Role of Personality in Construction Safety: Investigating the Relationships between Personality, Attentional Failure, and Hazard Identification under Fall-Hazard Conditions

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Abstract: Workers' attentional failures or inattention toward detecting a hazard can lead to inappropriate decisions and unsafe behaviors. Previous research has shown that individual characteristics such as past injury exposure contribute greatly to skill-based (e.g., attention failure) and perception-based (e.g., failure to identify and misperception) errors and subsequent accident involvement. However, a dearth of research empirically examined how a worker's personality affects his or her attention and hazard identification. This study addresses this knowledge gap by exploring the impacts of the personality dimensions on the selective attention of workers exposed to fall hazards. To this end, construction workers were recruited to engage in a laboratory eye-tracking experiment that consisted of 115 potential and active fall scenarios in 35 construction images captured from actual projects within the United States. Construction workers' personalities were assessed through the self-completion of the Big Five personality questionnaire, and their visual attention was monitored continuously using a wearable eye-tracking apparatus. The results of the study show that workers' personality dimensions—specifically, extraversion, conscientiousness, and openness to experience—significantly relate to and impact attentional allocations and the search strategies of workers exposed to fall hazards. A more detailed investigation of this connection showed that individuals who are introverted, more conscientious, or more open to experience are less prone to injury and return their attention more frequently to hazardous areas. This study is the first attempt to illustrate how examining relationships among personality, attention, and hazard identification can reveal opportunities for the early detection of at-risk workers who are more likely to be involved in accidents. A better understanding of these connections provides valuable insight into both practice and theory regarding the transformation of current training and educational practices by providing appropriate intervention strategies for personalized safety guidelines and effective training materials to transform personality-driven at-risk workers into safer workers.
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Introduction

Each year, the construction industry accounts for a disproportionate number of fatalities, lost work hours, and high injury rates (Esmaeili and Hallowell 2012). The majority of accidents in this sector are caused by workers' human errors, which lead to unsafe actions in high-risk environments (e.g., Beus et al. 2015). Concurrently, previous studies demonstrated that workers' individual characteristics are one of the causal factors of their unsafe behaviors (e.g., Garrett and Teizer 2009; Hasanzadeh et al. 2017a) and, among individual characteristics, personality traits have been identified as a significant factor that influences safety behaviors (Cellar et al. 2001; Sing et al. 2014). Because personality is likely to manifest in the decisions and behaviors of workers, personality traits have been considered one of the predictors of workplace accidents (Kaplan and Tetrick 2011).

Establishing a link between certain personality traits and accident involvement has been an attractive idea for decades because such a link would enable organizations to screen applicants based on their likely safety behaviors, assign workers to appropriate tasks to minimize the risk of accidents (Clarke and Robertson 2005), and/or develop personalized safety training for at-risk workers to improve their hazard identification skill (Hasanzadeh et al. 2017d). Previous studies have acknowledged the relative importance of personality differences in the involvement of workers in occupational accidents (Clarke and Robertson 2005; Sing et al. 2014). For instance, meta-analyses conducted by Clarke and Robertson (2005) demonstrated a negative correlation among emotional stability, agreeableness, and conscientiousness as it relates to workplace accident involvement. Additionally, recent studies have suggested that the relationship between personality and accident involvement may be mediated by failures in cognitive processes, such as poor selective attention or distractibility (Fig. 1). Another potential mechanism connecting personality with attention resides in affective states because affective states influence the items to which an individual attends in a scene and for how long (Hahn et al. 2015). Although such relationships present opportunities for better linking personality with accidents, lingering uncertainties

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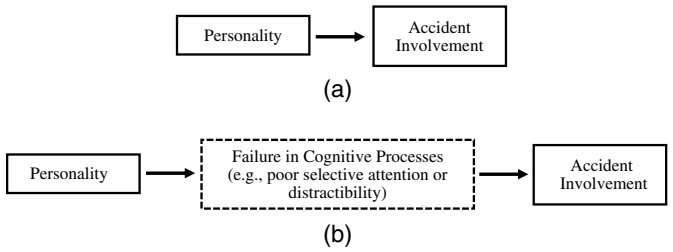

Fig. 1. Relationships between personality, failure in cognitive processes, and accident involvement: (a) traditional approach; and (b) alternative approach.

about the personality elements that best predict the at-risk behaviors that have been considerably understudied.

Historically, the absence of a reliable method for measuring attention has meant that few studies have been able to explore the interactions between personality and cognitive processes to predict the human errors that lead to accident involvements. Recently, however, researchers have started to use eye-tracking technologies to overcome this challenge. Eye tracking is widely accepted as the most direct and continuous measure of attention, given that where one looks is highly correlated with where one focuses attention (Hoffman and Subramaniam 1995). Because visual cues have a direct impact on attentional allocation, detecting eye-movement patterns provides insight into the allocation of attention. Consequently, researchers have begun to apply eye-tracking technologies to the study of individual characteristics to identify the characteristics that negatively impact attention and increase the likelihood of accidents within the construction industry (e.g., Hasanzadeh et al. 2017a, b).

Although the impact of personality-relevant behaviors has been studied in relation to eye movements and gaze patterns outside of the construction-safety sector (e.g., Cellar et al. 2001; Sing et al. 2014), the extent to which construction workers' personality impacts their attentional processes remains an empirical question. To address this important knowledge gap, this study builds on previous studies' outcomes (Hasanzadeh et al. 2017a, b) to determine the relationships between personality dimensions (specifically, the Big Five personality traits) and the attention and hazard identification skills of construction workers when exposed to fall hazards. The outcomes of this study will help determine the extent to which personality dimensions influence workers' attention to subsequently develop reliable leading indicators of human error. The results of this study will also provide a scientific basis for developing safety solutions and personalized training materials that adjust to workers' unique experiences and personality backgrounds. Foreseeably, the present research will better enable managers to prioritize safer construction outcomes when pairing workers with activities. Furthermore, given that the outcomes of this research will cross-validate eye-tracking metrics with personality dimensions, the findings of this study will reduce the need for eye-tracking technologies at construction sites.

Literature Review

To better understand the role of attention and personality in accident occurrence, this study conducted a comprehensive literature review regarding attention and construction safety, the theory of personality, methods for measuring personality dimensions, the role of personality in accident involvement, and how personality relates to attention.

Measuring Attention by Monitoring Eye Movements

In general, understanding and using information is highly related to many cognitive processes, including attention, perception, memory, language, imagination, and decision making (Anderson 2005). Considering that cognitive processes influence the pieces of information to attend to and those to ignore, understanding these processes is key to understanding and assessing behavior. Additionally, cognitive processes have been found to play a significant role in contributing to the human errors that lead to construction accidents. Thus, a better understanding of cognitive processes—especially those impacted by personality—as they relate to construction helps one identify the more predictable varieties of human fallibility and allows for the creation of strategies to avoid such errors.

One important element of cognitive processes is attention. Because humans are finite beings, their capacity for information processing is limited, which influences their attentional abilities. Moreover, emotional arousal, task difficulty, and an observer's interest/motivation related to a task can significantly affect the capacity of mental resources and attentional abilities, among a host of other factors (Duchowski 2007).

A growing number of psychological and neuropsychological studies have demonstrated a close relationship between attention and eye movements (e.g., Sun et al. 2008). The simple assumption in most attention studies employing eye-tracking is that by tracking someone's eye movements, the observer's general path of attention can be followed because visual attention is often correlated with cognitive processing. These studies tend to have two measurements of interest: fixations and saccades. Visual information obtains input from fixation points (a relatively stationary eye position of 100–200 milliseconds), whereas saccades move the eye to each fixation location. Because visual information processing is suppressed during saccades, most eye-tracking studies rely on fixation-derived metrics when the critical question of interest is where individuals are looking and for how long. Thus, by tracking eye movements, researchers can identify both what simply drew the observer's attention and what fully captured their attention, which in turn provides clues about how the person perceived the scene. Such insights help reveal perhaps one of the most important functions of attention: how attention guides fixations toward events that are relevant to ongoing behavior (Duchowski 2007).

In a recent study applying eye tracking to a construction worker's attention, Hasanzadeh et al. (2017a) found that the attentional allocation and hazard identification performance of construction workers can be predicted by tracking their fixation-derived eye-movement metrics. They showed that if workers attend to and identify a hazard, at least one of these two influential metrics changes: fixation count (the average number of times that each subject fixated his or her attention to a specific area within the scene (an area of interest, or AOI) and run count (the average number of times that each participant returned his or her attention to an AOI). For this reason, the present paper focuses on these two fixation-related metrics as precursors of worker safety hazard identification.

Visual Attention and Construction Safety

In the realm of construction safety research, attention is important because identifying hazardous situations is a complex and multidimensional cognitive process that requires the proper allocation of a workers' attention. As a result, eye tracking has been flourishing in studies related to construction safety (e.g., Dzeng et al. 2016; Hasanzadeh et al. 2016, 2017a, 2018a, b) because this tool serves as the most direct method for studying the attention of construction workers. Dzeng et al. (2016) used a set of virtual images in an eye-tracking experiment to study the impact of work experience on

worker attention. The results of their study showed that more experienced workers spent less processing time than less experienced workers and were more confident in identifying hazards.

To understand how safety knowledge—especially training, working experience, and injury exposure—influences construction workers' attentional allocation Hasanzadeh et al. (2017a) designed an eye-tracking experiment in which participants identified safety hazards presented in 35 construction site images that were ordered randomly, each of which showed multiple hazards with varying safety risk. The authors found that obtaining sufficient safety knowledge on a job site and improving safety awareness require the interaction of both tacit and explicit knowledge gained through work experience, injury exposure, and interactive safety training.

In a follow-up study, Hasanzadeh et al. (2017b) divided workers into three groups based on their hazard-identification performance to evaluate the impacts of workers' hazard-identification skills on their attentional distributions and visual search strategies. The results of the multivariate analysis of variance (MANOVA) and discriminant function analyses indicated that hazard-identification skills significantly impact workers' visual search strategies: workers with higher hazard-identification skills had lower dwell-time percentages, higher fixation counts, and higher run counts on hazardous areas within construction-scenario images. This study provided a proof-of-concept that certain eye movements metrics are predictive indicators of human error due to attentional failure.

Hasanzadeh et al. (2017b, d) also used eye-movement measures to determine the types of hazards that construction workers miss, ignore, or perceive to be insignificant. They found that differences in participants' attentional distributions and the hazard identification of workers with low and high hazard-identification skills stem from hazard type—not the number of hazards—within the scenarios. Further investigation of specific images revealed that at-risk workers dwelt on imminent danger (e.g., workers in dangerous areas) rather than spreading their attentional efforts to search for sources of nonobvious hazards, including electrical hazards, housekeeping hazards, and fall-protection-system-related hazards. The results of this experiment supported personalized safety training that targets at-risk workers.

More recently, Hasanzadeh et al. (2017c) expanded the application of eye-movement metrics to examine how working-memory load impacts a worker's attentional allocation and the detection of potential hazards in construction. Working memory (also known as short-term memory) refers to the mental workspace that offers limited capacity for maintaining information for short durations (Hitch and Baddeley 2017; Gevins et al. 1998). They conducted an eye-tracking experiment in which the working-memory load was manipulated. Participants received either high or low working-memory loads (digit strings that were either three or six digits in length) and then were asked to search for hazards in a scene as their visual attention was monitored continuously. The results demonstrated that, as working-memory load increases, the ability of participants to identify hazards decreases—workers under high-load conditions were approximately four times more likely to miss fall hazards than workers under low-memory load conditions. In addition, the results demonstrated that a significant difference exists among the visual search strategies of people under different working-memory loads. This work provided a proof-of-concept that eye movements can be used as indicators of variation in working-memory load among construction workers, which in turn offers opportunities for examining workers' ability to not only remain focused on a task in which they are engaged but also remain situationally aware of the surrounding construction environment. However, lingering unknowns about how personality characteristics mediate hazard-identification skills leave room for better targeting training for at-risk or inattentive workers to prevent construction workplace accidents; this paper attempts to address this limitation.

Big Five Personality Traits and Measurement

The most common definition of personality was introduced by Allport (1937): "Personality is the dynamic organization within the individual of those psychological systems that determine his characteristic behavior and thoughts" (Allport 1937, p. 28, cited in Hjelle and Ziegler 1976, p. 174). Considering that understanding personality is essential for explaining and predicting human behavior (Hjelle and Ziegler 1976), numerous studies have been conducted in the field of psychology to discover the nature and traits of human personality (e.g., Wiggins 1996; Pervin and John 1999; Azucar et al. 2018; Di Fabio and Saklofske 2018).

One of the most prevalent personality assessments is the Big Five personality traits model, which conducts a factor analysis on self- or peer-rated personality-relevant terms or adjectives extracted from the dictionary. The results show uncorrelated dimensions that can be used to discriminate personal traits. Replicated by several independent studies (e.g., Norman 1963; Borgatta 1964), this five-factor structure includes: (1) extraversion or surgency (talkative, assertive, energetic); (2) agreeableness (good-natured, cooperative, trustful); (3) conscientiousness (orderly, responsible, dependable); (4) emotional stability or neuroticism (calm, not neurotic, not easily upset); and (5) culture or openness (intellectual, polished, independent-minded).

One of the most reliable methods for measuring personality dimensions was developed by Goldberg (1992), who gathered a large number of terms to describe a human being and conducted a series of factor-analytic studies to develop and refine the set of 100 unipolar trait-descriptive adjectives. By selecting only adjectives that uniquely defined each factor, Goldberg (1992) indexed each of the five factors using a 20-item scale that had high internal consistency. The 100 adjectives reproduced the expected five-factor structure with extraordinary robustness and provided a standard representation for other studies (Saucier 1994). Goldberg (1992) also indicated that relatively small sets of variables could serve as markers of the Big Five structure and that even briefer marker sets might be advantageous under certain assessment conditions.

To address the need for a short instrument that measures the prototypical components of the Big Five, Saucier (1994) introduced a selection of only 40 adjectives based on Goldberg's research. The Mini-Marker subset developed by Saucier (1994) consists of fewer uses of difficult items, lower alpha reliabilities and inter-scale correlations, and higher mean inter-item correlations. Beneficially, Saucier's 40-item inventory can be completed by most subjects in a short time and can be expected to produce reasonable Big Five factors, even in rather small samples. In a similar study and with the goal of identifying components that are common across investigators, the Big Five Inventory (BFI) was constructed (John and Srivastava 1999). The 44-item BFI was developed to represent the Big Five prototype definitions.

The effort to provide simpler methods to measure the personality traits continued and very brief five- and 10-item inventories were developed and evaluated (Gosling et al. 2003). The rationale for developing very brief inventories was to provide short measures of the personality dimensions when time is limited or brevity is a high priority. Although somewhat inferior to standard multi-item instruments, these truncated approaches can be useful in situations in which the personality assessment is not the main topic of interest, and the diminished psychometric properties associated with brief measures can be tolerated (Gosling et al. 2003).

In the context of this construction-safety study, although the 100-adjective markers developed by Goldberg (1992) provided a conventional five-factor structure with extraordinary robustness, the test is still lengthy and requires approximately 10–15 min for the subjects (Saucier 1994). For some research, teaching, and assessment purposes—including those involved in this study—the compounding of 10–15 min can lead to a significant load on the subject's time and patience. Moreover, conceivably, the fatigability or short attention span of some subjects could make very brief measures desirable even in single-target ratings. Alternatively, other very brief inventories [e.g., five- and 10-items by Gosling et al. (2003)] can address the issue of time, but they are inferior to standard multi-item instruments in terms of sufficiently measuring five personality traits. The set of 40 adjectives introduced by Saucier (1994) can address both concerns about measurement robustness and time constraints. This 40-item inventory can be completed by most subjects in approximately 5 min and can be expected to produce reasonable Big Five factors even in rather small samples. The availability of this short set of Big Five markers broadens the potential application for the Big Five to assessment situations in which brevity is still highly prioritized. As a result, the 40-item inventory developed by Saucier (1994) was selected as the instrument to measure the personality traits of construction workers in this study.

Relationship between Personality Traits and Accidents

Extraversion

No consensus exists in the literature on the relationship between extraversion and accident involvement. Some studies specifically related to traffic accidents have found that individuals who are highly extroverted are significantly more likely to be involved in accidents (Fine 1963; Smith and Kirkham 1981). Researchers who support a positive association between extraversion and accident involvement explain this relationship by focusing on the role of vigilance and sensation-seeking (i.e., excitement-seeking). Because extraverts have poorer performance under monotonous conditions (such as driving) or in vigilance tasks (Koelega 1992), they may not find themselves as invested in the task relative to more introverted individuals. Moreover, extraverts may be more likely to commit fatigue-related errors or get injured (Eysenck 1962). People who are highly extroverted also tend to be more adventurous and more likely to take risks, which may increase their likelihood of accidents (Golimbet et al. 2007). For example, Sutherland and Cooper (1991) found a positive relationship between extraversion and accident involvement in the offshore oil and gas industry. They explained this link by noting that extroverted individuals usually engage in more unsafe behaviors, such as alcohol consumption or cigarette smoking.

In contrast, some studies have found a negative relationship between extraversion and accident involvement (Pestonjee and Singh 1980; Henning et al. 2009). These studies have demonstrated that extroverted individuals frequently request more information or data to make decisions, which helps them become better decision makers and increases the level of awareness of their situation (Staw and Barsade 1993). To date, therefore, the findings relating extraversion to accident involvement have been mixed. Perhaps consequently, Clarke and Robertson (2005) conducted a meta-analysis of these topics and found very little evidence of a significant relationship between accidents and extraversion.

Agreeableness

The findings from the literature on the relationship between agreeableness and accident involvement are relatively consistent (Cellar et al. 2001; Clarke and Robertson 2005; Henning et al. 2009): individuals who score highly on agreeableness have better safety attitudes and are involved in fewer accidents. To explain this negative correlation, researchers have found that individuals with a high degree of agreeableness are characterized by cooperativeness, warmth, kindness, and/or sympathy (e.g., Goldberg 1992; Saucier 1994; Gosling et al. 2003). These people normally possess strong interpersonal skills and are highly involved in teamwork settings. Because of their cooperativeness, they can effectively collaborate with others to solve problems. In contrast, less-agreeable individuals may be belligerent, hostile, and aggressive, which can increase the likelihood that they will be involved in accidents (Roy and Choudhary 1985). These people are frequently involved in arguments that cause stress or emotional arousal, which can directly or indirectly increase the risk of accidents (Deffenbacher et al. 1994). The role of agreeableness is more apparent in activities that require cooperation and teamwork (Barrick and Mount 1991; Mount et al. 1998).

Conscientiousness

A highly conscientious individual is typically organized, responsible, systematic, dependable, practical, and goal oriented (Saucier 1994; John and Srivastava 1999; Gosling et al. 2003). Similar to the findings on agreeableness, the literature consistently supports a negative correlation between conscientiousness and accident involvement (Hansen 1989; Cellar et al. 2001; Bogg and Roberts 2004; Clarke and Robertson 2005; Postlethwaite et al. 2009; Henning et al. 2009). In an attempt to justify that conscientious individuals are less likely to get involved in accidents, Bogg and Roberts (2004) noted that conscientious people are better at taking care of themselves and engage in fewer risky behaviors, such as drinking, smoking, and drugs, or risky activities that increase the likelihood of accidents at work. Similarly, Clarke and Robertson (2005) have argued that unconscientious individuals who are careless, unreliable, easily distracted, disorganized, or sloppy usually fail to follow the rules and regulations at work, which consequently may lead to a high rate of accidents. More importantly, evidence exists that unconscientious individuals are more susceptible to cognitive failures, which can increase the likelihood of an accident (Wallace and Vodanovich 2003).

Neuroticism

Neurotic people (low score on emotional stability) are described as nervous, anxious, temperamental, and depressed (Goldberg 1992; Saucier 1994; Gosling et al. 2003). Most scholars agree that neuroticism is positively correlated with the likelihood of being involved in occupational accidents (Eysenck 1970; Hansen 1989; Sing et al. 2014). Sing et al. (2014) analyzed the correlation of neuroticism to accident involvement in the construction sector and observed that neuroticism was highly correlated to both the degree of injury and the number of recorded injuries. A high degree of neuroticism is a main factor in distractibility, and people who score high on neuroticism become nervous or distracted or lose their temper easily while performing a task (Sutherland and Cooper 1991). More importantly, neurotics typically have a harsh reaction to stressors such as anxiety and fatigue, which impairs their cognitive abilities such as reaction time and judgment, dramatically increasing the likelihood of human errors (Steffy et al. 1986). Notably, whereas several studies have confirmed a positive relationship between neuroticism and accident involvement, other studies have shown little or no relationship between those two variables (Cellar et al. 2001; Clarke and Robertson 2005).

Openness to Experience

The relationship between openness and safety has received little attention because it relates to accident involvement and little

consensus exists in the literature. Some studies found a positive relationship (e.g., Lardent 1991; Clarke and Robertson 2005; Robbins and Judge 2014), whereas others found a negative (e.g., Henning et al. 2009) or no relationship (e.g., Cellar et al. 2001). Individuals who score high in openness to experience are likely to be curious, creative, imaginative, and intellectual (Saucier 1994; John and Srivastava 1999). Researchers who have observed a positive correlation between openness and accidents have stated that highly open people are enthusiastic about coping with change and willing to take risks, which may increase the likelihood of accident involvement. Furthermore, people with a high degree of openness are more prone to rule violations, experimentation, and improvisation—all attributes that may increase risk during otherwise routine activities. In contrast, those with a low score on openness are generally good at focusing on the tasks on which they are working and are less likely to be involved in accidents. Studies that have found significant positive correlations between openness and safety attitudes have concluded that more openness is associated with better learning attitudes and training proficiency, making it easier to develop a well-trained workforce (Barrick and Mount 1991; Salgado 1997).

Visual Attention and Personality

The relationships between personality traits and gazing behavior have been demonstrated in the context of visual information processing (Perlman et al. 2009) and social gazing (Rauthmann et al. 2012). Specifically, Perlman et al. (2009) investigated relationships between visual scan paths in response to emotional facial expressions for people with different levels of neuroticism. In their experiment, participants' eye movements were recorded as they were free-viewing facial expressions, such as happy, angry, fearful, sad, surprised, disgusted, and neutral. Neuroticism was then measured using the Neo Five-factor Inventory (i.e., a measurement tool of the five domains of personality). Perlman et al. (2009) found that a positive correlation exists between neuroticism and the amount of time spent looking at the eyes of fearful faces—a stimulus that is congruent with neurotics' more negative personalities.

Rauthmann et al. (2012) investigated the impact of personality traits on eye-movement patterns independent of stimuli. To achieve their objective, Rauthmann et al. (2012) tracked participants' eye movements when viewing two animations with maximum contrasts in terms of color, forms, movements, and velocity. An analysis of the data using linear mixed modeling indicated that the signature of eye movements (i.e., the number of fixations, the mean duration of fixations, and the dwelling time) could be predicted by three personality traits: neuroticism, extraversion, and openness. These findings suggest that how and where people look is related to internal factors such as personality.

In another eye-tracking study, Wu et al. (2014) focused on the relationship between personality traits and social attention. In this study, social attention was measured in terms of the amount of time people were looking at the eye regions of others. During the experiments, eye movements were recorded as subjects freely viewed thirty images featuring human faces. The results of the study indicated that extraversion and agreeableness were related to longer average fixation durations and longer total time spent looking at the eye region while subjects' openness to experience was related to lower average fixation duration on the eye region. The findings of this study implied that personality traits' impact on attention is influenced by the social situations to which viewers are exposed (Wu et al. 2014).

Although all of these applications of the Big Five traits suggest that personality affects visual attention, questions remain regarding the ways that personality traits impact attentional distribution when workers are exposed to hazards. Accordingly, this paper will examine this concept through a laboratory experiment.

Points of Departure

Construction workers must distribute their attention properly to maintain situational awareness in a dynamic construction site. Improper allocation of attention may expose workers to a hazardous situation and increase their accident involvement. As previously discussed, research has shown that personality traits impact attention, which in turn affect individual behavior. Previous research has also demonstrated the impact of personality traits on attention measures, as observed in eye-tracking outcomes. However, ongoing gaps in knowledge remain regarding which of these factors best explains how workers—especially construction workers—distribute their limited attentional resources when exposed to hazards on the job site.

By harnessing eye-tracking technology to monitor workers' attention when searching for fall hazards in construction scenarios, this study investigates the role of personality dimensions on construction workers' cognitive processes (specifically, attentional allocation and search strategy). Additionally, this study controlled for other attentional factors (i.e., task parameters and environmental variables) in the laboratory to more thoroughly examine the role of personality (as an individual characteristic) on workers' attentional allocation in safety-centric tasks. Thus, to achieve this overarching objective, we examined the following null hypotheses.

- *Null hypothesis 1 (H_{01})*: No association exists between Big Five personality traits and workers' attentiveness (fixation count or run count) to fall hazards.
- *Null hypothesis 2 (H_{02})*: Workers' Big Five personality traits have no impact on their attentiveness (fixation count or run count) to fall hazards on a construction site.

These hypotheses were developed based on the previous work conducted and validated by Hasanzadeh et al. (2017b) wherein Hasanzadeh and her colleagues indicated that two fixation-related attention measures—fixation count and run count—can be used to examine workers' attentiveness to hazards. These hypotheses will be rejected if a personality trait demonstrates a relationship with or impact on one of the two fixation-derived attention measures.

Methodology

To test the research hypotheses, independent variables (i.e., personality dimensions) were collected by distributing the mini-marker Big Five questionnaire to identify the traits that describe the subject's personality and to what degree. The data for the dependent variables (fixation-derived attention measures) were then collected by conducting an eye-tracking experiment in the laboratory in which workers were asked to scan 35 randomly ordered construction-scenario images to identify potential and active-hazards; the images contained a sum of potential and active fall-hazard scenarios. The general procedure can be observed in Fig. 2. The data collection and analysis processes are described in subsequent sections.

Selection of Construction-Scenario Images

The research team down selected 35 images from a pool of 150 images obtained from the safety managers of the Construction Industry Institute (CII). These scenario images were taken from residential and commercial construction sites across the United States. The selected images were of high quality, and a total of

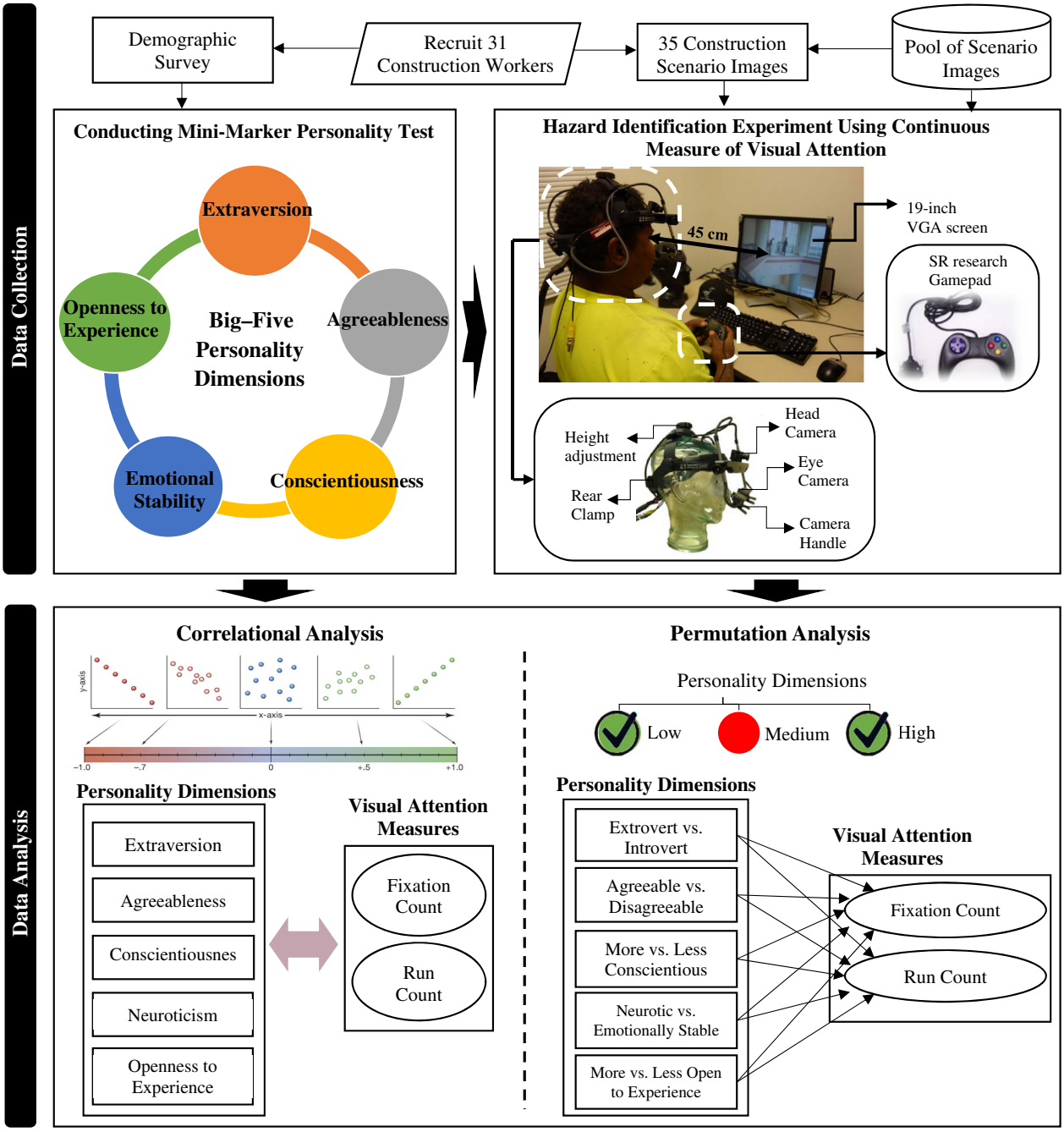

Fig. 2. Experimental procedure. Subjects participated in both the personality and hazard identification assessments, and each procedure's data were analyzed via their respective statistical treatments. (User image by authors; equipment images courtesy of EyeLink.)

115 potential and active fall-hazard scenarios ("areas of interest," or AOIs) were included in the images.

Participants

Construction workers at multiple construction sites in Lincoln and Omaha, Nebraska, were targeted as the potential subjects for the current study. Thirty-one construction workers were recruited for this study. All participants had normal or corrected-to-normal vision. Each participant filled out a Big Five questionnaire and a demographics survey related to past experience (Hasanzadeh et al. 2017a). Then, the subjects participated in an eye-tracking experiment that took approximately 30 min. Of the 31 participants, the data from three participants were excluded from the analysis because the researchers were unable to obtain satisfactory levels of calibration on the eye tracker. The resulting sample size of 28 participants was still sufficient for this experiment because studies on attention and eye movement behavior routinely utilize lower sample sizes compared with survey-style studies given the nature of the data: dozens of eye movements and fixations on each trial across a series of 35 trials. For studies on special populations to have commensurate sample sizes is quite common (e.g., Mogg et al. 2000; Perlman et al. 2009). Thus, the small sample size in eye-tracking studies is offset by adding considerably more trials and multiple observations on each trial. In this study, the number of subjects (28), the number of areas of interest (115), and the number of

trials (35) performed by each subject make this sample robust enough to conduct the eye-tracking study.

Participants were general laborers, 35.5% had fewer than five years of experience, 25.8% had between five and ten years of experience, and 38.7% had more than ten years of experience in the residential and commercial sectors of the construction industry. In terms of training, 60% of participants had received the Occupational Safety and Health Administration (OSHA) 10-h training and the remaining 40% had not received any formal safety training. A total of 69.9% of the participants reported that they had been exposed to an injury on the job site. All of the subjects who participated in this study were compensated with a gift card for their participation.

Big Five Personality Dimensions

Before conducting the eye-tracking experiment, the subjects were asked to fill out a demographic survey and personality assessment questionnaire. The Big Five personality dimensions were assessed using a 40-item mini-marker inventory (Saucier 1994). As previously described, Saucier (1994) introduced a selection of optimally robust and reliable measures of the subset of 40 adjectives based on the 100-adjective markers of Goldberg (1990). The Big Five personality questionnaire reflects a set of broad traits identified as follows:

- Extraversion (i.e., bashful, bold, energetic, extraverted, quiet, shy, talkative, withdrawn);
- Agreeableness (i.e., cold, cooperative, harsh, kind, rude, sympathetic, unsympathetic, warm);
- Conscientiousness (i.e., careless, disorganized, efficient, inefficient, organized, practical, sloppy, systematic);
- Neuroticism (i.e., envious, fretful, jealous, moody, relaxed, temperamental, touchy, unenvious); and
- Openness to experience (i.e., complex, creative, deep, imaginative, intellectual, philosophical, uncreative, unintellectual).

All participants completed the questionnaire and reported how accurately each trait describes themselves using a rating scale ranging from one (very inaccurate) to seven (very accurate). The scores indicated for "bashful," "quiet," "shy," "withdrawn," "cold," "harsh," "rude," "unsympathetic," "careless," "disorganized," "inefficient," "sloppy," "relaxed," "unenvious," "uncreative," and "unintellectual" were reversed, and then all 40 items were summed up for each personality dimension.

Eye-Tracking Experiment

Apparatus

The SR Research EyeLink II (manufactured by SR Research, Kanata, ON, Canada), with a high spatial resolution and a sampling rate of 500 Hz, was used to track and record participants' eye movements to determine where they attended. The EyeLink II uses cameras mounted on the headset to continuously monitor the path of a viewer's focus. Participants were seated approximately 45 centimeters (cm) from the computer screen on which they observed scenario images (Fig. 2).

Stimulus: Area of Interest

To extract eye-tracking metrics, an AOI—or an overlap or near-overlap of the stimulus (a hazardous situation) and the fixation points—needed to be defined. As previously mentioned, AOIs are visual environments of interest that the research team defined (Jacob and Karn 2003). To identify the AOIs, five safety managers reviewed the images to identify fall hazards in each scenario and to determine the hazards' associated risks. All safety managers had more than ten years of experience in residential and commercial buildings. In total, 115 fall-hazard AOIs were identified within the 35 scenario images, including fall to lower level (i.e., a worker is in the proximity of an unprotected edge, unguarded roof and floor openings, scaffolding, skylights); fall-protection systems (i.e., misuse of lanyard and other fall-protection systems); and ladder-related hazards (i.e., improper use of ladders, such as inappropriate type and length of ladder, unsecured straight ladders). The EyeLink Data Viewer Version 1.11.900 was used to map two-dimensional eye movement patterns of subjects to scenario scenes. Then, the eye movement data for each subject were linked to related fall-related AOIs to enable analysis.

Design and Procedure

Four examples of different scenario images are shown in Fig. 3.

The steps were as follows. First, the eye-tracking system was calibrated before each session. Then, participants were instructed that each image would appear on the screen for a maximum of 20 s, and they needed to identify potential and active hazards within the scene. The subjects' eyes were tracked throughout their viewing of the scenarios. Then, after viewing each scene, the subjects reported the number of identified hazards to the researcher. The screen would then change to reveal the next image. All procedures were approved by the University of Nebraska–Lincoln Institutional Review Board.

Statistical Analysis

Null Hypothesis 1 (H01): No Association Exists between Personality Traits and Workers' Attentiveness to Fall Hazards

To test the first hypothesis (H_{01}), the associations between a personality trait and workers' attentiveness were examined using correlation analysis. In this study, we used Kendall's tau, a nonparametric method that is more appropriate for investigating such associations because: (1) the data have one ordinal and one interval variable; (2) the data are non-normal; (3) it is less sensitive to outliers compared with Pearson's and Spearman's correlation coefficients; and (4) the data set has a large number of tied ranks—indicating that, after ranking, many scores will have the same rank. Therefore, the correlational analyses were performed using SPSS (Statistical Package for the Social Sciences) Version 22.0.

Null Hypothesis 2 (H02): Workers' Personality Traits Have No Impact on Their Attentiveness to Fall Hazards on a Construction Site

To test the second hypothesis (H_{02}) and further explore the difference in the attentional allocation of workers in terms of their personality traits, for each trait, subjects were divided into three groups based on the degree to which the subject demonstrated the personality trait: (1) below the 25th percentile equated to the "low" group; (2) between the 25th percentile and the 75th percentile served as "moderate"; and (3) higher than the 75th percentile was designated as "high." Then, the differences between the two extreme groups (low versus high) were examined using permutation Welch's t simulation. Permutation simulation was used for two main reasons. First, similar to many other behavioral studies, this study has some limitations regarding the number of subjects and non-random sampling from the population (Ludbrook 1994; LaFleur and Greevy 2009); thus, the permutation techniques can help overcome these limitations by reshuffling actual data using resampling without replacement to build large samples (e.g., 10,000 samples) from

Fig. 3. Examples of scenario images. (Images courtesy of David Ausmus.)

original data and obtain p-values based on created distributions (Adams and Anthony 1996; Anderson 2005). Second, the permutation techniques can provide higher power relative to nonparametric tests because it relies on using actual data rather than ranks (Ludbrook and Dudley 1998; Drummond and Vowler 2012). The deducer package in the Java Graphical User Interface (GUI) for R 1.7-9 of the open-source statistical package R Version R2.15.0 (R Development Core Team 2012) was used to perform permutation analysis. We set significant results at 0.05 (95% statistical significance) and 0.1 (90% moderately statistical significance) alpha levels, as subsequently discussed in greater detail.

Results and Findings

Descriptive statistics and Cronbach's alpha coefficients were calculated for all of the personality traits in the study before the analysis. Table 1 reports the number of items in the questionnaire, means, standard deviations, number of data points, and internal consistency (i.e., Cronbach alpha coefficients) for all personality traits. Because personality scales were collected using a Likert scale, the Cronbach alpha coefficient was used to evaluate the internal consistency of the personality traits. As Table 1 indicates, all Cronbach alpha values are greater than the suggested acceptable level (i.e., reliability coefficient of 0.70 or higher).

As previously mentioned, this study tested two main hypotheses regarding the associations between and the impact of personality traits and workers' attentiveness to fall hazards. Personality traits, which are extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience, are considered independent variables and two attention measures (i.e., fixation and run count) are considered dependent variables. The results of the statistical analysis for each hypothesis are described.

Table 1. Number of items, mean scores, and Cronbach alpha for all measures

Personality dimensions	Number of items	Cronbach's alpha	Mean	Standard deviation
Extraversion	8	0.78	40.22	7.52
Agreeableness	8	0.77	43.45	6.15
Conscientiousness	8	0.84	39.96	6.92
Neuroticism	8	0.72	37.68	7.77
Openness	8	0.76	41.07	7.45

Association between Personality Traits and Workers' Attentiveness

The results of Kendall's tau correlation analysis between the personality traits and measures of attention (i.e., eye-tracking metrics) are presented in Table 2. The results indicate that the null hypothesis, " no association exists between personality traits and workers' attentiveness to fall hazards," is only rejected for the extraversion and conscientiousness traits. Regarding the direction of the relationships, extraversion is negatively related to the number of fixations ($p = 0.060 < 0.1$) and the number of runs ($p = 0.016 < 0.05$); conscientiousness is positively correlated with the number of times fall hazards were visited by workers ($p = 0.018 < 0.05$).

Although the results of the correlational analyses demonstrate the direction of the relationship between some of the personality traits and various attention measures, they do not indicate how different levels of personality traits affect attention measures.

Table 2. Correlations between big five personality dimensions and workers' attention measures for 28 participants

Personality dimensions	Statistics	Fixation count	Run count
Extraversion	Correlation coefficient	−0.024***	−0.032**
	Significant	0.06	0.016
	N	3,104	3,104
Agreeableness	Correlation coefficient	−0.017	−0.016
	Significant	0.179	0.222
	N	3,104	3,104
Conscientiousness	Correlation coefficient	0.005	0.031**
	Significant	0.686	0.018
	N	3,104	3,104
Neuroticism	Correlation coefficient	0.008	−0.008
	Significant	0.524	0.557
	N	3,104	3,104
Openness to experience	Correlation coefficient	0.011	0.019
	Significant	0.372	0.152
	N	3,104	3,104

Note: *$p < 0.001$; **$p < 0.05$; and ***$p < 0.1$.

Thus, including an additional level of analysis to draw conclusions becomes necessary.

Impacts of Personality Traits on Attention

Descriptive statistics for eye-movement parameters (mean and standard deviation) within low and high groups across personality traits can be found in Table 3. Regarding their attentional allocation, considerable differences between low and high groups can be observed within all personality dimensions. However, inferential analysis is required to examine the significance of these differences.

To study whether the attentional distribution of workers with a low and high rank in each personality trait differs significantly from a purely random arrangement, a permutation of Welch's t-statistic was conducted. In total, 10 permutation simulations (two eye movement metrics for five personality dimensions) were each run 10,000 times to compare attention measures between high and low groups of personality traits. Significant results are indicated in Table 4. In contrast to the second null hypothesis, the results indicated that the extroversion personality trait has a significant negative impact on worker attentiveness to fall hazards as extroverts (high group) returned their attention less frequently to hazardous areas (Welch's $t = 2.077$; $p = 0.039 < 0.05$). Additionally, workers who are highly conscientious distributed their attention significantly differently across hazardous scenes; the run count analyses verified that highly conscientious workers more frequently returned their attention to hazards (Welch's $t = -2.728$; $p = 0.006 < 0.05$). The openness to experience trait has a significant impact on workers' attentiveness; workers who are more open to experience returned their attention more frequently to fall hazards (Welch's $t = -2.630$; $p = 0.009 < 0.05$). Regarding attentional allocation, agreeableness and neuroticism traits indicated no significant difference across groups. All significant differences are in terms of the run count measure of attention, which is highly related to the hazard identification skill of workers, according to Hasanzadeh et al. (2017b). These findings are discussed more in the "Discussion" section.

Table 3. Descriptive statistics of attention measures across big five personality dimensions for 28 participants

Personality dimensions	Groups	No.	Fixation count		Run count	
			Mean	SD	Mean	SD
Extraversion	Low	920	7.544	7.670	3.388	2.590
	High	804	6.968	6.817	3.129	2.570
Agreeableness	Low	804	7.214	7.157	3.205	2.644
	High	805	6.963	7.547	3.024	2.429
Conscientiousness	Low	804	6.981	7.610	2.964	2.498
	High	805	6.953	6.838	3.316	2.670
Neuroticism	Low	920	6.839	7.157	3.136	2.586
	High	804	7.104	7.553	3.137	2.594
Openness to experience	Low	920	6.732	7.045	3.004	2.364
	High	919	7.215	6.917	3.313	2.666

Table 4. Results of permutation test using Welch's t (B = 10,000)

Personality dimensions	Fixation count		Run count	
	Welch's t-statistic	p-value	Welch's t-statistic	p-value
Extraversion	1.653	0.107	2.077	0.039**
Agreeableness	0.685	0.495	1.435	0.157
Conscientiousness	0.079	0.934	−2.728	0.006**
Neuroticism	−0.746	0.459	−0.008	0.994
Openness to experience	−1.486	0.135	−2.630	0.009**

Note: *$p < 0.001$; **$p < 0.05$; and ***$p < 0.1$.

Discussion

Extraversion

The research findings demonstrated that the personality trait of extraversion is significantly related to the attentional allocation of construction workers. Workers who are extroverts are likely to have fewer fixations and return their attention to hazardous areas less often than those who are introverted. Previous eye-tracking studies indicated that workers who return their attention less frequently and fixate less often on hazardous areas have lower hazard identification skills (Hasanzadeh et al. 2017b). Considering that inability to detect a hazard is a common human error and the root cause of a large number of construction accidents (Garrett and Teizer 2009), the suggestion can be made that workers who are extroverts will be less likely to attend to hazards or will underestimate safety risks.

The findings of the present study are consistent with existing literature that shows that a high level of extraversion is positively related to the risk-taking behavior of individuals (Sutherland and Cooper 1991; Lajunen 2001; Henning et al. 2009). In fact, extroverted individuals have a greater risk propensity, which indicates that they are inclined to take a risk and engage in risky behavior. Additionally, extroverts might have poorer performance under monotonous conditions or in vigilance tasks; they will not get as involved in the task as an introvert will and are more likely to commit fatigue-related errors (Koelega 1992).

This study also presents data to explain a longstanding expectation about the link between engagement and accidents. Although previous studies have suggested that a lack of engagement with activities (i.e., improper allocation of attention) more frequently yields accidents, previous evidence exists to explain such a claim. The results of this study address this knowledge gap by providing empirical support: because being an extrovert impacts attentional distribution, workers with this personality trait tend to focus less on the potential hazards and are more likely to expose themselves

to the risk of injury. In other words, extroverts do not return their attention to hazardous areas frequently enough to identify and assess associated risks and, therefore, are more likely to make an improper decision or commit an unsafe act. This finding reveals an excellent opportunity for safety managers to use personality assessments to preemptively identify at-risk workers who may need additional training or safety management.

Agreeableness

The relationship between the personality trait of agreeableness and the attentional allocation of construction workers was one of the weakest in this study. A nonsignificant difference existed between workers with high and low agreeableness scores in terms of attentional allocation when exposed to fall hazards. Such a result can be explained by turning to the existing literature that examined the relationship between agreeableness and human performance.

Because the agreeableness trait is related to social/interpersonal relations—especially team working (Mount et al. 1998; Rauthmann et al. 2012)—it might be influential on safety behavior when a group of workers needs to cooperate to accomplish an activity. People with low agreeableness are typically belligerent, hostile, and aggressive. They are frequently involved in arguments that cause stress or emotional arousal within a group. In contrast, highly agreeable people normally possess high interpersonal skills and can effectively cooperate with others to solve problems. Previous studies suggested that crews with highly agreeable members performed effectively in risky activities (e.g., Salgado 2002; Clarke and Robertson 2005) because the group norms established among members supported safety-related behaviors, such as approaching and warning other workers who are engaging in unsafe acts to reduce the probability of accident involvement. Members who are highly agreeable tended to develop such a group norm and apply that to their own behavior (Clarke and Robertson 2005). Because the scope of the present study was limited to determining the role of personality in individual-level safety (i.e., isolated from other workers) and the images used for the eye-tracking experiment contained minimal social cues, that agreeableness had a limited (nonsignificant) impact on attentional allocation in this experimental context is reasonable.

Conscientiousness

The positive correlation between conscientiousness and the frequency at which workers returned their attention to a hazardous situation indicates that people who are more conscientious are likely to be more attentive to hazards than those who are less conscientious. The supplemental analysis (H_{02}) carried out on the data found that the group of workers who are less conscientious allocated less attention to hazards.

This finding is supported by the theory of conscientiousness at work presented by Viswesvaran and Ones (2008), who found that highly conscientious individuals focus more attention on exploring their tasks. The significant thoroughness in hazard identification expressed by the highly conscientious group is exhibited in their systematic attentional distribution in balancing between focused and distributed attention. The results of our study are also consistent with empirical studies that have found the role of conscientiousness in individual's safety performance and accident involvement (e.g., Arthur and Graziano 1996; Cellar et al. 2001; Clarke and Robertson 2005). Conscientious people are better at taking care of themselves, whereas the unconscientious ones—who are careless, unreliable, or easily distracted—usually fail to follow the rules and regulations at work and are more vulnerable to cognitive failures that, in turn, are predictive of workplace accidents. More conscientious workers may engage less frequently in risk-taking behavior and may avoid dangerous situations by allocating sufficient attention to identifying a hazard in advance.

Our finding pertaining to conscientiousness also suggests that selecting highly conscientious workers might be a viable approach to enhancing construction safety. These workers may better distribute their limited attentional resources to identify surrounding hazards. Beyond selection implications, this study highlights the critical role of safety managers in developing training and intervention techniques for modifying workers' conscientiousness traits because behavior associated with conscientiousness is well-established as being able to be improved, especially via training that emphasizes "rule-following" and "attention to detail" (Arthur and Doverspike 2001).

Neuroticism

This study found no significant correlations between neuroticism and attention measures. Previous studies showed that emotionally stable people are calm, unenvious, or relaxed, and this trait can be used as a valid predictor of job performance (Teng et al. 2009; Clarke and Robertson 2005). However, after dividing the workers into groups and comparing the less neurotic group with the more neurotic group, we found that the influence of workers' neuroticism on their attentional distribution and hazard identification was not significant as related to construction workers. One justification for this finding is that neuroticism is associated with maintaining rational thought and being free from negative emotions in decision making (Yang and Wang 2001). Therefore, the consequence of instability is revealed in reactions and decisions. Comparatively, the scope of the current study is limited to the recognition of hazards, which does not relate to behavioral response and may justify the nonsignificant result. However, the authors recommend expanding the scope of this study in future research to examine the impact of emotional stability traits on reaction and the decision making of workers when exposed to a hazardous situation. For more information on the impact of the neuroticism personality dimension on decision making in a real-world construction site with a hazardous situation, see Hasanzadeh et al. (2018b).

Openness to Experience

Openness to experience is the least studied trait in relation to safety behavior and accident involvement. Moreover, contradictory results were observed in previous studies, which makes it difficult to have an assertive prediction regarding this trait. Individuals who are highly open to experience exhibit an attraction to new ideas and pursue opportunities to address ambiguous situations (Liao and Lee 2009).

The results of the present study show that people with higher scores on openness traits returned their attention to the hazardous areas of scenes more frequently than people with lower scores on openness personality traits, perhaps suggesting that individuals who scored higher on openness actively sought information in the surrounding environment by processing the cues longer and in a more in-depth manner. This finding is in line with the findings of Matsumoto et al. (2010) and Rauthmann et al. (2012), which indicated that highly open individuals allocate more attention and deeper processing to the scene to obtain information from the hazardous stimulus. The current results might also reasonably be viewed from the standpoint of how the personal attribute of openness relates to providing a balance between focusing and

Table 5. Descriptive statistics of safety knowledge dimensions across various personality traits

Safety knowledge dimensions	Groups	Ex_Low (%)	Ex_High (%)	Ag_Low (%)	Ag_High (%)	Co_Low (%)	Co_High (%)	Ne_Low (%)	Ne_High (%)	Op_Low (%)	Op_High (%)
Years of experience	<5	50	28.5	43	50	50	14	50	0	50	12.5
	5< <10	12.5	28.5	0	12.5	12.5	57	12.5	43	12.5	25
	>10	37.5	43	57	37.5	37.5	29	37.5	57	37.5	62.5
Training	Yes	50	100	100	50	75	72	87.5	57	62.5	100
	No	50	0	0	50	25	28	12.5	43	37.5	0
Past injury exposure	Yes	62.5	71.5	71.5	62.5	62.5	72	50	100	75	87.5
	No	37.5	28.5	28.5	37.5	37.5	28	50	0	25	12.5

Note: Ex = extraversion; Ag = agreeableness; Co = conscientiousness; Ne = neuroticism; and Op = openness.

distributing attention (i.e., the balance between fixation and run count).

Cross Comparison of Safety Knowledge on Personality Characteristics

To further examine the role of personality in accident occurrence, this study conducted a cross comparison between indicators of safety knowledge (i.e., work experience, training, and past injury exposure, as taken from the demographics survey) and workers' personality groups (Table 5). All individuals identified in this study as being highly extroverted and open (i.e., those with a greater risk propensity and higher inclination to engage in risky behavior) had previously received safety training. This finding demonstrates that previous safety training did not achieve the desired level of improvement in workers' hazard identification skills. This study showed that even after providing OSHA training, extroverted workers still failed to identify hazards and were more likely to take risks.

The distribution of safety knowledge across high and low agreeable groups also manifested no significant difference. This finding reveals that obtaining safety knowledge through exposure, experience, and training did not necessarily improve the teamwork skills of workers because cooperation and teamwork are rarely emphasized in conventional safety training. A single disagreeable member exposes himself or herself and others to hazards and may be enough to degrade the team's capability to work cooperatively (Zohar 2011), suggesting that for project managers to evaluate and consider prosocial personality traits when making a selection may have particular value. Therefore, organizational interventions must be used to activate a worker's desires for communion and cooperation to improve safety-related behavior (Beus et al. 2015).

In terms of the conscientiousness trait, Table 5 indicates that workers who have obtained their safety knowledge through work experience and injury exposure are more conscientious, which is well-aligned with the previous study conducted by Hasanzadeh et al. (2017b). The study by Hasanzadeh et al. (2017b) confirmed that years of experience and injury exposure significantly improve workers' hazard identification and that these individuals may engage in less risk-taking behavior and may avoid dangerous situations by allocating sufficient attention to identifying a hazard in advance. The interesting point unearthed in this cross comparison is that, although gaining more experience will increase workers' consciousness, individuals who have more than 10 years of experience reported lower consciousness and indicated lower performance in the hazard identification experiment. Previous studies verified this finding that lower consciousness and more cognitive failure are more likely to occur among highly experienced individuals or under familiar conditions in which task are automated (e.g., Reason and Lucas 1984; Heckhausen and Beckmann 1990; Wallace and Vodanovich 2003; Zhao et al. 2009).

The descriptive statistics show that past injury exposure (i.e., either being injured or observing someone else being injured) affects workers' emotional stability (i.e., self-reported neuroticism level). However, the previous study by Hasanzadeh et al. (2017a) indicated that workers with past injury exposure identify related hazards faster, but the psychological consequence of this experience must not be undermined. These findings illustrate that safety knowledge must not be the only criterion in the selection process and personality assessment must also be taken into account.

Conclusions

The construction industry is one of the most hazardous industries, and the cause of most accidents is beyond the employee's control, with previous studies identifying skill-based (e.g., attention failure) and perceptual-based (e.g., failure to identify and misperceptions) errors as the main contributors to accidents. Accordingly, the identification of variables that impact a worker's attention is important to construction safety. A large number of studies indicated the impact of personality on accident involvement and suggested a potential relationship between personality and cognitive failures. However, no study has experimentally investigated the relationships between personality and attention in a construction safety context. Using personality questionnaire data and continuous monitoring of workers' attention via an eye-tracking experiment, this study addressed this knowledge gap by testing two major hypotheses using different statistical analyses. The results indicated significant relationships between certain personality traits and attentional allocation when workers are searching for hazards. Specifically, extraversion, conscientiousness, and openness to experience were significantly related to attentional allocation and search strategies of workers exposed to fall hazards. Workers who are introverted (less extroverted), more conscientiousness, and more open to experience distribute their limited attentional resources more properly to identify fall hazards within images.

The results of the cross-comparison of safety knowledge, demographics, and personality characteristics verified that providing conventional safety training cannot enhance a worker's desires for communion and cooperation to improve safety-related behavior, which is the employer's/project manager's responsibility to, first, consider prosocial personality traits when making a selection and, second, provide organizational interventions to facilitate communication and cooperation among the crew. Moreover, although obtaining safety knowledge through work experience and injury exposure can enhance a worker's conscious-awareness, highly experienced workers are at-risk because of the absence of mind, lower consciousness, and more cognitive failure when these tasks become automatic. This study also warns project managers about the psychological consequences of a worker's past injury exposure on their personality characteristics and safety-related behavior.

Therefore, both safety knowledge and personality assessment need to be considered in the selection criteria for the high-risk task.

This study provides a significant contribution to both academia and practice. Regarding academia, this study is one of the early attempts to determine the relationship between personality traits and attentional allocation to identify what contributes to the subsequent involvement of people in accidents. In other words, when relating personality to safety, this study indicates the importance of distinguishing between workers who are injury prone (one's propensity to experience an injury) versus injury preventive (one's willingness to participate in an injury-prevention effort) by monitoring their attentional distribution. A better understanding of these connections will lay a foundation for developing a worker's behavioral models to predict the likelihood of human error or unsafe behavior at a construction site.

Regarding contribution to practice, the results of this study provide the scientific basis for developing safety solutions and training materials according to workers' unique experiences and personality backgrounds. Given that the outcomes of this research show relationships between personality traits and attention, certain types of workers are safer (better in identifying hazards) than others. Therefore, construction companies may consider selection systems to identify the employees who potentially have lower attentiveness via personality assessment surveys. In response, project managers can assign extroverted, less conscientiousness, and/or less open to experience workers to less cognitively demanding tasks or provide focused training for distracted workers. Foreseeably, the understandings resulting from this study can play a prominent role in transforming the current training and educational practices by providing personalized safety guidelines and by developing much more effective training materials in the future.

Limitations and Future Studies

Some limitations exist related to this research that can be addressed by future studies. First, the current study considered each of the personality traits separately to study each trait's impact on attention measures. A future study might investigate the possible combination of personality characteristics that may impact workers' attentional allocation and hazard identification. Second, the present study has not considered the impact of variables, such as workers' safety knowledge, workers' training, job routinization, and fatigue, all of which may impact attention. Future studies must identify and examine the effect of possible moderators on the relationship between personality traits and workers' attentiveness. Third, the sample used in this feasibility study may limit the generalizability of the findings because workers were recruited only from Lincoln and Omaha, Nebraska. Although this study met the sample size requirement for an eye-tracking study and for statistical analysis, future studies might replicate this study in other geographical regions and increase the number of participants to address this limitation. Future studies would benefit from combining all of these important internal factors when determining the factors that are correlated with construction accidents. Fourth, this study examined workers' gaze behavior toward static images rather than toward a real-world construction site. Future studies might design an eye-tracking experiment on an actual construction site using a mobile eye-tracker to determine the extent to which dynamic settings change these results. Fifth, most participants in this study were male. Future studies should be conducted to understand the role of gender in attentional distribution of construction workers. Lastly, traits of agreeableness and openness to experience can be influenced by job-related factors in organizational contexts. However, in this study, the role of personality traits was examined in isolated individual sessions in which there was no influence from coworkers or an organization. Therefore, future studies should examine the association between the safety performance of crews and the level of agreeableness and determine the importance of openness in different organizational cultures.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request. Information about the *Journal*'s data-sharing policy can be found here: http://ascelibrary.org/doi/10.1061/(ASCE)CO.1943-7862.0001263.

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References

Adams, D. C., and C. D. Anthony. 1996. "Using randomization techniques to analyse behavioural data." *Animal Behav.* 51 (4): 733–738. https://doi.org/10.1006/anbe.1996.0077.

Allport, G. W. 1937. *Personality: A psychological interpretation*. New York: Henry Holt.

Anderson, J. R. 2005. *Cognitive psychology and its implications*. New York: Macmillan.

Arthur, W., Jr., and D. Doverspike. 2001. "Predicting motor vehicle crash involvement from a personality measure and a driving knowledge test." *J. Prev. Intervention Community* 22 (1): 35–42. https://doi.org/10.1080/10852350109511209.

Arthur, W., and W. G. Graziano. 1996. "The five-factor model, conscientiousness, and driving accident involvement." *J. Personality* 64 (3): 593–618. https://doi.org/10.1111/j.1467-6494.1996.tb00523.x.

Azucar, D., D. Marengo, and M. Settanni. 2018. "Predicting the Big 5 personality traits from digital footprints on social media: A meta-analysis." *Personality Individual Differences* 124 (Apr): 150–159. https://doi.org/10.1016/j.paid.2017.12.018.

Barrick, M. R., and M. K. Mount. 1991. "The Big Five personality dimensions and job performance: A meta-analysis." *Personnel Psychol.* 44 (1): 1–26. https://doi.org/10.1111/j.1744-6570.1991.tb00688.x.

Beus, J. M., L. Y. Dhanani, and M. A. McCord. 2015. "A meta-analysis of personality and workplace safety: Addressing unanswered questions." *J. Appl. Psychol.* 100 (2): 481–498. https://doi.org/10.1037/a0037916.

Bogg, T., and B. Roberts. 2004. "Conscientiousness and health-related behaviors: A meta-analysis of the leading behavioral contributors to mortality." *Psychol. Bull.* 130 (6): 887–919. https://doi.org/10.1037/0033-2909.130.6.887.

Borgatta, E. F. 1964. "The structure of personality characteristics." *Syst. Res. Behav. Sci.* 9 (1): 8–17. https://doi.org/10.1002/bs.3830090103.

Cellar, D. F., Z. C. Nelson, C. M. Yorke, and C. Bauer. 2001. "The five-factor model and safety in the workplace: Investigating the relationship between personality and accident involvement." *J. Prev. Intervention Community* 22 (1): 43–52. https://doi.org/10.1080/10852350109511210.

Clarke, S., and I. T. Robertson. 2005. "A meta-analytic review of the Big Five personality factors and accident involvement in occupational and non-occupational settings." *J. Occup. Organ. Psychol.* 78 (3): 355–376. https://doi.org/10.1348/096317905X26183.

Deffenbacher, J. L., E. R. Oetting, and R. S. Lynch. 1994. "Development of a driving anger scale." *Psychol. Rep.* 74 (1): 83–91. https://doi.org/10.2466/pr0.1994.74.1.83.

Di Fabio, A., and D. H. Saklofske. 2018. "The contributions of personality and emotional intelligence to resiliency." *Personality Individual Differences* 123 (Mar): 140–144. https://doi.org/10.1016/j.paid.2017.11.012.

Drummond, G. B., and S. L. Vowler. 2012. "Different tests for a difference: How do we do research?" *Adv. Physiol. Educ.* 36 (1): 3–5. https://doi.org/10.1152/advan.00121.2011.

Duchowski, A. 2007. *Eye tracking methodology: Theory and practice*. 2nd ed. London: Springer.

Dzeng, R. J., C. T. Lin, and Y. C. Fang. 2016. "Using eye-tracker to compare search patterns between experienced and novice workers for site hazard identification." *Saf. Sci.* 82 (Feb): 56–67. https://doi.org/10.1016/j.ssci.2015.08.008.

Esmaeili, B., and M. R. Hallowell. 2012. "Diffusion of safety innovations in the construction industry." *J. Constr. Eng. Manage.* 138 (8): 955–963. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000499.

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

Eysenck, H. J. 1970. "The personality of drivers and pedestrians." *Med. Sci. Law* 3: 416–423.

Fine, B. J. 1963. "Introversion-extraversion and motor vehicle driver behavior." *Perceptual Motor Skills* 16 (1): 95–100. https://doi.org/10.2466/pms.1963.16.1.95.

Garrett, J., and J. Teizer. 2009. "Human factors analysis classification system relating to human error awareness taxonomy in construction safety." *J. Constr. Eng. Manage.* 135 (8): 754–763. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000034.

Gevins, A., M. E. Smith, H. Leong, L. McEvoy, S. Whitfield, R. Du, and G. Rush. 1998. "Monitoring working memory load during computer-based tasks with EEG pattern recognition methods." *Hum. Factors* 40 (1): 79–91. https://doi.org/10.1518/001872098779480578.

Goldberg, L. R. 1990. "An alternative 'description of personality': The Big-Five factor structure." *J. Personality Social Psychol.* 59 (6): 1216–1229. https://doi.org/10.1037/0022-3514.59.6.1216.

Goldberg, L. R. 1992. "The development of markers for the Big-Five factor structure." *Psychol. Assess.* 4 (1): 26–42. https://doi.org/10.1037/1040-3590.4.1.26.

Golimbet, V., M. Alfimova, I. Gritsenko, and R. Ebstein. 2007. "Relationship between dopamine system genes and extraversion and novelty seeking." *Neurosci. Behav. Physiol.* 37 (6): 601–606. https://doi.org/10.1007/s11055-007-0058-8.

Gosling, S. D., P. J. Rentfrow, and W. B. Swann Jr. 2003. "A very brief measure of the big-five personality domains." *J. Res. Personality* 37 (6): 504–528. https://doi.org/10.1016/S0092-6566(03)00046-1.

Hahn, S., D. R. Buttaccio, J. Hahn, and T. Lee. 2015. "Rapid communication: Personality and attention: Levels of neuroticism and extraversion can predict attentional performance during a change detection task." *Q. J. Exp. Psychol* 68 (6): 1041–1048. https://doi.org/10.1080/17470218.2015.1032986.

Hansen, C. P. 1989. "A causal model of the relationship among accidents, biodata, personality, and cognitive factors." *J. Appl. Psychol.* 74 (1): 81–90.

Hasanzadeh, S., B. Esmaeili, and M. Dodd. 2016. "Measuring construction workers' real-time situation awareness using mobile eye-tracking." In *Proc., Construction Research Congress*, 2894–2904. Reston, VA: ASCE.

Hasanzadeh, S., B. Esmaeili, and M. Dodd. 2017a. "Measuring the impact of working memory load on the safety performance of construction workers." In *Proc., Computing in Civil Engineering*, 158–166. Reston, VA: ASCE.

Hasanzadeh, S., B. Esmaeili, and M. Dodd. 2017b. "Measuring the impacts of safety knowledge on construction workers' attentional allocation and hazard detection using remote eye-tracking technology." *J. Manage. Eng.* 33 (5): 04017024. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000526.

Hasanzadeh, S., B. Esmaeili, and M. D. Dodd. 2017c. "Impact of construction workers' hazard identification skills on their visual attention." *J. Constr. Eng. Manage.* 143 (10): 04017070. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001373.

Hasanzadeh, S., B. Esmaeili, and M. D. Dodd. 2018a. "Examining the relationship between construction workers' visual attention and situation awareness under fall and tripping hazard conditions: Using mobile eye tracking." *J. Constr. Eng. Manage.* 144 (7): 04018060. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001516.

Hasanzadeh, S., B. Esmaeili, and M. D. Dodd. 2018b. "Examining the relationship between personality characteristics and worker's attention under fall and tripping hazard conditions." In *Proc., Construction Research Congress 2018*, 412–422. Reston, VA: ASCE.

Hasanzadeh, S., B. Esmaeili, M. D. Dodd, and E. Pellicer. 2017d. *Using eye movements to identify hazards missed by at-risk workers*. Fargo, ND: ISEC.

Heckhausen, H., and J. Beckman. 1990. "Intentional action and action slips." *Psychol. Rev.* 97 (1): 36–48. https://doi.org/10.1037/0033-295X.97.1.36.

Henning, J. B., C. J. Stufft, S. C. Payne, M. E. Bergman, M. S. Mannan, and N. Keren. 2009. "The influence of individual differences on organizational safety attitudes." *Saf. Sci.* 47 (3): 337–345. https://doi.org/10.1016/j.ssci.2008.05.003.

Hitch, G., and A. D. Baddeley. 2017. "Working memory." In *Exploring working memory*, 43–79. New York: Routledge.

Hjelle, L. A., and D. J. Ziegler. 1976. *Personality theory: Basic assumptions, research, and theory.* New York: McGraw-Hill.

Hoffman, J. E., and B. Subramaniam. 1995. "The role of visual attention in saccadic eye movements." *Percept. Psychophys.* 57 (6): 787–795. https://doi.org/10.3758/BF03206794.

Jacob, R. J., and K. S. Karn. 2003. "Eye tracking in human-computer interaction and usability research: Ready to deliver the promises." In *Mind's eye*, 573–605. Amsterdam, Netherlands: Elsevier. https://doi.org/10.1016/B978-044451020-4/50031-1.

John, O. P., and S. Srivastava. 1999. "The big-five trait taxonomy: History, measurement, and theoretical perspectives." In Vol. 2 of *Handbook of personality*, 102–138. New York: Guilford Press.

Kaplan, S., and L. E. Tetrick. 2011. "Workplace safety and accidents: An industrial and organizational psychology perspective." In *APA handbooks in psychology: APA handbook of industrial and organizational psychology.* Vol. 1 of *Building and developing the organization*, edited by S. Zedeck, 455–472. Washington, DC: American Psychological Association. http://doi.org/10.1037/12169-014.

Koelega, H. S. 1992. "Extraversion and vigilance: 30 years of inconsistencies." *Psychol. Bull.* 112 (2): 239–258. https://doi.org/10.1037/0033-2909.112.2.239.

LaFleur, B. J., and R. A. Greevy. 2009. "Introduction to permutation and resampling-based hypothesis tests." *J. Clin. Child Adolesc. Psychol.* 38 (2): 286–294. https://doi.org/10.1080/15374410902740411.

Lajunen, T. 2001. "Personality and accident liability: Are extraversion, neuroticism and psychoticism related to traffic and occupational fatalities?." *Personality Individual Differences* 31 (8): 1365–1373. https://doi.org/10.1016/S0191-8869(00)00230-0.

Lardent, C. L. 1991. "Pilots who crash: Personality constructs underlying accident prone behaviour of fighter pilots." *Multivariate Exp. Clin. Res.* 10 (1): 1–25.

Liao, C., and C. Lee. 2009. "An empirical study of employee job involvement and personality traits: The case of Taiwan." *Int. J. Econ. Manage.* 3 (1): 22–36.

Ludbrook, J. 1994. "Advantages of permutation (randomization) tests in clinical and experimental pharmacology and physiology." *Clin. Exp. Pharmacol. Physiol.* 21 (9): 673–686. https://doi.org/10.1111/j.1440-1681.1994.tb02570.x.

Ludbrook, J., and H. Dudley. 1998. "Why permutation tests are superior to t and F tests in biomedical research." *Am. Statistician* 52 (2): 127–132. https://doi.org/10.1080/00031305.1998.10480551.

Matsumoto, K., S. Shibata, S. Seiji, C. Mori, and K. Shioe. 2010. "Factors influencing the processing of visual information from non-verbal communications." *Psychiatry Clin. Neurosci.* 64 (3): 299–308. https://doi.org/10.1111/j.1440-1819.2010.02077.x.

Mogg, K., N. Millar, and B. P. Bradley. 2000. "Biases in eye movements to threatening facial expressions in generalized anxiety disorder and

depressive disorder." *J. Abnormal Psycho.* 109 (4): 695–704. https://doi.org/10.1037/0021-843X.109.4.695.
Mount, M. K., M. R. Barrick, and G. L. Stewart. 1998. "Five-factor model of personality and performance in jobs involving interpersonal interactions." *Hum. Perform* 11 (2): 145–165.
Norman, W. T. 1963. "Toward an adequate taxonomy of personality attributes: Replicated factor structure in peer nomination personality ratings." *J. Abnormal Social Psychol.* 66 (6): 574–583. https://doi.org/10.1037/h0040291.
Perlman, S. B., J. P. Morris, B. C. Vander Wyk, S. R. Green, J. L. Doyle, and K. A. Pelphrey. 2009. "Individual differences in personality predict how people look at faces." *PLoS One* 4 (6): e5952. https://doi.org/10.1371/journal.pone.0005952.
Pervin, L. A., and O. P. John, eds. 1999. *Handbook of personality: Theory and research*. New York: Elsevier.
Pestonjee, D. M., and U. B. Singh. 1980. "Neuroticism-extroversion as correlates of accident occurrence." *Accid. Anal. Prev.* 12 (3): 201–204. https://doi.org/10.1016/0001-4575(80)90019-6.
Postlethwaite, B., S. Robbins, J. Rickerson, and T. McKinniss. 2009. "The moderation of conscientiousness by cognitive ability when predicting workplace safety behavior." *Personality Individual Differences* 47 (7): 711–716. https://doi.org/10.1016/j.paid.2009.06.008.
Rauthmann, J. F., C. T. Seubert, P. Sachse, and M. R. Furtner. 2012. "Eyes as windows to the soul: Gazing behavior is related to personality." *J. Res. Personality* 46 (2): 147–156. https://doi.org/10.1016/j.jrp.2011.12.010.
R Development Core Team. 2012. *R: A language and environment for statistical computing, version R2.15.0*. Report prepared for the R Foundation for Statistical Computing. Vienna, Austria: R Development Core Team.
Reason, J. T., and D. Lucas. 1984. "Absent-mindedness in shops: Its incidence, correlates and consequences." *Br. J. Clin. Psychol.* 23 (2): 121–131. https://doi.org/10.1111/j.2044-8260.1984.tb00635.x.
Robbins, S., and T. Judge. 2014. *Essentials of organizational behavior.* 12th ed. New York: Pearson.
Roy, G. S., and R. K. Choudhary. 1985. "Driver control as a factor in road safety." *Asian J. Psychol. Educ.* 16 (3): 33–37.
Salgado, J. F. 1997. "The five factor model of personality and job performance in the European community." *J. Appl. Psychol.* 82 (1): 30–43. https://doi.org/10.1037/0021-9010.82.1.30.
Salgado, J. F. 2002. "The big five personality dimensions and counterproductive behaviors." *Int. J. Sel. Assess.* 10 (1–2): 117–125. https://doi.org/10.1111/1468-2389.00198.
Saucier, G. 1994. "Mini-markers: A brief version of Goldberg's unipolar Big-Five markers." *J Personality Assess.* 63 (3): 506–516. https://doi.org/10.1207/s15327752jpa6303_8.
Sing, C., P. Love, I. Fung, and D. Edwards. 2014. "Personality and occupational accidents: Bar benders in Guangdong Province, Shenzhen, China." *J. Constr. Eng. Manage.* 140 (7): 05014005. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000858.
Smith, D. I., and R. W. Kirkham. 1981. "Relationship between some personality characteristics and driving record." *Br. J. Social Psychol.* 20 (4): 229–231. https://doi.org/10.1111/j.2044-8309.1981.tb00491.x.
Staw, B. M., and S. G. Barsade. 1993. "Affect and managerial performance: A test of the sadder-but-wiser vs. happier-and-smarter hypotheses." *Administrative Sci. Q.* 38 (2): 304–331. https://doi.org/10.2307/2393415.
Steffy, B. D., J. W. Jones, L. R. Murphy, and L. Kunz. 1986. "A demonstration of the impact of stress abatement programs on reducing employees' accidents and their costs." *Am. J. Health Promotion* 1 (2): 25–32. https://doi.org/10.4278/0890-1171-1.2.25.
Sun, Y., R. Fisher, F. Wang, and H. M. Gomes. 2008. "A computer vision model for visual-object-based attention and eye movements." *Comput. Vision Image Understanding* 112 (2): 126–142. https://doi.org/10.1016/j.cviu.2008.01.005.
Sutherland, V. L., and C. L. Cooper. 1991. "Personality, stress and accident involvement in the offshore oil and gas industry." *Personality Individual Differences* 12 (2): 195–204. https://doi.org/10.1016/0191-8869(91)90103-I.
Teng, C. I., S. S. Chang, and K. H. Hsu. 2009. "Emotional stability of nurses: Impact on patient safety." *J. Adv. Nurs.* 65 (10): 2088–2096. https://doi.org/10.1111/j.1365-2648.2009.05072.x.
Viswesvaran, C., and D. S. Ones. 2008. "Perspectives on models of job performance." *Int. J. Sel. Assess.* 8 (4): 216–226. https://doi.org/10.1111/1468-2389.00151.
Wallace, J. C., and S. J. Vodanovich. 2003. "Workplace safety performance: Conscientiousness, cognitive failure, and their interaction." *J. Occup. Health Psychol.* 8 (4): 316–327. https://doi.org/10.1037/1076-8998.8.4.316.
Wiggins, J. S. ed. 1996. *The five-factor model of personality: Theoretical perspectives*. New York: Guilford Press.
Wu, D. W. L., W. F. Bischof, N. C. Anderson, T. Jakobsen, and A. Kingstone. 2014. "The influence of personality on social attention." *Personality Individual Differences* 60 (Apr): 25–29. https://doi.org/10.1016/j.paid.2013.11.017.
Yang, M. K., and G. S. Wang. 2001. "The effects of an emotional management programme on the work emotional stability and interpersonal relationships of vocational school students." *Global J. Eng. Educ.* 5 (2): 175–183.
Zhao, D., J. Lucas, and W. Thabet. 2009. "Using virtual environments to support electrical safety awareness in construction." In *Proc., 2009 Winter Simulation Conf. (WSC)*, 2679–2690. Austin, TX: IEEE. http://dx.doi.org/10.1109/WSC.2009.5429258.
Zohar, D. 2011. "Safety climate: Conceptual and measurement issues." In *Handbook of occupational health psychology*, edited by J. C. Quick, and L. E. Tetrick. 2nd ed., 141–164. Washington, DC: American Psychological Association.