Management*, 144(7): 1-18.

Hasanzadeh, S., Esmaeili, B. and Dodd, M. (2018). “Examining the Relationship between Construction Workers’ Visual Attention and Situation Awareness under Fall and Tripping Hazard Conditions: Using Mobile Eye Tracking”. *Journal of Construction Engineering and Management*, 144(7): 1-18.

Hasanzadeh, S., and J. M. de la Garza. (2019). “Understanding roofer’s risk compensatory behavior through passive haptics mixed-reality system.” *In Proc., Computing in Civil Engineering 2019: Visualization, Information Modeling, and Simulation*, 137–145. Reston, VA: ASCE.

Hasanzadeh, S., Dao, B., Esmaeili, B., and Dodd, M. D. (2019). “Role of personality in construction safety: investigating the relationships between personality, attentional failure, and hazard identification under fall-hazard conditions.” *Journal of construction engineering and management*, *145*(9), 04019052.

Hasanzadeh, S., and J. M. de la Garza. (2020). “How may risk tolerance, cognitive appraisal, and outcome expectancy motivate risk-taking behavior? The implication of risk compensation through multi-sensor mixed-reality system.” *In Proc., Construction Research Congress (CRC 2020)*. Reston, VA: ASCE.

Hasanzadeh, S. and de la Garza, J. (2020). “Productivity-Safety Model: Debunking the Myth of the Productivity-Safety Divide through a Mixed-Reality Residential Roofing Task”. *Journal of Construction Engineering and Management,* 146(11): 1-16.

Hasher, J., Zacks, R. and May, C. (1999). “Inhibitory control, circadian arousal, and age”. In D. Gopher & A. Koriat (Eds.), Attention and performance XVII. Cognitive regulation of performance: Interaction of theory and application (pp. 653–675). Cambridge, MA: MIT Press.

Hayes, A. (2015). "An Index and Test of Linear Moderated Mediation". *Multivariate Behavioral Research*, 50:1–22.

Hayes, A. (2018). "Partial, conditional, and moderated mediation: Quantification, inference, and interpretation". *Communication Monographs*, 85(1): 4–40.

Heaver, C., Goonetilleke, K., Ferguson, H. and Shiralkar, S. (2011). "Hand–arm vibration syndrome: a common occupational hazard in industrialized countries". *The Journal of Hand Surgery*, 36(5): 354–363.

Heckhausen, J. and Heckhausen, H. (2006). Motivation und Handeln. Heidelberg: Springer.

Hedayati, S., Sadeghi-Firoozabadi, V., Bagheri, M., Heidari, M. and Sze, N. (2021). "Evaluating differences in cognitive functions and personality traits among air traffic controllers with and without error history". *Safety Science,* 139: 1-8.

Heidari, A., Olbina, S. and Glick, S. (2021). "Automated Positioning of Anchors for Personal Fall Arrest Systems for Steep- Sloped Roofs". *Buildings,* 11(10): 1-26.

Heinrich, H, Petersen, D. and Roos, N. (1980). "Industrial accident prevention". New York: McGraw-Hill.

Heitz, R., Unsworth, N. and Engle, R. (2004). "Working Memory Capacity, Attention Control and Fluid Intelligence". *Handbook of Understanding and Measuring Intelligence,* pp. 61-77.

Henderson, J. (2004). "Personality and Behavioral Correlates of accident proneness". Dissertation Submitted to *North Central University, Prescott, Arizona;* pp.1-90.

Hinze, J. (1993). "Construction contracts". McGraw-Hill, New York

Hinze, J. (1997). "The distractions theory of accident causation". *A.A. Balkema, Rotterdam, Netherlands*.

Hinze, W. and Olbina, S. (2008). "Problem areas in personal fall protection". In Proceedings of the 14th Rinker International Conference CIB W99 Evolution of and Directions in Construction Safety and Health, Gainesville, FL, USA, 9–11 March 2008; pp. 406–418.

Hinze, J., Hallowell, M. and Baud, K. (2013). "Construction-Safety Best Practices and Relationships to Safety Performance". *Journal of Construction Engineering and Management,* 139(10): 04013006-1-8.

Hoffman (1997). "Nail Gun Injuries of the Hand." *American Family Physician*. 56:1643-1646.

Hofmann, D. and Stetzer, A. (1996). "A Cross-Level Investigation of Factors Influencing Unsafe Behaviors and Accidents". *Personnel* Psychology, 49: 307-339.

Hogan, J. and Foster, J. (2013). "Multifaceted Personality Predictors of Workplace Safety Performance: More Than Conscientiousness". *Human Performance,* 26:20–43.

Hoła, B. (2010). "Methodology of hazards identification in construction work course". *Journal of Civil Engineering and Management*, *16*(4): 577-585.

Hollingworth, A. and Bahle, B. (2019). "Eye tracking in visual search experiments". In *Spatial Learning and Attention Guidance* (pp. 23-35). Humana, New York, NY.

Hollingworth, A. and Luck, S. (2009). "The role of visual working memory (VWM) in the control of gaze during visual search". *Attention, Perception, & Psychophysics,* 71(4): 936-949.

Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H. and Van de Weijer, J. (2011). Eye tracking: A comprehensive guide to methods and measures. Oxford, UK: Oxford University Press.

Holte, K., Kjestveit, K. and Lipscomb, H. (2015). "Company size and differences in injury prevalence among apprentices in building and construction in Norway". *Safety Science,* 71: 205–212.

Homan, A., Hollenbeck, J., Humphrey, S., Knippenberg, D., Ilgen, D. and Van Kleef, G. (2017). "Facing Differences With an Open Mind: Openness to Experience, Salience of Intragroup Differences, and Performance of Diverse Work Groups". *Academy of Management Journal*, 51(6): 1-6.

Horak, F.B. et al. (1992). "Separate systems for tonic, triggered, and centrally initiated postural control: effects of levodopa". *Society of Neuroscience Abstracts,* 18: 1406-1415.

Hough, L. (1992). "The "Big Five" personality variables–construct confusion: Description versus prediction." *Human Performance,* 5 (1–2): 139–155.

Hsiao, H. and Simeonov, P. (2001). "Preventing falls from roofs: a critical review". *Ergonomics*, 44: 537–561.

Hu, X., Zheng, J., Fan, T., Su, N., Yang, C. and Luo, L. (2020). "Using Multilevel Mediation Model to Measure the Contribution of Beliefs to Judgments of Learning". *Frontiers in Psychology,* 11(637): 1-19.

Huang, Y., Chen, J., DeArmond, S., Cigularov, K. and Chen, P. (2007). "Roles of safety climate and shift work on perceived injury risk: A multi-level analysis". *Accident Analysis and Prevention,* 39:1088–1096.

Hurrell, J. (2005). “Organizational stress intervention”. In: Handbook of work stress. Barling J, Kelloway EK and Frone MR (Eds.), 7–34, Sage Publications, Thousand Oaks, CA.

Irzmańska, E. (2015). “Protective Footwear And The Risk Of Slipping In Older Workers – Definitions, Achievements, Recommendations”. *AUTEX Research Journal*, 15(3): 181-190.

Jacob, R. J. K., & Karn, K. S. (2003). “Eye tracking in human computer interaction and usability research”. In J. Hyönä, R. Radach, & H. Deubelin (Eds.), The mind’s eye cognitive and applied aspects of eye movement research (pp. 143–156). Amsterdam, The Netherlands: Elsevier Science.

Jaffar, N., Abdul-Tharim, A., Mohd-Kamar, I. and Lop, N. (2011). “A literature review of ergonomics risk factors in construction industry”. *Procedia Engineering*, 20: 89–97.

Jahangiri, M., Reza, Solukloei, H. and Kamalinia, M. (2019). “A neuro-fuzzy risk prediction methodology for falling from scaffold”. *Safety Science*, 117: 88-99.

James, W. (1890). “The principles of psychology”. New York: Dover Publications.

James, W. (1913). The principles of psychology, Vol. 2, Dover, New York.

Jensen-Campbell, L., Knack, J. and Gomez, H. (2010). “The Psychology of Nice People”. *Social and Personality Psychology Compass*, 4(11): 1042–1056.

Jensen, J. and Patel, P. (2011). “Predicting counterproductive work behavior from the interaction of personality traits.” *Personality Individual Differences*, 51(4): 466–471.

JFABIAN (2021). “Workplace Injury Statistics – 2020 Data for Workplace Accidents, Injuries, and Deaths”. *Work Injury Source*, 1-2. https://workinjurysource.com/workplace-injury-statistics-2019/ Assessed 02 Feb, 2021.

Jonah, B. A. (1997). “Sensation seeking and risky driving”. In T. Rothengatter & E. Carbonell Vaya (Eds.), Traffic and transport psychology: Theory and application (pp.259–267). Oxford: Pergamon.

Jusoh, N., Bahari, S. and Rahman, S. (2015). “Does Personality affect Safety Performance?”*3rd Scientific Conference on Occupational Safety and Health: Sci- Cosh*, 12(1): 5-8.

Kaber, D., S. Jin, M. Zahabi, and C. Pankok. (2016). “The effect of driver cognitive abilities and distractions on situation awareness and performance under hazard conditions”. *Transportation Research Part F Traffic Psychology and Behavior*, 42 (1): 177–194.

Kahneman, D., Slovic, P. and Tversky, A. (eds.) (1982). Judgement under Uncertainty: Heuristics and Biases. Cambridge: Cambridge University Press.

Kane, M., Bleckley, M., Conway, A. and Engle, R. (2001). "A controlled-attention view of WM capacity." *Journal of Experimental Psychology*: General, 130: 169–183.

Kao, K., Spitzmueller, C., Cigularov, K. and Thomas, C. (2019). "Linking safety knowledge to safety behaviors: a moderated mediation of supervisor and worker safety attitudes". *European Journal of Work and Organizational Psychology*, 28(2): 206–220.

Karakhan, A. and Gambatese, J. (2018). "Hazards and Risk in Construction and the Impact of Incentives and Rewards on Safety Outcomes". *Practice Periodical on Structural Design and Construction*, 23(2): 1-8.

Kaskutas, V., Dale, A., Lipscomb, H. and Evanoff, B. (2013). "Fall prevention and safety communication training for foremen: Report of a pilot project designed to improve residential construction safety". *Journal of Safety Research*, 44: 111–118.

Kaspar, K. and König, P. (2012). "Emotions and personality traits as high-level factors in visual attention: a review". *Frontiers in Human Neuroscience*, 6(321): 1-14.

Keinan, G., Friedland, N., Kahneman, D., & Roth, D. (1999). "The effect of stress on the suppression of erroneous competing responses". *Anxiety, Stress and Coping*, 12: 455-476.

Kelly, J. and Karau, S. (2012). "Group Decision Making: The Effects of Initial Preferences and Time Pressure". *SAGE Publications,* pp. 1342-1354.

Kern, M. (2020). "Conscientiousness". The University of Melbourne, 123-127.

Kerstholt, J. (1994). "The effect of time pressure on decision-making behaviour in a dynamic task environment". *Acta Psychologica* 86: 89-104.

Khdair, W., Shamsudin, F. and Subramaniam, C. (2012). "Conscientiousness , Management Practices and Safety Performance: A Proposed Relationship in The Oil and Gas Industry in Iraq". *International Journal on Social Science Economics and Art*, 2(1): 20–25.

Kim, Y. and Cribbie, R. (2018). "ANOVA and the variance homogeneity assumption: Exploring a better gatekeeper". *British Journal of Mathematical and Statistical Psychology*, 71: 1–12.

Kim, S. and Hong, S. (2020). "Comparing Methods for Multilevel Moderated Mediation: A Decomposed-first Strategy". *Structural Equation Modeling: A Multidisciplinary Journal*, 27(5): 661-677.

Kim, S., Lee, H., Hwang, S., Yi, J. and Son, J. (2021). "Construction workers' awareness of safety information depending on physical and mental load". *Journal of Asian Architecture and Building Engineering*, pp. 1-11.

Klockner, K. and Hicks, R. (2015). "Cognitive failures at work, mindfulness, and the Big Five". *Global Science and Technology Journal of Psychology*, 2(1): 1-7.

Knight, P., Iverson, D. and Harris, M. (2012). "Early driving experience and influence on risk perception in young rural people". *Accident Analysis & Prevention*, 45, 775–81.

Knoll, F. (2014). "Human Error - Case Studies". *Vulnerability, Uncertainty, and Risk,* pp. 2710 - 2719.

Koelega, H. S. (1992). "Extraversion and vigilance: 30 years of inconsistencies". *Psychological Bulletin*, 112, 239–258.

Konradt, U., Andreßen, P. and Ellwart, T. (2009). "Self-leadership in organizational teams: A multilevel analysis of moderators and mediators". *European Journal of Work and Organizational Psychology,* 18(3): 322-346.

Kowler, E., Anderson, E., Dosher, B. and Blaser, E. (1995). "The Role of Attention in the Programming of Saccades". *Vision Research*, 35(13): 1897- 1916.

Kristjánsson, K. (2006). "Agreeableness". *Journal of Value Inquiry*, 40 (1): 33–43.

Krueger, c. and Tian, L. (2004). "A Comparison of the General Linear Mixed Model and Repeated Measures ANOVA Using a Dataset with Multiple Missing Data Points". *Biological Research for Nursing*, 6(2): 151-157.

Kruglanski, A. and Webster, D. (1996). "Motivated closing of the mind: "Seizing" and "freezing". *Psychological Review*, 103: 263-283.

Kuzel, M., Cohen, H., Rauschenberger, R. and Cohen, J. (2013). "Evaluation of mobile eye tracking for forensic analysis of pedestrian falls". Human Factors and Ergonomics Society Annual Meeting, Los Angeles, CA: SAGE Publications, 57: 570–574.

Kyllonen, P. and Christal, R. (1990). "Reasoning ability is (little more than) working-memory capacity?". *Intelligence*, 14:389–433.

LaBelle, J. E. (2005). “The paradox of safety hopes and rewards: Are you rewarding the right behavior?” *Professional Safety,* 50(12): 37–42.

Lachowicz, M., Sterba, S. and Preacher, K. (2015). “Investigating multilevel mediation with fully or partially nested data”. *Group Processes & Intergroup Relations*, 18(3): 274–289.

Lajunen, T. (2001). “Personality and accident liability: Are extraversion, neuroticism and psychoticism related to traffic and occupational fatalities?”. *Personality and Individual Differences,* 31: 1365-1373.

Lan, A. and Galy, B. (2017). “Evaluation of a Horizontal Lifeline System Used during Installation of Residential Roofs”. *Journal of Construction Engineering and Management*, 143(5): 1-7.

Langenberg, B., Helm, J. and Mayer, A. (2020). “Repeated Measures ANOVA with Latent Variables to Analyze Interindividual Differences in Contrasts”. *Multivariate Behavioral Research,* 1-20.

Langford, D., Rowlinson, S. and Sawacha, E. (2000). “Safety behavior and safety management: its influence on the attitudes of workers in the UK construction industry”. *Engineering, Construction and Architectural Management*, 7(2): 133-140.

Lambert, A., Watson, J., Cooper, J. and Strayer, D. (2010). “The Roles of Working Memory Capacity, Visual Attention and Age in Driving Performance”. *Proceedings of the Human Factors and Ergonomics Society 54th Annual Meeting*, pp. 170-174.

Lambert, T., Jones, K., Brazel, J. and Showalter, S. (2017). “Audit time pressure and earnings quality: An examination of accelerated filings”. *Accounting, Organizations and Society*, 58: 50-66.

Landay, K., Wood, D., Harms, P., Ferrell, B. and Nambisan, S. (2020). “Relationships between personality facets and accident involvement among truck drivers”. *Journal of Research in Personality*, 84: 1-10.

Lan, J., Wong, C. and Mao, C. (2017). “The effect of leadership on work-related flow: a moderated mediation model”. *Leadership and Organization Development Journal*, 38(2): 210-228.

Landay, K., Wood, D., Harms, P., Ferrell, B. and Nambisan, S. (2020). “Relationships between personality facets and accident involvement among truck drivers”. *Journal of Research in Personality,* 84: 1-10.

Lavino, G. and Neumann, N. (2010). “Psychology of risk perception”. Nova Science, New York.

Lawani, K., Tong, M., Hare, B. and Emina, F. (2019). “Improving Productivity and Worker Safety: An Action Research using OSM with Crane Erect”. *Productivity, Performance and Quality,* pp. 1-10.

Le, Q., Pedro, A. and Park, C. (2015). "A Social Virtual Reality Based Construction Safety Education System for Experiential Learning". *Journal of Intelligent and Robotic Systems,* 79:487–506.

Lee, K., Sheldon, K. and Turban, D. (2003). "Personality and the goalstriving process: The influence of achievement goal patterns, goal level, and mental focus on performance and achievement," *Journal of Applied Psychology*, 88: 256-265.

Lee, J. and Nussbaum, M. (2013). "Experienced workers may sacrifice peak torso kinematics/kinetics for enhanced balance/stability during repetitive lifting". *Journal of Biomechanics*, 46: 1211–1215.

Lee, S. and Dalal, R. (2016). "Climate as situational strength: Safety climate strength as a cross-level moderator of the relationship between conscientiousness and safety behavior". *European Journal of Work and Organizational Psychology*, 25:1, 120-132.

Lee, S., Klauer, S., Olsen, E., Simons-Morton, B., Dingus, T., Ramsey, D. and Ouimet, M. (2008). 'Detection of Road Hazards by Novice Teen and Experienced Adult Drivers'. *Journal of the Transportation Research Board,* 2078: 26–32.

Lengyel, G., Carlberg, K., Samad, M. and Jonker, T. (2021). "Predicting visual attention using the hidden structure in eye-gaze dynamics". *Association for Computing Machinery*, pp. 1-9.

Leung, M., Liang, Q. and Olomolaiye, P. (2015). "Impact of job stressors and stress on the safety behavior and accidents of construction workers". *Journal of Management Engineering*, 32 (1): 1-10.

Levene, H. (1960). "Robust tests for equality of variances". In I. Olkin et al. (Eds.), Contributions to probability and statistics: Essays in honor of Harold Hotelling (pp. 278-292). Stanford, CA: Stanford University Press.

Li, J., Li, H., Wang, H., Umer, W., Fu, H. and Xing, X. (2019). "Evaluating the impact of mental fatigue on construction equipment operators' ability to detect hazards using wearable eye-tracking technology". *Automation in Construction*, 105: 1-14.

Li, J., Li, H., Umer, W., Wang, H., Xing, X., Zhao, S. and Hou, J. (2020). "Identification and classification of construction equipment operators' mental fatigue using wearable eye-tracking technology". Automation in Construction, 109: 1-15.

Liang, H., Chen, S., Hsu, J. and Chang, C. (2004). "Work-related upper limb amputations in Taiwan, 1999-2001". *American Journal of Industrial Medicine*, 46:649–655.

Liang, N., Yang, J., Yu, D., Prakah-Asante, K., Curry, R., Blommer, M., Swaminathan, R. and Pitts, B. (2021). "Using eye-tracking to investigate the effects of pre-takeover visual engagement on situation awareness during automated driving". *Accident Analysis and Prevention*, 157: 1-12.

Liao, C. and Lee, C. (2009). "An Empirical Study of Employee Job Involvement and Personality Traits: The Case of Taiwan". *International Journal of Economics and Management*, 3(1): 22 – 36.

Liao, P., Sun, X. and Zhang, D. (2021). "A multimodal study to measure the cognitive demands of hazard recognition in construction workplaces". *Safety Science*, 133: 1-11.

Lichtenstein, S., Slovic, P., Fischhoff, B., Combs, B. and Layman, M. (1978). "Perceived frequency of low-probability lethal events". *Journal of Experimental Psychology: Human Learning and Memory,* 4: 551–578.

Liko, G., Esmaeili, B., Hasanzadeh, S., Dodd, M., and Brock, R. (2019). "Working-Memory Load as a Factor Determining the Safety Performance of Construction Workers" *In Proceedings of ASCE 2020 Construction Research Congress (CRC) Conference,* Tempe, Arizona, pp. 499-507.

Lim, T., Park, S., Lee, H. and Lee, D. (2016). "Artificial Neural Network–Based Slip-Trip Classifier Using Smart Sensor for Construction Workplace". *Journal of Construction Engineering and Management*, 142(2): 1-10.

Lingard, H. (2013). "Occupational health and safety in the construction industry". *Construction Management and Economics*, *31*(6), 505-514.

Linkov, V., Zaoral, A., Rˇezácˇ, P. and Pai, C. (2019). "Personality and professional drivers' driving behavior". *Transportation Research Part F,* 105-110.

Lipscomb, H., Dement, J., Li, L., Nolan, J. and Patterson, D. (2003b). "Work-related injuries in residential and drywall carpentry". *Applied Occupational and Environmental Hygiene,* 18(6):479–488.

Lipscomb, H., Glazner, J., Bondy, j., Guarini, K. and Lezott, D. (2006). "Injuries from slips and trips in construction". *Applied Ergonomics,* 37: 267–274.

Lipscomb, H., Nolan, J. and Patterson, D. (2015). "Musculoskeletal Concerns Do Not Justify Failure to Use Safer Sequential Trigger to Prevent Acute Nail Gun Injuries". *American Journal of Industrial Medicine,* 58: 422-427.

Lipscomb, H., Schoenfisch, A. and Cameron, W. (2013). "Work-Related Injuries Involving a Hand or Fingers Among Union Carpenters in Washington State, 1989 to 2008". *Journal of Occupational and Environmental Medicine*, 55(7): 832-838.

Llanes-Jurado, J., Marín-Morales, J., Moghaddasi, M., Khatri, J., Guixeres, J. and Alcañiz, M. (2021). "Comparing Eye Tracking and Head Tracking During a Visual Attention Task in Immersive Virtual Reality". Springer Nature Switzerland, 12763:32–43.

Lu, Y., Hinze, J., and Li, Q. (2011). "Developing fuzzy signal detection theory for workers' hazard perception measures on subway operations." Safety Science, 49 (3): 491–497.

Luck, S. and Ford, M. (1998). “On the role of selective attention in visual perception”. *Proceedings of the National Academy of Sciences of the USA*, 95: 825–830.

Ma, Y., Qi, S., Zhang, Y., Lian, G., Lu, W. and Chan, C. (2020). “Drivers’ Visual Attention Characteristics under Different Cognitive Workloads: An On-Road Driving Behavior Study”. *International Journal of Environmental Research and Public Health*, 17: 1-19.

Ma, H., Wu, Z. and Chang, P. (2021). “Social impacts on hazard perception of construction workers: A system dynamics model analysis”. *Safety Science*, 138: 1-12.

Mack, A. and Rock, I. (1998). “Inattentional blindness”. Cambridge, MA: MIT Press.

MacKinnon, D., Valente, M. and Gonzalez, O. (2020). “The Correspondence Between Causal and Traditional Mediation Analysis: The Link is the Mediator by Treatment Interaction. *Prevention Science*, 21:147–157.

Maiti, P. (2007). “The role of behavioral factors on safety management in underground mines”. *Safety Science*, 45: 449–471.

Mallia, L., Lazuras, L., Violani, C. and Lucidi, F. (2015). “Crash risk and aberrant driving behaviors among bus drivers: The role of personality and attitudes towards traffic safety”. *Accident Analysis and Prevention*, 79: 145-151.

Man, K. and Chan, A. (2018). “Influence of Personality and Safety Climate on Risk Perception of Hong Kong Construction Workers”. *Proceedings of the International Multi Conference of Engineers and Computer Scientists*, pp. 1-6.

Man, S., Chan, A. and Wong, H. (2017). “Risk-taking behaviors of Hong Kong construction workers – A thematic study”. *Safety Science*, 98: 25–36.

Mangharam, J., Moorin, R. and Straker, L. (2016). “A comparison of the burden and resultant risk associated with occupational falls from a height and on the same level in Australia”. *Ergonomics*, 59(12): 1646-1660.

Mäntylä, T, Karlsson, M. and Marklund, M. (2009). “Executive control functions in simulated driving.” *Applied Neuropsycholy*, 16(1):11-18.

Mäntylä, M., Petersen, K., Lehtinen, T. and Lassenius, C. (2014). “Time Pressure: A Controlled Experiment of Test Case Development and Requirements Review”. *ICSE*, pp. 83-94.

Marom, B., Ratzon, N., Carel, R. and Sharabi, M. (2019). " Return-to-Work Barriers Among Manual Workers After Hand Injuries: 1-Year Follow-up Cohort Study”. Archives of Physical Medicine and Rehabilitation, 100:422-432.

Matthew A. Napierala (2012). “What Is the Bonferroni Correction?”. *AAOS Now*, 1-2.

Mathieu, J. E., DeShon, R. P., & Bergh, D. D. (2008). Mediational inferences in organizational research: Then, now and beyond. *Organizational Research Methods*, 11: 203-223.

Matthews, G. (1999). Personality and skill: A cognitive–adaptive framework. In P. L. Ackerman, P. C. Kyllunen, & R. D. Roberts (Eds.), Learning and individual differences: Process, trait and context determinants (pp. 251–274). Washington, DC: American Psychological Association

Matthews, G. and Deary, I. (1998). “Personality traits”. Cambridge: Cambridge University Press.

Martin, M. (1983). “Cognitive failure: Everyday and laboratory performance”. *Bulletin of Psychonomic Society*, 21: 97–100.

Mat, N., Jansriboot, P. and Mat, N. (2019). “Big Five Personality, Transformational Leadership, Psychological Safety, and Employee Engagement of Private Sector Employees in Southern Thailand”. *Jurnal Pengurusan*, 56:1-19.

Maule, A. and Hockey, R. (1993). “State, stress, and time pressure”. In O. Svenson, & A. J. Maule (Eds.), Time pressure and stress in human judgement and decision making (pp. 83−101). New York: Plenum.

Maule, A. and Mackie, P. (1990). “A componential investigation of the effects of deadlines on individual decision making”. In K. Borcherding (Ed.), Contemporary issues in decision making. Amsterdam: North-Holland

Mayer, J., Bittner, R., Nikolić, D., Bledowski, C., Goebel, R. and Linden, D. (2007). “Common neural substrates for visual working memory and attention”. *NeuroImage*, 36: 441–453.

Mazloumi, A., Kumashiro, M., Izumi, H. and Higuchi, Y. (2008). “Quantitative Overload: a Source of Stress in Data-Entry VDT Work Induced by Time Pressure and Work Difficulty”. *Industrial Health*, 46: 269–280.

McCabe, B., Alderman, E., Chen, Y., Hyatt, D. and Shahi, A. (2017). “Safety Performance in the Construction Industry: Quasi-Longitudinal Study”. *Journal of Construction Engineering and Management,* 143(4): 1-11.

McCrley, J. and Kramer, A. (2008). “Eye movements as a window on perception and cognition”. *Neuroergonomics*, 3:95.

McCollough, A. and Vogel, E. “Your inner spam filter: What makes you so smart? Might be your lizard brain”. *Scientific American Mind*, pp. 74-77.

McCrae, R. R., & Costa, P. T. (1997). “Conceptions and correlates of openness to experience”. In R. Hogan, J. Johnson, & S. Briggs (Eds.), Handbook of personality psychology (pp. 825-847). San Diego, CA: Academic Press.

McCrae, R. R., & Costa, P. T., Jr. (1987). Validation of the five-factor model of personality across instruments and observers. Journal of Personality and Social Psychology, 52, 81–90.

McCrae, R. and John, O. (1992). “An introduction to the five-factor model and its applications.” *Journal of Personality*, 60(2): 175–215.

McIntyre, M. and Graziano, W. (2016). “Seeing People, Seeing Things: Individual Differences in Selective Attention”. *Personality and Social Psychology Bulletin*, 42(9): 1258–1271.

McLain, D. and Jarrell, K. (2007). “The perceived compatibility of safety and production expectations in hazardous occupations”. *Journal of Safety Research*, 38(3): 299–309.

Memarian, B. and Mitropoulos, P. (2016). “Supervisor Practices for Productivity and Safety: A Hot Asphalt Roofing Case Study”. *The American Institute of Constructors*, 41(1): 17-30.

Merino, G., Riascos, C., Costa, A., Elali, C. and Merino, E (2018). “The focus of visual attention in people with motor disabilities through eye tracking: an experience in public built environment”. *Gestão e Tecnologia de Projetos, São Carlos*, 13(3): 7-20.

Miller, G., Galanter, E. and Pribram, K. (1960). “Plans and the structure of behavior”. Holt, Rinehart and Winston, Inc., New York.

Mistikoglu, G., Gerek, I., Erdis, E., Usmen, M., Cakan, H. and Kazan, E. (2015). “Decision tree analysis of construction fall accidents involving roofers”. *Expert Systems with Applications*, 42: 2256-2263.

Mitropoulos, P., Abdelhamid, T. and Howell, G. (2005). “Systems model of construction accident causation”. *Journal of construction engineering and management*, 131(7): 816-825.

Mitropoulos, P. and Cupido, G. (2009). “Safety as an emergent property: investigation into the work practices of high-reliability framing crews”. *Journal of Construction Engineering and Management*, 135(5): 407–415.

Mohammadi, A., Tavakolan, M. and Khosravi, Y. (2018). “Factors influencing safety performance on construction projects: A review”. *Safety Science*, 109: 382-397.

Mitropoulos, P., & Namboodiri, M. (2011). New method for measuring the safety risk of construction activities: Task demand assessment. *Journal of Construction Engineering and Management*, 10.1061/(ASCE)CO.1943-7862.0000246, 30–38.

Moore, T. and Fallah, M. (2001). “Control of eye movements and spatial attention”. *Proceedings of the National Academy of Sciences of the USA*, 98(3): 1273–1276.

Moore, J. and Wagner, J. (2014). “Fatal events in residential roofing”. *Safety Science*, 70: 262-269.

Mount, M. and Barrick, M. (1998). “Five Reasons why the Big Five Article has Frequently been Cited”. Personnel Psychology, 51: 849-857.

Mullen, J. (2004). “Investigating factors that influence individual safety behavior at work”. *Journal of Safety Research*, 35: 275– 285.

Murray, I., Fleck, B., Brash, H., MacRae, M., Tan, L. and Minns, R. (2009). “Feasibility of saccadic vector optokinetic perimetry: a method of automated static perimetry for children using eye tracking”. *Ophthalmology*, 116 (10): 2017-2026.

Nadhim, E., Hon, C., Xia, B., Stewart, I. and Fang, D. (2016). “Falls from Height in the Construction Industry: A Critical Review of the Scientific Literature”. International Journal of Environmental Research and Public Health, 13(638): 1-20.

Nasarwanji, M., Pollard, J. and Kocher, L. (2019). “Using High-Fidelity Physical Simulations of the Environment to Evaluate Risk Factors for Slips and Falls in the Mining Industry”. *AHFE*, pp. 373–381.

Nenonen, N. (2013). “Analysing factors related to slipping, stumbling, and falling accidents at work: Application of data mining methods to Finnish occupational accidents and diseases statistics database”. *Applied Ergonomics*, 44: 215-224.

Nepal, M., Park, M. and Son, B. (2006). “Effects of Schedule Pressure on Construction Performance”. *Journal of Construction Engineering and Management*, 132(2): 182-188.

Newbold, E. (1926). “A contribution to the study of the human factor in the causation of accidents”. London: Industrial Health Research Board.

Nielsen, M. B., and S. Knardahl. (2015). “Is workplace bullying related to the personality traits of victims? A two-year prospective study.” *Work Stress*, 29 (2): 128–149.

Nilsson, D. (1989). “Vision optics and evolution”. *BioScienc*e, 39(5): 298–307.

Niu, Y., Todd, R., Kyan, M. and Anderson, A. (2012). “Visual and emotional salience influence eye movements,”. *ACM Transactions on Applied Perception*, 9(3): 1-12.

Nordlöf, H., Wiitavaara, B., Winblad, U., Wijk, K. and Westerling, R. (2015). "Safety culture and reasons for risk-taking at a large steel-manufacturing company: Investigating the worker perspective". *Safety* Science, 73: 126-135.

Norušis, M. (2002). SPSS 11.0 guide to data analysis, Prentice Hall, Upper Saddle River, N.J

Noton, D. and Stark, L. (1971). "Eye Movements and Visual Perception". *Scientific American*, 35-43.

Nowrouzi-Kia, B., Gohar, B., Casole, J., Chidu, C., Dumond, J., McDougall, A. and Nowrouzi-Kia, B. (2018). "Systematic review of lost-time injuries in the global mining industry". *Work*, 60: 49–61.

Occupational Health and Safety (OHS 2020) https://ohsonline.com/Articles/2020/02/01/A-New-Year-of-Hand-Safety.aspx Accessed 9th September, 2021

Occupational Safety and Health Administration (2015). "Duty to Have Fall Protection; 29 CFR 1926.501". Washington, DC, USA.

O'Connor, T., Loomis, D., Runyan, C., Abboud dal Santo, J. and Schulman, M. (2005). "Adequacy of Health and Safety Training Among Young Latino Construction Workers". *Journal of Occupational and Environmental Medicine*, 47(3): 272- 277.

Oh, S. and Kim, M. (2004). "The role of spatial working memory in visual search efficiency". *Psychonomic Bulletin & Review*, 11 (2): 275-281.

Oleske, D. and Hahn, J. (1992). "Work-related injuries of the hand: data from an occupational injury/illness surveillance system". *Journal of Community Health*, 17(4): 205-219.

Oliver, A., Cheyne, A., Tomas, J.M., Cox, S., (2002). "The effects of organizational and individual factors on occupational accidents*". Journal of Occupational and Organizational Psychology*, 75: 473–488.

Olivers, C. (2008). "Interactions between visual working memory and visual attention". *Frontiers in Bioscience*, 13: 1182-1191.

Ordonez, L. and Benson III, L. (1997). "Decisions under time pressure: how time constraint affects risky decision making". *Organizational Behavior and Human Decision Processes*, 71 (2): 121–140.

OSHA (2019). https://www.osha.gov/data/commonstats Accessed 7th sept, 2021

Oshioa, A., Takub, K., Hiranoc, M. and Saee, G. (2018). "Resilience and Big Five personality traits: A meta-analysis". *Personality and Individual Differences*, 127: 54-60.

O'Sullivan M. and Colville J. (1993). "The economic impact of hand injuries". *Journal of Hand Surgeries*, 18: 395–398.

Pashler, H. (1998). The psychology of attention. Cambridge, MA: The MIT Press

Payne, J., Bettman, J. and Luce, M. (1996). "When time is money: Decision behavior under opportunity-cost time pressure". *Organizational Behavior and Human Decision Processes*, 66(2): 131−152.

Pek, S., Turner, N., Tucker, S., Kelloway, E. and Morris, J. (2017). "Injunctive safety norms, young worker risk-taking behaviors, and workplace injuries". *Accident Analysis and Prevention,* 106: 202–210.

Peltzman, S. (1975). "The effects of automobile safety regulation". *Journal of Political Economy*, 83(4): 677–725.

Pernice, K. and Nielsen, J. (2009). How to conduct eyetracking studies. Nielsen Norman Group.

Perry, M., McQueen, A. and Kim, S. (2015). "Evaluating Fall Safety Compliance Among Skilled Trades in Construction". Small Study Final Report; CPWR: Silver Spring, MD, USA,

Pestongee, D. and Singh, U. (1980). "Neuroticism-Extraversion as Correlates of Accident Occurrence". *Accident Analysis and Prevention*, 12: 201-204.

Peters, K., Diepenbruck, E., Frank, A. and Ingianni, G. (1999). "Functional and socio-economic results after inpatient rehabilitation of complex hand injured patients". *Journal of Orthopedics and its Frontier Areas*, 137: 516-520.

Petterson, M., Beck, M. and Wong, J. (2008). "Were you paying attention to where you looked? The role of executive working memory in visual search". *Psychonomic Bulletin & Review*, 15(2): 372-377.

Peugh, L. (2010). "A practical guide to multilevel modeling". *Journal of School Psychology*, 48: 85–112.

Piechurska-Kuciel, E. (2019). "Mediation effect of self-efficacy in the relationship between neuroticism and L2 attainment". *Journal of Multilingual and Multicultural Development,* 1-14.

Pili, J., Izadi, N. and Golbabaei, F. (2013). "Factors Associated with Needle Stick and Sharp Injuries among Health Care Workers". *International Journal of occupational Hygiene*, 5(4): 191-197.

Pinheiro, R., Pradhananga, N., Jianu, R. and Orabi, W. (2016). "Eye-Tracking Technology for Construction Safety: A

Feasibility Study". *33rd International Symposium on Automation and Robotics in Construction*, pp. 1-9.

Pollard, J., Heberger, J. and Dempsey, P. (2014). "Maintenance and repair injuries in US mining". *Journal of Quality in Maintenance Engineering*, 20(1): 20-31.

Poole, A., and Ball, L. J., (2006). "Eye tracking in HCI and usability research: Current Status and Future Prospects". *Encyclopedia of human computer interaction*, 1: 211-219.

Posner, M. and DiGirolamo, G. (1998). "Executive attention: Conflict, target detection, and cognitive control": Cambridge, MA, US: The MIT Press.

Postlethwaite, B., Robbins, S., Rickerson, J. and McKinniss, T. (2009). "The moderation of conscientiousness by cognitive ability when predicting workplace safety behavior". *Personality and Individual Differences*, 47: 711–716.

Pourmazaheriana, M., Baqutayana, S. and Idrus, D. (2017). "The Role of the Big Five Personality Factors on Accident: A Case of Accidents in Construction Industries". Journal of Science, Technology and Innovation Policy, 3(2): 46-55.

Preacher, K. and Hayes, A. (2008). "Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models". *Behavior Research Methods,* 40 (3): 879-891.

Preacher, K., Rucker, D. and Hayes, A. (2007). "Addressing Moderated Mediation Hypotheses: Theory, Methods, and Prescriptions". *Multivariate Behavioral Research*, 42(1): 185-227.

Raad, B. and Mlacic, B. (2015). "Big Five Factor Model, Theory and Structure". *International Encyclopedia of the Social & Behavioral Sciences*, 2(2): 559-566.

Radomsky, M., Ramani, R. and Flick, J. (2001). "Slips, Trips and Falls in in Construction & Mining: Causes & Controls". *Occupational Safety*, pp. 30-37.

Raes, A., Bruyneel, L., Loeys, T., Moerkerke, B. and De Raedt, R. (2013). "Mindful attention and awareness mediate the association between age and negative affect". *Journal of Gerontology, Series B: Psychological Sciences and Social Sciences*, 70(2): 179–188.

Rajapakse, A., Emad, G., Lützhöft, M. and Grech, M. (2019). "A study on time constraints and task deviations at sea leading to accidents – a cultural-historical perspective". *Maritime Policy and Management,* 46(4): 436-452.

Ramey, M., Yonelinas, A. and Henderson, J. (2019). "Conscious and unconscious memory differentially impact attention: Eye movements, visual search, and recognition processes". *Cognition*, 185: 71-82.

Ramosaj, b., Amro, L. and Pauly, M. (2020). “A cautionary tale on using imputation methods for inference in matched-pairs design”. *Bioinformatics*, 36(10): 3099–3106.

Rasmussen, J. (1997). “Risk management in a dynamic society: a modeling problem”. *Safety Science*, 27(2): 183-213.

Raudenbush, S. and Bryk, A. (2002). Hierarchical linear models: Applications and data analysis methods. Thousand Oaks, CA: Sage.

Rauthmann, J., Seubert, C., Sachse, P. and Furtner, M. (2012). “Eyes as windows to the soul: Gazing behavior is related to personality.” J. *Res. Pers.,* 46: 147–156.

Reason, J. (1990). “Human Error”. Cambridge University Press, New York.

Reason, J. (2005). “Safety in the operating theatre – Part 2: Human error and organizational failure”. *Quality Safety Healthcare Journal*, pp. 56-61.

Rendon-Velez, E., van Leeuwen, P., Happee, R., Horváth, I., van der Vegte, W. and de Winter, J. (2016). “The effects of time pressure on driver performance and physiological activity: A driving simulator study”. *Transportation Research Part F*, 41: 150-169.

Renner, W. and Anderle, F. (2000). “Venturesome and extraversion as correlates of juvenile drivers’ traffic violations”. *Accident Analysis and Prevention* 32: 673–678.

Rey-Merchan, M., Arquillos, A. and Soto-Hidalgo, J. (2021). “A Fall from Height prevention proposal for construction sites based on Fuzzy Markup Language, JFML and IoT solutions”. *IEEE International Conference on Fuzzy Systems*; pp. 1-6.

Richardson, J. (2007). “Measures of short-term memory: a historical review.” *Cortex,* 43(5):635–650.

Ricker, T., AuBuchon, A. and Cowan, N. (2010). “Working memory”. *Cognitive Science,* 1: 573-585.

Ringen, K. and Seegal, J. (1995). “Safety and Health in the Construction Industry”. *Annual Review of Public Health*, 16:165-88.

Roberts, R., Hager, L. and Heron, C. (1994). “Prefrontal cognitive processes: Working memory and inhibition in the antisaccade task”. *Journal of Experimental Psychology: General*, 123: 374-393.

Roberts, D., Doherty, M. and Lane, L. (2015). "Human Performance – Addressing the Human Element in Electrical Safety". *Institute of Electrical and Electronics Engineers,* pp. 1-6.

Rockwood, N. J. and Hayes, A. F. (2017). "MLmed: An SPSS macro for multilevel mediation and conditional process analysis." Poster presented at the annual meeting of the *Association of Psychological Science (APS),* Boston, MA.

Roskes, M., Elliot, A., Nijstad, B. and De Dreu, C. (2013). "Time Pressure Undermines Performance More Under Avoidance Than Approach Motivation". *Personality and Social Psychology Bulletin*, 39(6): 803–813.

Rozenfeld, O., Sacks, R., Rosenfeld, Y., and Baum, H. (2010). "Construction job safety analysis". *Safety Science,* 48(4): 491–498.

Rundmo, T. (1992). "Risk perception and safety on offshore petroleum platforms—part 1: perceived risk, job stress and accidents". *Safety Science* 15: 53–68.

Sacks, R., Perlman, A. and Barak, R. (2013). "Construction safety training using immersive virtual reality". *Construction Management and Economics*, 31(9): 1005-1017.

Sacks, R., Perlman, A. and Barak, R. (2013). "Construction safety training using immersive virtual reality". *Construction Management and Economics*, 31(9): 1005-1017.

Salgado, J. (2002). "The Big Five Personality Dimensions and Counterproductive Behaviors". *International Journal of Selection and Assessment,* 10(1): 117-125.

Salvucci, D. and Goldberg, J. (2000). "Identifying Fixations and Saccades in Eye-Tracking Protocols". *Eye Tracking Research & Applications Symposium,* 71-78.

Sanders, M. and McCormick, E. (1993). "Human factors in engineering and design". McGraw-Hill, New York, 7.ed.

Saucier, G. (1994). "Mini-markers: A brief version of Goldberg's unipolar Big-Five markers." *J Personality Assess*. 63 (3): 506–516.

Sawacha E., Naoum S. and Fong, D. (1999). "Factors affecting safety performance on construction sites". *International Journal of Project Management,* 17(5): 309-315.

Scanlon, M., Drescher, D. and Sarkar, K. (2007). "Improvement of Visual Attention and Working Memory through a Web-based Cognitive Training Program". *Lumos Labs, Inc,* pp. 1-5.

Schwebel, D., Severson, J., Ball, K. and Rizzo, M. (2006). “Individual difference factors in risky driving: The roles of anger/hostility, conscientiousness, and sensation-seeking”. *Accident Analysis and Prevention,* 38: 801–810.

Scott, G. and Wiegand, D. (2005). “People-Based Safety: Exploring the role of Personality in Injury Prevention”. *Professional Safety,* 50(12): 28-36.

Scott, k., Fisher, G., Barón, A., Tompa, E. and Stallones, L. (2018). “Same-level fall injuries in US workplaces by age group, gender, and industry”. *American Journal of Industrial Medicine,* 61:111–119.

Seo, D. (2005). “An explicative model of unsafe work behavior”. *Safety Research,* 43(3):187–211.

Shappell, A. and Wiegmann, D. (1997). “A Human Error Approach to Accident Investigation: The Taxonomy of Unsafe Operations”. *The International Journal of Aviation Psychology,* 7(4): 269-291.

Shavit, S., Golub, J. and Lustig, L. (2020). “The Risks of Being Otologist, an Ergonomic and Occupational Hazard Review”. *Otology and Neurotology,* 41(9): 1182-1189.

Shin, M., Lee, H., Park, M., Moon, M. and Han, S. (2014). “A system dynamics approach for modeling construction workers’ safety attitudes and behaviors”. *Accident Analysis and Prevention,* 68: 95-105.

Shipstead, Z., Harrison, T. and Engle, R. (2012). “Rapid communication Working memory capacity and visual attention: Top-down and bottom-up guidance”. *The Quarterly Journal of Experimental Psychology*, 65(3): 401–407.

Shorrock, S. and Kirwan, B. (2002). “Development and application of a human error identification tool for air traffic control”. *Applied Ergonomics*, *33*(4): 319-336.

Shumway-Cook, A. and Woollacott, M. (1995). “Motor control: Theory and application”, Williams and Wilkins, Baltimore, MD, pp. 120-122.

Simeonov, P. (2016). “Fall Risk Associated with Restricted and Elevated Support Surfaces”. *Fall Prevention and Protection*, pp. 119-139.

Simeonov, P., Hsiao, H., Dotson, B. and Ammons, D. (2003). “Control and Perception of Balance at Elevated and Sloped Surfaces”. *Human Factors,* 45(1): 136–147.

Sokolowski, S., Cantrell, N. and Griffin, L. (2019). “Firefighting Turnout Boots: How a Human Factors Approach Can Improve Performance”. *Springer Nature,* 790: 59–67.

Solomon, T., Hasanzadeh, S., Esmaeili, B. and Dodd, M. (2021). “Impact of Change Blindness on Worker Hazard Identification at Jobsites”. *Journal of Management in Engineering*, 37(4): 1-14.

Sorock, G., Lombardi, D., Hauser, R., Eisen, E., Herrick, R. and Mittleman, M. (2001). "A Case-Crossover Study of Occupational Traumatic Hand Injury: Methods and Initial Findings". *American Journal of Industrial Medicine*, 39: 171-179.

Souza, A. and Oberauer, K. (2017). "The contributions of visual and central attention to visual working memory". *The Journal of Attention, Perception and Psychophysics, 79*:1897–1916.

Stamatis, D. H. (2003). "Failure mode and effect analysis: FMEA from theory to execution". ASQ Quality Press.

Starkweather, J. (2010). "Homogeneity of Variances", pp. 1-3.

Steffy, B., Jones, J., Murphy, L. and Kunz, L. (1986). "A demonstration of the impact of stress abatement programs on reducing employees' accidents and their costs". *American Journal of Health Promotion*, 1: 25–32.

Stewart, I. and Fang, D. (2016). "Falls from Height in the Construction Industry: A Critical Review of the Scientific Literature". *International Journal of Environmental Research and Public Health*, 13(638): 1-20.

Steyin, L. (2010). "Psychological factors as Predictors of Employees' Attitudes towards Workplace Safety in a Public Electricity Company in South Africa". *Doctoral Thesis submitted to the University of the Free Stae Bloemfontein*, 1-143.

Sugama, A. and Seo, A. (2021). "Analysis of Postural Instability in the Upright Position on Narrow Platforms and the Interactions with Postural Constraints". *Sensors*, 21(3909): 1-17.

Svenson, O. and Edland, A. (1987). "Change of preferences under time pressure: Choices and judgments". *Scandinavian Journal of Psychology*, 28: 322-330.

Swift, V., Wilson, K. and Peterson, J. (2020). "Zooming in on the attentional foundations of the Big Five". *Personality and Individual Differences*, 164: 1-10.

Tao, D., Zhang, R. and Qu, X. (2017). 'The role of personality traits and driving experience in self-reported risky driving behaviors and accident risk among Chinese drivers'. Accident Analysis and Prevention 99: 228–235.

Taylor E. (2015). "Safety benefits of mandatory OSHA 10 h training". *Safety Science*, 77: 66–71.

Taylor, W. (1988). "Hand-arm vibration syndrome: a new clinical classification and an updated British standard guide for hand transmitted vibration". British Journal of Industrial Medicine, 45:281-282.

Templer, K. (2012). "Five-Factor Model of Personality and Job Satisfaction: The Importance of Agreeableness in a Tight and Collectivistic Asian Society". *Applied Psychology: An International Review*, 61 (1), 114–129.

Tett, R. and Guterman. H. (2000). "Situation trait relevance, trait expression, and cross-situational consistency: Testing a principle of trait activation." *J. Res. Personnel*, 34(4): 397–423.

Theeuwes, J., Kramer, A. and Irwin, D. (2011). "Attention on our mind: The role of spatial attention in visual working memory". *Acta Psychologica*, 137: 248-251.

Thomas, R., Esper, T. and Stank, T. (2011). "Coping with time pressure in interfirm supply chain relationships". *Industrial Marketing Management*, 40: 414-423.

Thoms, P. and Venkataraman, R. (2002). "Relation of Managers' Personality to Accident and Injury Rates" *Psychological Reports*, 91: 1107-1115.

Thoms, P., Moore, K. and Scott, K. (1996). "The relationship between self-efficacy for participating in self-managed work groups and the big five personality dimensions". *Journal of Organizational Behavior*, 17: 349-362.

Thorrisen, M. (2013). 'Personality and Driving Behavior :The Role of Extraversion and Neuroticism in Drivers' Behavior Toward Bicyclists'. Master Thesis in Health- and Social Psychology, University of Oslo; pp. 1-66.

Tibu, F., Sheridan, M., McLaughlin, K., Nelson, C., Fox, N. and Zeanah, C. (2016). "Disruptions of working memory and inhibition mediate the association between exposure to institutionalization and symptoms of attention deficit hyperactivity disorder". *Psychological Medicine*, 46: 529–541.

Tobi Pro (2021). "Understanding Pro Lab's eye tracking metrics". https://www.tobiipro.com/learn-and-support/learn/steps-in-an- eye-tracking-study/data/understanding-Pro-Labs-eye-tracking-metrics/ Accessed 13th September 2021

Todorov, V. and Filzmoser, P. (2010). "Robust statistic for the one-way MANOVA". *Computational Statistics and Data Analysis*, 54: 37-48.

Tofighi, D. and Thoemmes, F. (2014). "Single-Level and Multilevel Mediation Analysis". *Journal of Early Adolescence*, 34(1): 93 –119.

Toole, T. (2002). "Construction Site Safety Roles". *Journal of Construction Engineering and Management*, 128(3): 203-210.

Turner, M. and Engle, R. (1989). "Is Working Memory Capacity Task Dependent?". *Journal of Memory and Language*, 28: 127-154.

Underwood, G., Chapman, P., Brocklehurst, N., Underwood, J. and Crundall, D. (2003). "Visual attention while driving: sequences of eye fixations made by experienced and novice drivers. *Ergonomics,* 46(6): 629-646.

Unsworth, N. and Spillers, G. (2010). "Working memory capacity: Attention control, secondary memory, or both? A direct test of the dual-component model". *Journal of Memory and Language*, 62: 392–406.

Uppal, N. (2017). "Moderation effects of perceived organizational support on curvilinear relationship between neuroticism and job performance". *Personality and Individual Differences* 105: 47–53.

Usmen, M. and Vilnitis, M. (2015). "Evaluation of Safety, Quality and Productivity in Construction". *Materials Science and Engineering*, 96: 1-11.

van de Merwe, K., van Dijk, H. and Zon, R. (2012). "Eye Movements as an Indicator of Situation Awareness in a Flight Simulator Experiment". *The International Journal of Aviation Psychology,* 22(1): 78-95.

van der Molen, H., Koningsveld, E., Haslam, R. and Gibb, A. (2005). "Ergonomics in building and construction: Time for implementation". *Applied Ergonomics*, 36(4): 387-389.

Vaughn, E. (1993). "Chronic exposure to an environmental hazard risk perceptions and self-protective behavior". *Health Psychology*, 12(1): 74 – 85.

Vialatte, F. and Cichocki, A. (2008). "Split-test Bonferroni correction for QEEG statistical maps". *Biological Cybernetics,* 98:295–303.

Vickers, J. (2007). Perception, cognition, and decision training: The quiet eye in action. Human Kinetics.

Visser, T., Tichon, J. and Diver, P. (2012). "Reducing the Dangers of Operator Distraction through Simulation Training, In Leigh, E (Ed.) SimTecT2012 : Asia Pacific Simulation Training Conference and Exhibition". *Conference Proceedings. SA Simulation Australia Ltd, Australia*, pp. 1-4.

Wade, C. and Davis, J. (2005). "Experience on an Elevated inclined Surface and Postural Control". *Proceedings of the Human factors and Ergonomics Society 49th Annual Meeting,* pp. 1311-1314.

Wagenaar, W. and Groeneweg J. (1987). "Accidents at sea: Multiple causes and impossible consequences". *International Journal of Man-Machine Studies*, 27: 587-598.

Walkins, J. (2011). "Construction workers' perceptions of health and safety training programs". *Construction Management and Economics,* 29: 1017–1026.

Wallace, J. (2004). "A Multilevel Examination of Occupational Safety: Regulatory Focus as an Explanatory Link Between Climate, Conscientiousness, and Performance". Georgia Institute of Technology, Doctor of Philosophy Dissertation.

Wallace, J. and Vodanovich, S. (2003). "Workplace Safety Performance: Conscientiousness, Cognitive Failure, and Their Interaction". *Journal of Occupational Health Psychology*, 8(4): 316–327.

Walumbwa, F. and Schaubroeck, J. (2009). "Leader Personality Traits and Employee Voice Behavior: Mediating Roles of Ethical Leadership and Work Group Psychological Safety". *Journal of Applied Psychology,* 94(5): 1275–1286.

Wang, L. and Preacher, K. (2015). "Moderated Mediation Analysis Using Bayesian Method". *Structural Equation Modeling: A Multidisciplinary Journal*, 22(2): 249-263.

Weisstein, Eric W (2021). "Bonferroni Correction." From Math World- A Wolfram Web Resource. https://mathworld.wolfram.com/BonferroniCorrection.html

Wenson, O. and Edland, A. (1987). "Change of preferences under time pressure: choices and judgements". *Scandinavian Journal of Psychology*, 28: 322-330.

Westaby, J. and Lee, B. (2003). "Antecedents of injury among youth in agricultural settings: A longitudinal examination of safety consciousness, dangerous risk taking, and safety knowledge". *Journal of Safety Research,* 34: 227 – 240.

Westman, M. and Eden, D. (1997). "Effects of respite from work on burnout: Vacation relief and fade-out". *Journal of Applied Psychology*, 82, 516–527.

Whyte, A. and Carroll, L. (2002). "A preliminary examination of the relationship between employment, pain and disability in an amputee population". *Disability and Rehabilitation*, 24:462–470.

Wickens, C., Hollands, J., Banbury, S. and Parasuraman, R. (2013). Engineering psychology and human performance. Routledge, NY: Psychology Press.

Wilbers, A., Vennekoetter, A., Koster, M., Hamborg, K. and Kaspar, K. (2015). "Personality traits and eye movements: an eye-tracking and pupillometry study" *In Proceedings of the 18th European Conference on Eye Movements*.

Wilde, G. (1982). "The theory of risk homeostasis: Implications for safety and health". *Risk Analysis*, 2(4): 209–225.

Wilks, S. (1932). "Certain generalizations in the analysis of variance". *Biometrika*, 24:471–494.

Wilks, S. (1935). “On the independence of k sets of normally distributed statistical variables”. *Econometrika,* 3:309–326.

Williams, O. (2017). “Analysis of Fatal Building Construction Accidents: Cases and Causes”. *Journal of Multidisciplinary Engineering Science and Technology,* 4(8): 8030-8040.

Winn, G., Seaman, B. and Baldwin, J. (2004). “Fall Protection Incentives in the Construction Industry: Literature Review and Field Study”. *International Journal of Occupational Safety and Ergonomics*, 10(1): 5-11.

Wittbrodt, N., Gross, A. and Thüring, M. (2010). “Challenges for the communication environment and communication concept for remote airport traffic control centers”. *IFAC Proc,* 43(13): 129–134.

Wolff, H. and Kim, S. (2012). “The relationship between networking behaviors and the Big Five personality dimensions”. *Career Development International,* 17(1): 43-66.

Wong, T., Man, S. and Chan, A. (2020). “Critical factors for the use or non-use of personal protective equipment amongst construction workers”. *Safety Science,* 126: 1-12.

Woodman, G. and Chun, M. (2006). “The role of working memory and long-term memory in visual search”. *Visual Cognition,* 14: 808-830.

Woodman, G. and Luck, S. (2004). “Visual search is slowed when visuospatial working memory is occupied”. *Psychonomic Bulletin & Review,* 11(2): 269-274.

Woodman, G., Vogel, E. and Luck, S. (2001). “Visual Search Remains Efficient when Visual Working Memory is Full”. *American Psychological Society,* 12(3): 219-224.

Xia, N., Xie, Q., Hu, X., Wang, X. and Meng, H. (2020). “A dual perspective on risk perception and its effect on safety behavior: A moderated mediation model of safety motivation, and supervisor’s and coworkers’ safety climate”. *Accident Analysis and Prevention* 134: 1-12.

Xia, N., Tang, Y., Li, D. and Pan, A. (2021). “Safety Behavior among Construction Workers: Influences of Personality and Leadership”. *Journal of Construction Engineering and Management*, 147(4): 1-11.

Xu, Q., Chong, H. and Liao, P. (2019). “Exploring eye-tracking searching strategies for construction hazard recognition in a laboratory scene”. *Safety Science,* 120: 824-832.

Xu, X., Le, N., He, Y. and Yao, X. (2020). “Team Conscientiousness, Team Safety Climate, and Individual Safety Performance: a Cross-Level Mediation Model”. *Journal of Business and Psychology,* 35:503–517.

Yang, K., Aria, S., Ahn, C. and Stentz, T. (2014). “Automated Detection of Near-miss Fall Incidents in Iron Workers Using Inertial Measurement Units”. *Construction Research Congress*, pp. 935-944.

Zampogna, A., Mileti, I., Palermo, E., Celletti, C., Paoloni, M., Manoni, A., Mazzetta, I., Costa, G., Pérez-López, C. and Camerota, F. (2020). “Fifteen years of wireless sensors for balance assessment in neurological disorders”. Sensors, 20: 3247-3255.

Zhang, Z., Zyphur, M. and Preacher, K. (2009). “Testing Multilevel Mediation Using Hierarchical Linear Models Problems and Solutions”. *Organizational Research Methods*, 12(4): 695-719.

Zhang, M., Murphy, L., Fang, D. and Caban-Martinez, A. (2015). “Influence of fatigue on construction workers’ physical and cognitive function”. *Occupational Medicine*, 65(3): 245–250.

Zhang, J., Xiang, P., Zhang, R., Chen, D. and Ren, Y. (2020). “Mediating Effect of Risk Propensity between Personality Traits and Unsafe Behavioral Intention of Construction Workers”. *Journal of Construction Engineering and Management*, 146(4): 1-12.

Zhao, H. and Seibert, S. (2006). “The Big Five personality dimensions and entrepreneurial status: A meta-analytical review.” *Journal of Applied Psychology*, 91(2): 259–271.

Zhao, F., Schnotz, W., Wagner, I. and Gaschler, R. (2014). “Eye Tracking Indicators of Reading Approaches in Text-Picture Comprehension”. *Frontline Learning Research*, 6: 46-66.

Zickerick, B., Thönes, S., Kobald, O., Wascher, E., Schneider, D. and Küper, K. (2020). “Differential Effects of Interruptions and Distractions on Working Memory Processes in an ERP Study”. *Frontiers in Human Neuroscience*, 14(84): 1-13.

Zitzmann, S. and Helm, C. (2021). “ Multilevel Analysis of Mediation, Moderation, and Nonlinear Effects in Small Samples, Using Expected a Posteriori Estimates of Factor Scores”. *Structural Equation Modeling: A Multidisciplinary Journal,* 28(4): 529–546.

Ziv, G. (2016). “Gaze Behavior and Visual Attention: A Review of Eye Tracking Studies in Aviation”. *The International Journal of Aviation Psychology*, 26(3-4): 75-104.

Zuckerman, M. (2007). “The sensation seeking scale V (SSS-V): Still reliable and valid”. *Personality Individual Differences,* 43(5): 1303–1305.

Zitzmann, S. and Helm, C. (2021). “ Multilevel Analysis of Mediation, Moderation, and Nonlinear Effects in Small Samples, Using Expected a Posteriori Estimates of Factor Scores”. *Structural Equation Modeling: A Multidisciplinary Journal,*28(4): 529–546.

BIOGRAPHY

Olugbemi Aroke earned her Bachelor of Science degree in Quantity Surveying in 2009 and a Master of Science degree in Construction Management in 2014 both from the University of Lagos, Nigeria. She gained admission to George Mason University in 2018 as a PhD student in Civil Engineering with a focus in Construction Engineering and Management under the advisorship of Dr. Behzad Esmaeili. During her 4-year study, she actively conducted industry-driven research in the field of construction safety, specializing in injury prevention strategies, hazard identification, and risk management using a variety of qualitative and quantitative data mining methods and experimental techniques.

Olugbemi has worked for Design-Build and Project Management firms as a cost estimator and project engineer, and recently joined AECOM, an American multinational engineering firm as a Project Control Analyst. She is a CMAA-certified Construction Manager-in-Training and a member of a number of professional and student organizations, including the American Society of Civil Engineers (ASCE), Construction Management Association of America (CMAA) and Design-Build Institute of America (DBIA).

Ms. Aroke was very involved in University activities, most notably as the Civil Engineering representative of the Graduate and Professional Student Association (GAPSA) and as a facilitator of the Civil Engineering STEM camp for middle and high school students at George Mason University. She is a recipient of several awards, including the Best Teaching Assistant of the Year 2019, the Construction Management Association of America (CMAA) National Capital Chapter Fellowship, and the distinguished Michael J. Casey Endowed Scholarship from the Department of Civil, Infrastructure and Environmental Engineering, George Mason University.