Using Worker Characteristics, Personality, and Attentional Distribution to Predict Hazard Identification Performance: A Moderated Mediation Analysis

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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 visual attentional indicators. Through an integrated moderated mediation model, the attentional distribution, search strategy, and hazard-identification performance of participants were examined across 115 fall hazards. Results indicate that individuals with more work experience and safety training were better at hazard identification independent of visual attention and regardless of personality. Furthermore, individual differences in conscientiousness and openness personality dimensions significantly moderated the associations between (1) worker characteristics and visual attention; and (2) 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 and design personalized intervention strategies to improve the hazard-identification skills of workers. **DOI: 10.1061/(ASCE)CO.1943-7862.0002295.** © *2022 American Society of Civil Engineers.*

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, accidents are consistently reported in thousands for permanent disabilities, injuries, deaths, and heavy losses (Wallace and Vodanovich 2003; Alexander et al. 2017; Hinze et al. 2013; Chan et al. 2018). 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. 2017a). 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 and de la Garza 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 and de la Garza (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 increase. 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 et al. (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 et 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

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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. 2017c). 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). Because 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; 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 on 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 in this paper 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.

Background

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. 2017a). 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.

Work Experience

The concept of familiarity and perception of hazards suggests that work experience is negatively correlated with work injury (Maiti 2007). Conversely, inexperience 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. (2017a) 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 toward 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 safety 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.

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 et al. (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 et al. (2017c) showed that the basic safety training [i.e., Occupational Safety and Health Administration (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. 2017c). 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.

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 impact 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 (2003) 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. (2017a) 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.

Big Five Personality Traits and Safety Performance

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 et al. (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.

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 et al. (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). Because 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). Because 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 and 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).

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 is 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 toward objects of interest and suppressing focus from other distracting elements aids effective processing—and detection—of potentially hazardous situations (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). Because visual acuity is suppressed during saccades—with very little visual processing taking place—perception mostly occurs during fixations, making them a critical metric for measuring attention and cognitive processes (Salvucci and Goldberg 2000). Additionally, eye movements reflect information processing and are useful when assessing attention during a 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 offers a reliable approach for tracking workers' focus of attention (Fang and Cho 2015; Hasanzadeh et al. 2017a, b, c, 2018, 2019; Aroke et al. 2020; Liko et al. 2019). An essential 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.

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 multicomponent 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 a 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 tracking) 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:

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 2003; Hasanzadeh et al. 2017b; Aroke et al. 2020), previous research has generally overlooked the questions of *how* worker 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).

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.

Data Collection

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. The sample size of 51 employed in this study is in keeping with other methodologies in the body of knowledge as previous studies have utilized a range of 12 (e.g., Li et al. 2019) to 47 (e.g., Xu et al. 2019) participants for their eye-tracking experiments. 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 (46%), 1–5 years (24%), and more than 5 years (29%). A total of 45% of recruited workers had received the Occupational Safety and Health Administration 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 5 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 injury on the job. All participants had normal or corrected-to-normal vision. All research procedures were approved by the Institutional Review Board (IRB) of George Mason University.

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; Fabian 2021), the current study focused on fall hazards.

Areas of interest (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 10 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. 1), which tracks eye-movement patterns in real time using corneal reflections and pupil tracking at a rate of 500 Hz. 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 cm from the computer screen on which they observed scenario images. Thresholds for detecting the onset of saccadic movements were accelerations of $8{,}000°/s^2$, 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 previous studies (e.g., Hasanzadeh et al. 2017a, 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.

Images appeared for 20 s, 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 min for each participant to complete the entire experiment.

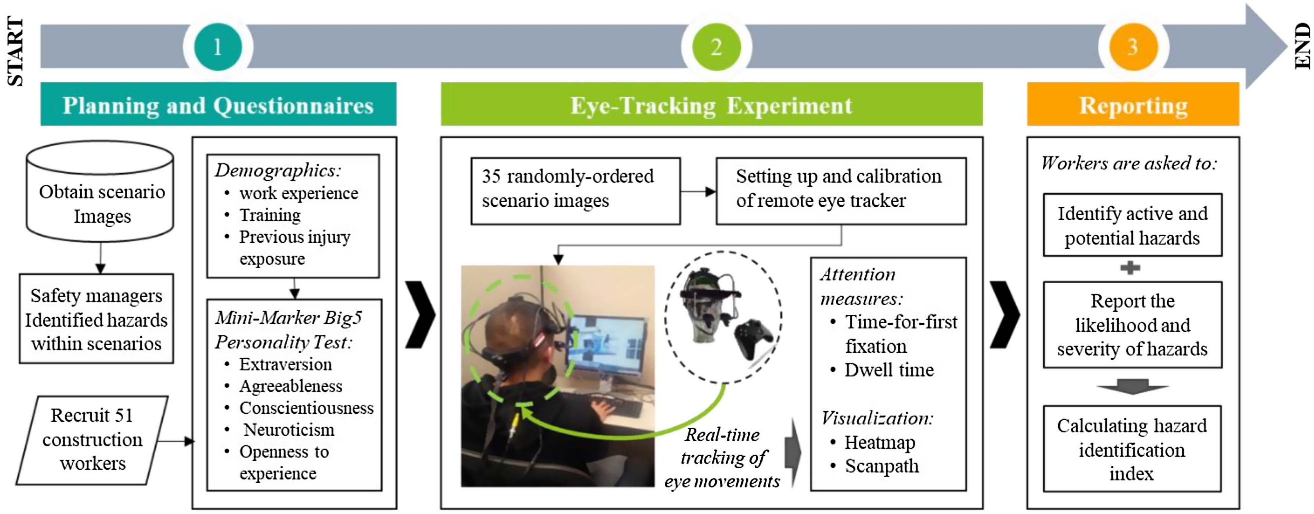

Fig. 1. Data collection procedure.

Data Analysis

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).

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; and (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 (Fig. 3)].

Measures

Predictor Variables: Worker Characteristics. The independent or predictor variables were worker characteristics including work experience, safety training, and previous injury exposure. Work experience ranged from "no experience" to "highly experienced," while injury exposure was categorized based on whether participants had never been injured or possessed work-related injury experience. Training was classified according to whether participants had received no training, informal onsite training, or the formal OSHA 10-h/30-h training.

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

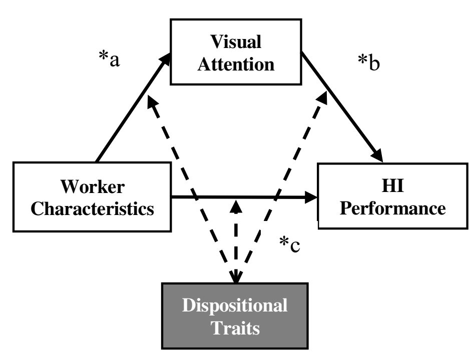

Fig. 2. A moderated mediation model showing personality traits as moderators in the association between worker characteristics, visual attention, and hazard identification.

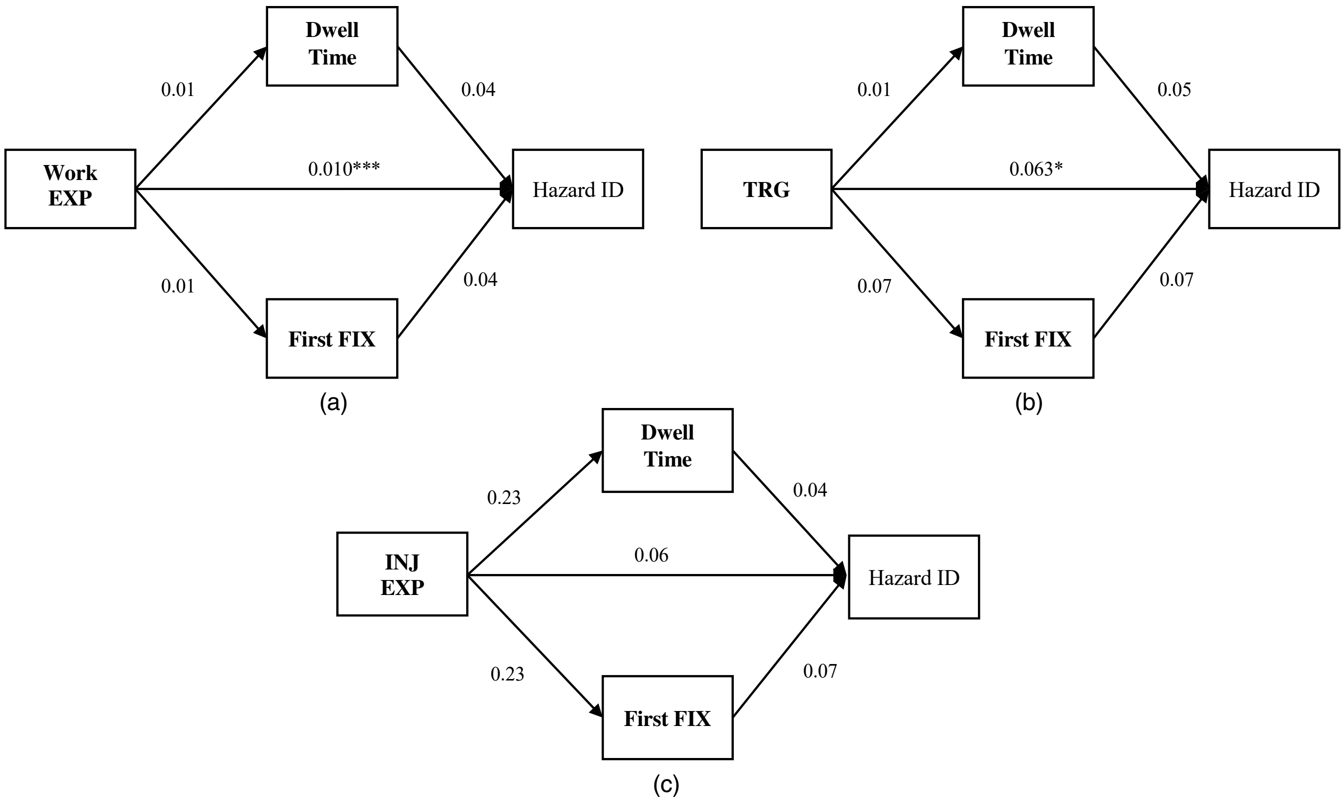

Fig. 3. Unstandardized estimates of model paths demonstrating effects of worker characteristics and visual attention on hazard-identification performance (*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$).

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

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

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.

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 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 1 (very inaccurate) to 7 (very accurate). Personality scores for each dimension were 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.

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 (CI) 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 $p < 0.10$ but discuss them as trending toward significance and emphasize the need for replication in future research.

The multicollinearity, reliability, and correlation among the five personality traits were examined to ensure the fitness of the variables for inclusion in the study. Multicollinearity 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 multicollinearity, 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.

Results

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 10-h/30-h training (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 ($r = 0.324$, $p = 0.038$).

Mediation Model

As detailed previously, 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 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.

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.

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 series of moderated mediation models were examined (Fig. 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 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.

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 ($p < 0.10$) 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 ($B = 0.011$,

Table 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				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				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				0.018	−0.008	0.063

Note: First fixation = time to first fixation; L-CI = lower confidence interval; and U-CI = upper confidence interval. *$p < 0.05$; **$p < 0.01$; and ***$p < 0.001$.

Table 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		

Note: TTTF = time-to-first-fixation; L-CI = lower confidence interval; and U-CI = upper confidence interval. Interactions: Int_1 = predictor X moderator; Int_2 = dwell time X moderator; and Int_3 = TTFF X moderator. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$; and $^{****}p < 0.001$.

$p = 0.021$), 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 $p < 0.10$). 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.

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 ($B = 0.160$, $p = 0.010$) levels of conscientiousness, and there was a trend ($p < 0.10$) toward a significant conditional effect at high levels of conscientiousness ($B = 0.304$, $p = 0.062$).

Injury Exposure

Conscientiousness moderated one of the "*a* paths" from predictor—injury exposure—to mediator (time-to-first-fixation), as there was a trend ($p < 0.10$) 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 personality dimension, 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 ($p < 0.10$) 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.

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).

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 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, 2019; Aroke et al. 2020; Liko et al. 2019). 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).

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 10-h 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 individuals tend low in this trait 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).

Conversely, 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 in identifying 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

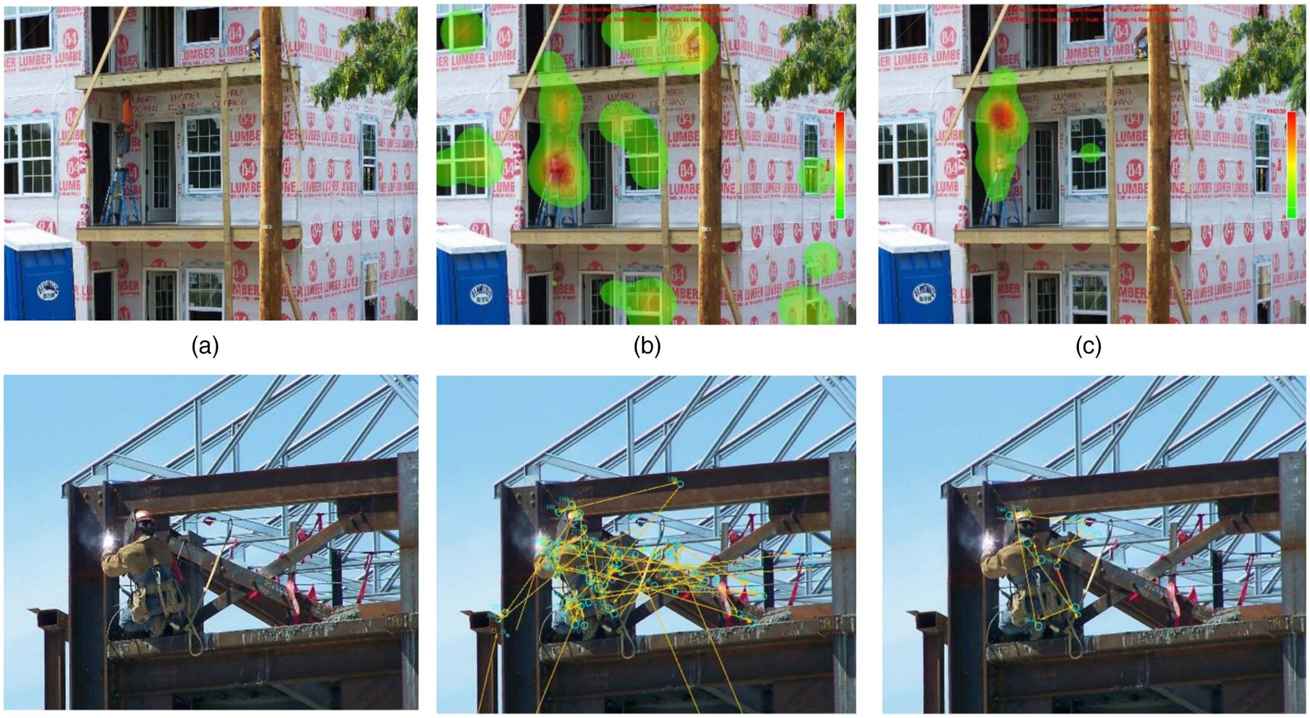

Fig. 4. Attentional distributions (heat maps): (a) original picture; (b) attentional distribution of an experienced, highly conscientious worker; (c) attentional distribution of an experienced, less conscientious worker; (d) original picture; (e) search strategy of an experienced, highly conscientious worker who had received safety training; and (f) search strategy of a less conscientious worker who had received safety training. (Images courtesy of David Ausmus.)

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. 4).

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 and McCrea 1992). These individuals may be unwilling to deviate from the status quo, but comfortable with following routines and procedures 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 involvement.

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 that 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 under *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; Gao 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 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 McCrea 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 noncontrolled environment.

Fig. 5 demonstrates the differences in the attentional allocation of previously injured workers: A worker who scored high in the openness to experience trait distributed their attention across the scene in a balanced manner to assess all potentially hazardous areas and, as a result, achieved a higher hazard-identification performance.

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 psychographic differences play in their safety performance when exposed to risks on 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 design 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. Second, the current study only considered workers' dominant personalities. However, due to the possibility that some individuals may possess a combination of personality dimensions (e.g., a worker may be highly conscientious and agreeable), future studies may consider traits in conjunction with one another in order to investigate how these interactions may influence a worker's safe behavior. Third, 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. Fourth, it is noteworthy to state some challenges associated with conducting a moderated mediation analysis. There were statistically significant interactions between worker characteristics and the personality moderators in several instances. However, the conditional effects of the predictor (worker characteristics) on the outcome (hazard identification) did not significantly vary at low, medium, and high values of the moderator (due to a

(a) (b) (c)

Fig. 5. Attentional distributions (heat maps): (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. (Images courtesy of David Ausmus.)

p-value less than 0.05 or a confidence interval that straddled zero). In other cases, the direct effect of worker characteristic variables on hazard identification presented highly statistically significant values across all levels of a moderator. Still, the absence of a statistically significant interaction between the predictor and moderator variables brought about an overall interpretation of statistical invariability across all moderator levels and a rejection of the null hypotheses. Thus, the interpretation of a conditional effect of a predictor on an outcome as contingent on statistical interaction may affect moderated mediation efforts, especially with a modest sample size.

Conclusions

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 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 strategies 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 impact of worker characteristics (work experience, training, and injury exposure) on 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 of ways future construction management studies may harness multidimensional factors when assessing the effect of different demographic and psychographic traits in construction-safety discussions.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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