Examining the Relationship between Personality Characteristics and Worker's Attention under Fall and Tripping Hazard Conditions

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Abstract

A worker's attentional and cognitive failures—such as lack of attention, failure to identify a tripping hazard, or misperception about a hazard's risks—can lead to unsafe behaviors and, consequently, accidents. Previous literature has shown that individual characteristics such as personality may affect human's selective attention. However, few studies have attempted to empirically examine how a worker's personality affects attention and situation awareness on a jobsite. The present study examines how workers' emotional stability (neuroticism) affects their cognitive failures (especially attentional failure) when they are exposed to fall-to-same-level hazardous conditions. To achieve this goal—and given that eye movements represent the most direct manifestation of visual attention—the personalities of construction workers were assessed via self-completion questionnaires, and their attention and situation awareness were monitored continuously and in real-time using a mobile wearable eye-tracking apparatus. Correlational analyses revealed the significant relationship between neuroticism and the attentional distribution of workers. These results suggest that workers do not allocate their attention equally to all hazardous areas and these differences in attentional distribution are modulated by personality characteristics (neuroticism). A more detailed investigation of this connection yielded a specific pattern: less neurotic workers periodically look down and scan ahead to obtain feedforward information about tripping hazards, and these individuals remain fully aware of the environment and its associated hazards. The findings of this study suggest the value assessing personality to identify workers who are more likely to be involved in accidents.

INTRODUCTION

The construction industry is among one of the most hazardous industries in the United States, and each year accidents result in thousands of fatalities and lost work hours (Esmaeili and Hallowell 2012). The majority of accidents are caused by workers' unsafe acts (caused by human error) in high-risk environments (e.g., Beus et al. 2015).Since 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).

Numerous previous studies have sought to understand the relationship between personality traits and safety-related outcomes (e.g., Beus et al. 2015). For example, a study examining firefighters provided evidence that there is a significant

positive relationship between personality (psychopathic deviate) and frequency of injury (Liao et al. 2001). Furthermore, psychological studies have suggested that personality affects worker's safety-related behaviors, which in turn affect accident occurrence. However, no attempts have been made to empirically examine *how* personality is connected to situation awareness and safety-related behavior of workers. Therefore, determining the ways in which personality traits shape the safe/unsafe behavior of workers remains an important empirical enterprise.

Understanding how individual differences (e.g., personality) influence the behaviors of workers is especially important in construction since tasks in the construction industry are goal-directed and demand a high capacity of cognitive function. Cognitive failure refers to perceptual, attentional, memory, and/or action-related mental lapses. The current study focused on attentional failure as one of the main cognitive lapses in the construction industry. Prior studies (Hasanzadeh et al. 2016) identified the direct relationship between attention and situation awareness—the perception of those elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in near future (Endsley 1995)—but did not investigate personality factors in the initial analyses. Therefore, in the present study, we employed a real-world experiment to investigate the interaction between personality, attention, and situation awareness. We hypothesized that worker's cognitive failures (especially attentional failure)) positively relate to neuroticism, since neurotic individuals are prone to experience stress, fear, and disgust, which may put them at a higher risk of exposure to hazards and subsequent improper decision-making. To limit the scope of this paper, we focused on tripping hazards. This study also tested the general hypothesis that workers with various levels of emotional stability (as indicated by their neuroticism score) allocate their attention differently when exposed to fall-to-same-level hazards. A mobile eye tracker was used for real-time monitoring of attention and of workers' situation awareness in a live construction environment. Results of this study illustrate how examining relationships between personality, attention, and situation awareness can open up the possibility of early identification of workers who are more likely to be involved in accidents.

BACKGROUND

Previous literature has shown that individual differences in personality influence cognitive processes, especially attention (e.g., Costa and McCrae 1992). This influence becomes important in dynamic settings—such as construction sites—since attention determines which information requires further processing, which in turn dictates the worker's ability to maintain situational awareness (Endsley 1995). Furthermore, due to the natural limits of attention, excessive attentional demands in a dynamic construction environment can considerably constrain a worker's ability to simultaneously detect and perceive all hazards, which can also degrade the worker's level of situation awareness (Hasanzadeh et al. 2016; 2016). Consequently, determining the influence of individual characteristics (e.g., personality) on attention yields parallel vital data about the influence of personality on situation awareness.

One of the potential mechanisms connecting personality with attention resides in *affective states*. Affective states influence which items an individual attends to in a scene and how long they process these items (Hahn et al. 2015). One such affective

state, neuroticism, was first introduced by Eysenck (1947). In particular, the personality dimension labelled "neuroticism" is one of the most robust traits in various theories of personality. Tellegen (1982) later conceptualized neuroticism as negative emotionality, and Strelau and Sawadzki's (1993) as reactive emotionality. Though the definition of this term varies in detail, the boundaries of the state generally range from stability (low N) to instability (high N).

Several studies support the idea that individuals high in neuroticism are anxious, easily aroused, and assumed to be less effective at regulating their behavior. For example, previous studies in driving showed that neuroticism correlates with aggressive and risky driving (e.g., Jovanovic´ et al. 2011). High neuroticism (lack of emotional stability) also reflects inflexibility and the tendency towards unstable emotions, cognition, and behavior when faced with high demand and/or constantly changing tasks (e.g., Robinson et al. 2006). Moreover, Flehmig and his colleagues (2007) examined the cognitive behavior of neurotic individuals and suggested that those with higher neuroticism scores experienced increased noise (i.e., lapses in attention) within their information processing during attention-demanding tasks.

In sum, situation awareness plays a salient role in fall-to-same level accidents, and attention—which corresponds to visual sensory input—helps one detect, perceive, and avoid tripping hazards. Concurrently, cognitive processes and attention are affected by individual personality traits—including neuroticism (emotional stability)—and these traits often manifest in the decisions and behaviors of workers. Consequently, when failures in situation awareness, attention, or other cognitive processes take place and cause accidents, personality may be at fault. Therefore, understanding the role of personality in cognitive failures and human errors can help prevent accidents in the construction workplace.

POINT OF DEPARTURE

In the present study, we examine whether neuroticism (emotional stability) relates to workers' cognitive failures (specifically, attention failures) and situation awareness in everyday working situations. To this end, we conducted a real-world eye-tracking experiment and compared the outcomes of that test with workers' self-reported personality assessments to test two null hypotheses:

- *Null hypothesis 1 (H_{01}): There is no association between workers' neuroticism scores and workers' attentiveness (i.e., fixation count, run count, dwell time) to fall-to-same level hazards.*
- *Null hypothesis 2 (H_{02}): Workers' neuroticism scores (emotional stability levels) have no impact on their attentiveness (i.e., fixation count, run count, dwell time) and situation awareness to fall-to-same level hazards.*

RESEARCH METHODS

First, each participant filled out a demographic survey and personality questionnaire (described below). Then, the subjects were asked to complete the eye-tracking scenario by wearing an eye tracker while walking along a path in a construction site during normal work activities (Figure 1). Participants were free to choose their own path and had to cope with potential causes of hazards (e.g., tripping and struck-by hazards) on their way to the end point. However, they received specific instructions as to where to start and finish their walk through the jobsite.

Participants and Experimental Environment

Fourteen undergraduate and graduate students (12 males, 2 females) participated in this study, and all subjects were required to have experience working for a construction company. Participants' experience ranged from one-to-six years, with an average of two and a half years. All participants had normal or corrected-to-normal vision, and each participant received a gift card as compensation for their participation. Data were analyzed for 11 of the 14 workers, since three participants' data were removed owing to difficulties with the eye tracker's calibration. The construction site (experimental setting) was located at the University of Nebraska-Lincoln campus (240,000-square-feet facility).

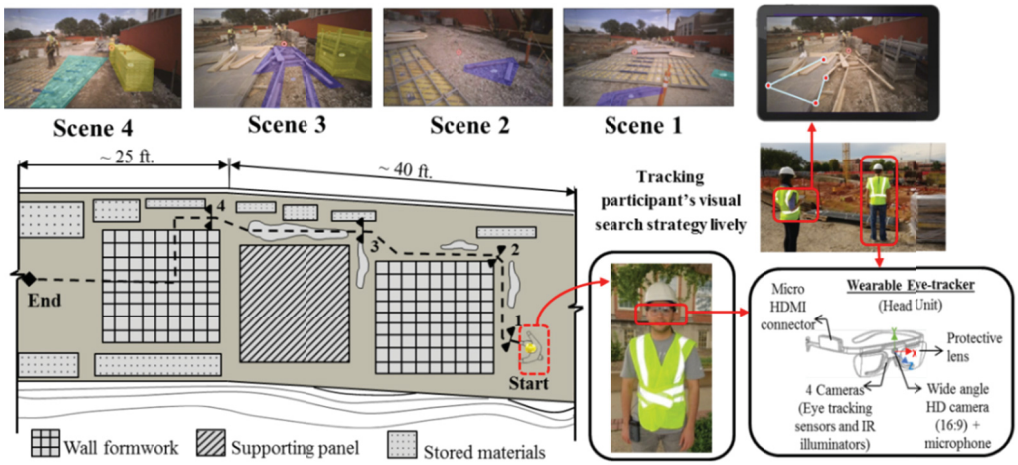

Figure 1. Schematic model of the experiment setting and path.

Big Five Personality Questionnaire

Personality was assessed using a forty-item mini-marker inventory introduced by Saucier in 1994. This questionnaire reflects a set of broad traits identified as (a) Extraversion, (b) Agreeableness, (c) Conscientiousness, (d) Neuroticism, and (e) Openness to Experience; the scope of this paper is limited to the "Neuroticism" personality trait. All participants completed the questionnaire and reported how accurately each trait describes them using a rating scale ranging from one ("very inaccurate") to seven ("very accurate"). Eight adjectives reflect neuroticism in forty-item mini-marker inventory, including envious, fretful, jealous, moody, relaxed, temperamental, touchy, and unenvious. The data were summed to calculate the neuroticism score for each participant.

Apparatus

A wearable mobile eye tracker (Tobii Pro glasses 2) was used to track workers' natural behavior and to monitor their attentional focus in real time. This eye tracker consists of four cameras (with a sampling rate of 100 Hz) directed toward the subject's eyes as well as one wide-angle camera directed toward the scene. The tablet that runs the controller software allowed the researchers to observe in both recorded and real-time what the subject fixated (Figure 1). The calibration process required between 2 and 5 minutes.

Areas of Interest

In order to investigate the attentional distribution of workers, areas of interest (AOIs) had to be defined first. Three safety experts (with at least ten years of

experience) were asked to evaluate a scene and determine which areas represented hazardous situations that participants must attend to in order to maintain situational awareness during the scenario. The AOIs may have been seen from different angles by participants, so multiple snapshots (scenes) had to be taken from the eye-tracking recordings to confirm that the experts saw all path perspectives as well as potential hazards. A previous study by Hasanzadeh and her colleagues (2017c) showed that to retain awareness while exposed to tripping hazards, a worker needs to both obtain feedforward information about hazards and detect immediate tripping hazards. Thus, the categories of AOIs in Figure 1 were defined based on these informative categories:

1. *Feedforward information*: The AOIs highlighted in turquoise in each scene include objects that need to be visually attended to in advance: (a) leftover lumber on the ground in Scene 1, and (b) wall formwork left on the ground and blocking the path in Scene 4.
2. *Immediate tripping hazards*: The AOIs highlighted in purple include immediate potential tripping hazards: (a) vertically stacked panels left on the ground in Scene 1, (b) leftover lumber on the ground in Scene 2, and (c) pile of lumber scraps in Scene 3.

Each hypothesis would have to be evaluated against each of these categories of AOIs to establish the impact of personality on situation awareness and attentional allocation.

Analytical Procedure

An image-recognition technology was used to map the raw fixation data to the AOIs over the four scenes. The Tobii Pro Glass Analyzer software then extracted attention measures for each participant across the identified AOIs for quantitative analysis and also to create visualizations for qualitative analysis. In this study, three eye movement measures were taken into account: fixation count (the number of fixations within each AOI); run count (the number of visits to each AOI), and dwell time (the total time each participant fixated each AOI over the course of the experiment).

To examine the general relationship between workers' personality (especially neuroticism or emotional stability), attention, and situation awareness in the live construction site, two bivariate correlation analyses (Kendall's tau and Pearson Correlations) were applied. For further investigation, the workers were divided into two (low: below mean, vs. high: above mean) groups based on their neuroticism scores (emotional stability). The personality trait neuroticism was considered an independent variable to examine the difference between groups in terms of their attentional allocation to the tripping hazards. Additionally, the permutation statistical technique generated a reference distribution by recalculating data statistics using resampling (10,000 samples), which increased the power of the analysis and compensated for a small sample size. To conduct the permutation Welch's t simulation, we used the Deducer package in the Java Graphical User Interface for R 1.7-9 of the open-source statistical package R (version R2.15.0) (R Development Core Team). This study considered a 95% confidence level ($p < 0.05$) as significant and a 90% confidence level ($p < 0.1$) as moderately significant.

RESULTS AND FINDINGS

Association between Neuroticism and Workers' Attentiveness

Construction workers are required to divide their attention properly throughout a scene to identify potential causes of tripping hazards while walking at a jobsite. Table 1 shows the correlation between neuroticism and attention measures across AOIs. The results showed that neuroticism significantly correlates with the attentional allocation of workers in feedforward AOIs; as the level of neuroticism increases, the workers looked down at their step's exact landing area and did not focus their attention on potential causes of tripping hazards in advance, which reduced their situation awareness. Concurrently, lower neuroticism coincided with longer dwell times (r= -0.501, *p*-value= 0.096<0.1), more fixation counts (r= -0.693, *p*-value= 0.018<0.05), and more run counts (r= -0.737, *p*-value= 0.016<0.05) toward potential causes of tripping hazard to obtain feedforward information and assess the hazards' associated risks. For this reason, we could reject the null hypothesis 1 for feedforward information.

Table 1. Correlations between neuroticism and workers' attention measures

Feedforward information AOIs across Scenes 1 and 4				
Neuroticism	Scenes	Run count	Fix Count	Dwell time
Corr. Coef	Scene 1	-0.737^{*k}(-0.884, -0.515)	-0.693^{*k} (-0.882,-0.455)	-0.501^{**k}(-0.848, -0.077)
p-value		0.016	0.018	0.096
Corr. Coef	Scene 4	-.586^{*k}(-0.922, -0.138)	-.613^{*k}(-0.999, 0.026)	-.613^{*k}(-0.999, 0.026)
p-value		0.026	0.017	0.017
Immediate tripping AOIs across Scenes 1-3				
Corr. Coef	Scene 1	-0.280^{k}(-0.763, 0.309)	-0.141^{k}(-0.655, 0.414)	-0.104^{k}(-0.608, 0.446)
p-value		0.318	0.635	0.723
Corr. Coef	Scene 2	-0.128^{k}(-0.565, 0.313)	-0.024^{k}(-0.546, 0.392)	-0.024^{k}(-0.546, 0.392)
p-value		0.636	0.926	0.926
Corr. Coef	Scene 3	-0.220^{k}(-0.678, 0.367)	0.147^{p}(-0.534, 0.709)	0.000^{k}(-0.539, 0.527)
p-value		0.376	0.666	1.000

$^{*}p< 0.05$, $^{**}p< 0.1$ ^{k} Kendall's tau correlation, ^{p} Pearson correlation

In terms of immediate tripping-related hazards, null hypothesis 1 could not be rejected. Therefore, we see no evidence of an association between neuroticism and workers' attentiveness when they are exposed to immediate tripping hazards, such as those in Scenes 1, 2, and 3. Such outcomes validate (Hasanzadeh et al. 2017c) since workers with low situation awareness still attend to immediate tripping hazards.

Although the results of the correlational analyses demonstrate the direction of relation between neuroticism personality trait and various attention measures, they do not indicate how different levels of neuroticism impact attention measures. Further investigation was carried out by dividing workers into two groups based on their neuroticism score and comparing their attentional distribution.

Impacts of Neuroticism (Emotional Stability) on Workers' Attentiveness

To study whether the attentional distribution of workers with low and high neuroticism score differs significantly from a purely random arrangement, permutation Welch's t-statistic simulations were conducted. In total, 15 permutation simulations were each run 10,000 times to compare attention measures between workers with different levels of neuroticism (emotional stability).

Contrary to the second null hypothesis, workers' neuroticism scores have a significant impact on their attentiveness to feedforward information AOIs (Table 2). Less neurotic individuals pay more attention to potential causes of fall-to-same level hazards to obtain feedforward information. On the other hand, more neurotic subjects allocated most of their attention to the areas under their feet, with minimal allocation of attentional resources to other potentially hazardous areas in Scenes 1 and 4. As Table 2 shows, only workers who are less neurotic (emotionally stable) gazed in advance toward the leftover lumber on the ground in Scene 1 in order to obtain feedforward information, whereas neurotic workers paid no attention to the potential tripping hazard beforehand (i.e., did not fixate on this AOI). Therefore, neurotic workers are at greater risk of exposure to tripping hazards ($p_{\textit{Scene 1- run count}} = 0.038 \leq 0.05$; $p_{\textit{Scene 4- fixation count}} = 0.040 \leq 0.05$).

Table 2. Attention measures acquired for the feedforward information AOIs.

ET metrics	Scene	Low neuroticism		High neuroticism		Permutation results	
		Mean	SD	Mean	SD	Welch's t	*p*- value
Run count	Scene 1	2.200	1.789	0.000	0.000	2.750*	0.038
	Scene 4	9.400	2.510	3.800	2.950	3.233*	0.020
Fixation count	Scene 1	6.000	7.517	0.000	0.000	1.785*	0.040
	Scene 4	49.200	27.372	10.800	8.468	2.997*	0.012
Dwell time	Scene 1	0.120	0.177	0.000	0.000	1.514	0.115
	Scene 4	0.988	0.544	0.216	0.169	3.030*	0.007

*$p < 0.05$, **$p < 0.1$

As Scene 4 shows (Figure 1), the walkway was blocked by framework and stored materials so subjects had to scan ahead to identify alternative paths in order to pass the hazard. The descriptive results in Table 2 indicate that workers who are emotionally stable distributed their attention across the scene to obtain such feedforward information about an alternative path. These results support the results of the permutation simulations, which show that less neurotic individuals have higher situation awareness obtained by dwelling significantly longer ($p_{\textit{Scene 4- dwell time}} = 0.007 \leq 0.05$), fixating more ($p_{\textit{Scene 4- fixation count}} = 0.012 \leq 0.05$), and returning their attention more frequently ($p_{\textit{Scene 4- run count}} = 0.020 \leq 0.05$) to the alternative path in advance.

An aggregated heat map for each group in Figure 2 helped visualize these differences between groups in terms of attentional allocation. The visualizations demonstrate that emotionally stable individuals (those with a low neuroticism score) distribute their attention across the scene by providing a balance between focused and distributed attention. This distribution helps them to maintain situational awareness. In Figure 2, black arrows in the left-most column represent subjects' walking path and dot colors represent individual participants.

Table 3 shows means, standard deviations, and results of permutation tests for three attention measures across Scenes 1-3, which include immediate tripping AOIs. What differentiates the feedforward information-related AOI and immediate tripping-related AOIs is the proximity to participants: the sources of hazards that require feedforward information become immediate tripping hazard when the subject is in close proximity (less than 3 feet) and needs to step over them. Although there are slight differences in descriptive statistics, the null hypothesis cannot be rejected—

there is no difference between the attentional allocation of workers with low and high neuroticism towards immediate tripping hazards (Table 3).

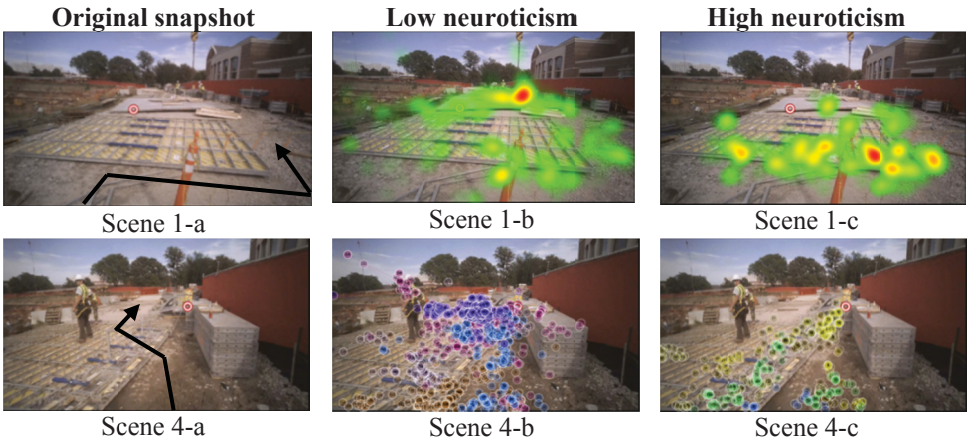

Figure 2. Aggregated scan paths and heat maps in Scene 1 and 4 indicating attentional distribution and visual search strategy within each neuroticism group.

Table 3. Attention measures acquired for the immediate tripping AOIs.

ET metrics	Scene	Low neuroticism		High neuroticism		Permutation results	
		Mean	SD	Mean	SD	Welch's t	*p*- value
Run count	Scene 1	1.200	1.643	0.500	0.577	0.887	0.474
	Scene 2	2.400	1.817	1.600	1.673	0.724	0.475
	Scene 3	9.333	1.862	9.600	5.857	-0.098	0.936
Fixation count	Scene 1	8.800	14.738	2.750	4.856	0.861	0.707
	Scene 2	18.600	16.517	22.600	29.611	-0.264	0.820
	Scene 3	191.000	99.968	202.400	54.925	-0.239	0.822
Dwell time	Scene 1	0.180	0.295	0.065	0.117	0.796	0.809
	Scene 2	0.380	0.327	0.459	0.602	-0.259	0.801
	Scene 3	4.589	1.954	4.279	1.080	0.333	0.760

$^{*}p< 0.05$, $^{**}p< 0.1$

DISCUSSION

The traditional approaches toward preventing accidents mainly focus on quantifying accident data itself. In contrast, the current research investigated individual differences in subjects' personalities to detect behavioral causes of fall-to-same level accidents. The findings show that specific types of personality factors—namely, neuroticism—can predict the at-risk behavior of workers that lead to more accidents. In other words, differences in attentional distribution are modulated by workers' level of emotional stability (neuroticism level).

The consequences of neuroticism appear in the reactions and decisions of individuals. Highly neurotic individuals easily become distracted and lose their attention while working on a task. Inversely, those who are emotionally stable are characterized as calm, unenvious, or relaxed, which helps them stay focused and attentive to their tasks by identifying proximate hazards and responding properly. Further investigation showed that emotionally unstable (highly neurotic) workers engage in risk-taking behavior by not obtaining feedforward information about potential causes of tripping hazard in advance. This finding aligns well with Iverson and Erwin's study (1997) and Sing et al.'s study (2014), which showed that lack of

emotional stability (high neuroticism) might lead lapses in attention, thereby increasing the risk of injuries and number of recorded injuries. Therefore, receiving feedforward information about the path ahead allows workers to adjust their gait proactively before encountering an obstacle or potential tripping hazard. However, the results showed that there is no significant difference between workers with different neuroticism scores when in close proximity to hazards.

Although no tripping accidents occurred during the experiment, investigations into the attentional distribution of workers have shown that emotionally stable workers identify hazards by obtaining feedforward information, which in turn relieves their cognitive load and frees more cognitive resources to detect other potential environmental hazards. Allocating limited attentional resources properly and in a balanced way are important habits for detecting hazards, perceiving them, and making proper decisions to avoid potential accidents.

There are some limitations related to this research that can be addressed by future studies. First, since the construction site is dynamic, the research team had a short amount of time to test subjects, which limited the potential number of participants. Replication experiments should include larger sample sizes. Second, the current study considered only neuroticism out of Big Five personality questionnaire. A future study might investigate the possible combination of personality characteristics that may impact the attentional allocation of workers. Third, the scope of this study was limited to fall-to-same level hazards. Future studies may explore the relationship between attention and personality toward other hazards. Despite these limitations, the results of this study advance our knowledge and understanding of the impacts of personality on attention and the situation awareness of workers toward fall-to-same level hazards. These findings provide a framework for objectively differentiating less situationally aware workers from more situationally aware workers based on their emotional stability.

CONCLUSIONS

Up to 80% of accidents are rooted in the individual differences of workers. Accordingly, identifying the personality traits that impact workers' attention and situation awareness in live construction sites is critical to preventing fall-to-same level accidents. This study examined differences in the attentiveness and situation awareness of workers with different neuroticism levels (emotional stability level). The workers were asked to complete a scenario in a real-world construction site while their attentional distributions were monitored using eye-tracking technique. The results showed that workers who are emotionally stable distribute their limited of attentional resources more broadly in order to obtain feedforward information about sources of hazards in dynamic construction environments. Less neurotic (emotionally stable) individuals periodically look down and scan ahead to remain fully aware of the environment and its associated hazards. However, highly neurotic individuals might experience lapses in attention and fail to detect fall-to-same level hazards in advance by only allocating their attention to where they are stepping. Taken together, this study confirms and clarifies the meaningful connection between individuals' personality traits, attentional distributions, and workplace safety.

Better understanding of these connections provides valuable insights both to practice and theory since the ability to objectively differentiate workers' level of

situation awareness via personality assessment will facilitate accurate detection of at-risk workers. Emotional stability is changeable and can be improved and learnt (Williams et al. 2006), so techniques for stabilizing emotions based on environmental psychology can be used by safety managers to stabilize the emotions of workers and consequently improve their situation awareness. Foreseeably, the results of this study can play a prominent role in transforming current training and educational practices by providing personalized safety guidelines that will yield effective training materials in the future.

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