Accident Analysis and Prevention 70 (2014) 24–32

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

The influence of dispositional mindfulness on safety behaviors: A dual process perspective

Jingyu Zhang[a], Changxu Wu[a,b,*]

[a] Chinese Academy of Sciences, China
[b] State University of New York

ARTICLE INFO

Article history:
Received 14 August 2013
Received in revised form
15 November 2013
Accepted 12 March 2014

Keywords:
Dispositional mindfulness
Safety behaviors
Intelligence
Work experience
Conscientiousness
Dual process

ABSTRACT

Based on the dual process model of human cognition, this study investigated the influence of dispositional mindfulness on operators' safety behaviors and its boundary conditions. In a sample of 212 nuclear power plant control room operators, it was found that both safety compliance and safety participation behaviors were positively influenced by dispositional mindfulness as measured by the 14-item Freiburg Mindfulness Inventory. This effect was still positive after controlling for age, intelligence, work experience and conscientiousness. Moreover, two boundary conditions were identified: the impact of dispositional mindfulness of safety behaviors was stronger among operators who were either more experienced or more intelligent. Theoretically, the framework we used to understand the benefit of mindfulness on safety behaviors has been proved to be useful. Practically, it provides a new and valid criterion that could be used in operators' selection and training program to improve organizational safety.

1. Introduction

Safety at the workplace is an enduring and pivotal issue for high risk industries such as nuclear power plants. While technical failures have been reduced dramatically in the last three decades, unsafe human behaviors have become one of the most important sources of injuries and accidents (Christian et al., 2009). As a result, it is very important to investigate factors that can influence rule compliance and proactive safety behaviors (Griffin and Neal, 2000; Neal and Griffin, 2006). In general, when a candidate factor is (1) a proximal rather than distal predictor of the outcome variables (e.g. driving skills vs. automobile knowledge in predicting accident involvement) and (2) can be changed by deliberate interventions (e.g. training), the factor can then be regarded as a good predictor in both a theoretical (validity) and a practical (alterability) sense.

Recent research suggests that mindfulness may be such a factor. As a concept originally adopted by Buddhist tradition, mindfulness has been defined by modern scientific research as a mental state with the characteristics of present-focused awareness and attention (Bishop et al., 2004; Brown et al., 2007; Langer, 1989). As people differ in their propensity to be mindful, many efforts have been made to evaluate how dispositional mindfulness can influence human health, cognition and behaviors (Herndon, 2008; Kohls et al., 2009; Schmertz et al., 2009). Though most focus on the effect of dispositional mindfulness on well-being (for a review, see Brown et al., 2007), recent research has witnessed its unique contribution to work performance in contexts that are dynamic, complex and safety-oriented (Dane, 2011; Dane and Brummel, 2013; Kass et al., 2011; Zhang et al., 2013). In this kind of environment, being mindful can be helpful since mindful people are more likely to have a broader attentional scope encompassing both internal and external stimuli and therefore may be more able to notice potential risks (Kontogiannis and Malakis, 2009), make unbiased judgments (Kiken and Shook, 2011) and control their unsafe or risky behaviors (Feldman et al., 2011; Lakey et al., 2007).

Though these initial findings are very exciting in establishing a link between dispositional mindfulness and performance, many questions still remain unresolved. In the first place, some research has investigated the influence of mindfulness on task performance, focusing on the efficiency of fulfilling such tasks (Dane, 2011; Shao and Skarlicki, 2009), but given the difference between behaviors that are conducted mainly to enhance efficiency and those mainly to prevent errors, a more relevant framework explaining the relationship between individual mindfulness and safety behaviors in an high risk work setting is needed (see Weick et al., 1999, 2008 for a theory of mindfulness at an organizational level). Second, more research is needed to detect whether the effect of mindfulness can be differentiated from other trait-like variables which have been repeatedly confirmed as important predictors of safety behaviors

* Corresponding author at: Chinese Academy of Sciences and State University of New York.
E-mail address: changxu.wu@gmail.com (C. Wu).

http://dx.doi.org/10.1016/j.aap.2014.03.006
0001-4575/© 2014 Published by Elsevier Ltd.

(e.g. conscientiousness). Without proving the incremental validity of dispositional mindfulness, it is hard to come to any conclusion about its uniqueness. Thirdly, it is important to investigate what variables can promote or hinder the mindfulness-performance relationship since such knowledge will expand our understanding of the inner mechanisms of mindfulness (e.g. how mindful practice can influence deliberate thinking or intuitive decision making). However, other than a very few attempts (Dane, 2011; Zhang et al., 2013), this question has received inadequate attention.

To address the above issues, in our research, we drew upon relevant literature from the dual process model of human cognition to establish a framework to account for the influence of mindfulness on safety behaviors (Brown and Ryan, 2003; Dane, 2011; Evans, 2008). In particular, we investigated whether the effect of mindfulness is additive to conscientiousness and bounded by workers' individual differences in their experience and intelligence, which are the two important characteristics of the dual process system.

1.1. A dual process perspective about safety behaviors

In high risk organizations, safety behaviors are important since lack of safety behaviors are the direct antecedents of accidents and injuries (Neal and Griffin, 2006). Based on a human performance framework, Griffin and Neal (2000) defined safety behaviors as behaviors that constitute work performance for safety-oriented tasks. They further categorized this construct into an in-role dimension and an extra-role dimension. Termed 'safety compliance', the in-role dimension refers to the core activities that are formally required to maintain workplace safety, such as adhering to standard work procedures. Meanwhile, the extra-role dimension, termed 'safety participation', describes proactive behaviors that are not directly linked to individual safety but that nevertheless help colleagues and entire organization improve safety. These behaviors include activities such as warning others when their actions may cause danger or making suggestions to the organization to improve safety related regulations.

Like all kinds of human performance, the operator's safety behavior is governed by two basic cognitive systems: (1) an unconscious, autonomous and effortless processing system (system 1) that functions at high speed, driven mainly by intuitions, heuristics, past experiences, etc.; and (2) a conscious, controlled, effortful processing system (system 2) using reasoning, fluid intelligence, etc., in a slow and serial manner (for a recent review, see Evans, 2008). Problems in the use of the dual process system can undermine operator safety behaviors.

Consider the case of operators working in a nuclear power plant control room. In most cases, operators are performing their tasks using an experience-based heuristic judgment (system 1) (Endsley, 1995; Klein, 1999). By comparing observed stimuli with prototypes stored in long-term memory, certain schemas including knowledge (e.g. alternative solutions) and actions (e.g. turning a machine off) will be activated and implemented in an associative manner without people being aware of the whole process. Generally, this is very effective in dealing with complex information and familiar situations. However, if operators erroneously categorize a new stimuli pattern as an old but fundamentally different prototype or they have stored wrong or biased prototypes (e.g. a previous established belief that taking shortcuts is harmless), they are likely to make a wrong decision. This automatic system is also important in dealing with social-motivational information. For example, recent studies have suggested that implicit attitudes (as measured by reaction time based unconscious favor over safety words) could influence safety behaviors beyond mere consideration of their explicit attitudes (Burns et al., 2006). Moreover, system 1 is important for emotional experience such as fairness perception and empathy, two important antecedents of helping and participatory behaviors (Johnson and Lord, 2010). However, if an operator has established negative implicit attitudes or emotions, it is hard to remove their effect. While biased decisions may directly hinder safety compliance behaviors, the involvement of system 1 in the social-motivational process can play an important role in safety participatory behaviors (Neal and Griffin, 2006). As a result, the failure to use system 1 can reduce both facets of safety behaviors.

When operators encounter a new event they have never experienced before, system 2 will be activated. In this situation, operators' attention is captured by odd stimuli (or patterns) that cannot be matched with any previously established prototype. Therefore, they have to allocate their limited attentional resources to gain further information. With no ready solutions in mind, they will reason logically based on this information and basic rules and principles to form certain hypotheses about the possible root causes of the problems and implement a series of experimental solutions. However, the use of system 2 can deplete one's limited mental resources and be stressful, especially in case when under a heavy workload (Vidulich and Tsang, 2012; Xie and Salvendy, 2000). When their cognitive resources are depleted, it is very likely that they will encounter cognitive failures (e.g., fail to maintain sustained attention, make correct judgments or execute a planned action) or suffer emotional burdens such as burnout and reduced motivation (Wallace and Vodanovich, 2003; Turner et al., 2012). In all these failures to use system 2, both safety compliance and participation behaviors can be undermined.

1.2. Mindfulness and safety behaviors

It can be reasoned from current evidence that mindfulness can improve safety behaviors by improving the use of the dual system. As indicated by recent analyses, mindfulness is related to metacognition and executive attention which can moderate the dual system in a positive way (Brown and Ryan, 2003; Brown et al., 2007; Dane, 2011). This benefit is achieved through an improved attention toward the present moment (Brown et al., 2007; Langer, 1989) which can improve the tendency to process information received from both external stimuli and internal mental states in a deeper and more open manner (see Chiesa et al., 2011 for a recent review).

On the one hand, mindfulness is believed to improve the benefit and reduce the harm of using system 1. Being more aware of their otherwise unattended inner experiences and intuitions (Brown and Ryan, 2003; Ostafin et al., in press), mindful people are more likely to learn from these and thus improve their performance (Dane, 2011; Rerup, 2005). Evidence also suggests mindfulness training, as well as a higher level of dispositional mindfulness, can improve situational awareness,[1] which is generally known as a state of "knowing what's going on". This is highly dependant on the use of past experience and pivotal for performing functionally in high risk industries (Endsley, 1995; Vidulich and Tsang, 2012), thus providing a good basis for all types of safety behaviors (Feldman et al., 2011; Kass et al., 2011; Mrazek et al., 2013). Moreover, in the literature on self-regulation, mindfulness has been found to reduce

[1] Dispositional mindfulness and situational awareness are conceptually different from each other. Whereas the former is a trait-like construct that reflect one's proneness to maintain a present-focused attention to both internal and external environment, the latter reflects a mental state about knowing the task-related environment. In general, we can use trait-state, general-specific, and antecedent-consequence framework to understand their relationship. While mindful people are more prone to have a high level of situational awareness (SA) in various kinds of situations, people having high level of situational awareness in a particular task environment may not have high SA in another situation nor necessarily have higher level of mindfulness.

the link between an implicit favoring of some negative object (e.g. a positive and automatic desire for cigarettes) and real interaction with such objects (e.g. smoking) (Levesque and Brown, 2007; Ostafin et al., in press). Given that safety behaviors can be influenced by an implicit desire to take shortcuts (Burns et al., 2006; Zohar and Erev, 2007), being mindful can promote safety performance by attenuating such a link. Moreover, recent research has found evidence that mindfulness can improve job satisfaction, intrinsic motivation and reducing emotional burdens which are also important predictors of safety behaviors (Hülsheger et al., 2013).

On the other hand, mindfulness has been found to increase the thoroughness and efficiency of using system 2. As suggested by Langer (1989), mindful people are more likely to treat everything they encounter as if for the first time and are reluctant to simplify their perceptions. This tendency is believed to be especially important for safety issues in high risk industries (Weick et al., 1999), since the consequence of overlooking seemingly minor problems may be disastrous. In addition, mindful people are less likely to be influenced by negative emotional burdens (Jha et al., 2010; Hülsheger et al., 2013). Since workers in nuclear power plants generally face a heavy workload and risky environment (Vicente et al., 2004; Warm et al., 2008), it is important for the conduct of safety behaviors to keep staff sheltered from these factors by making the use of system 2 more efficiently (Kecklund and Svenson, 1997; Turner et al., 2012). This efficiency may also reduce cognitive failures such as attentional deviation, memory bias and action slips (Dane, 2011; Mrazek et al., 2013; Herndon, 2008).

Taken together, it seems that mindful people are more likely to use their autonomous processing system beneficially implementing the effortful processing system more thoroughly and efficiently. As all these are useful for those working in a dynamic, complex and error-intolerant environment, we postulate that people who are dispositionally mindful will have a higher level of safety performance in a high risk industry such as nuclear power plants. Therefore, Hypothesis 1 is:

H1. Dispositional mindfulness is positively related to safety behaviors (compliance and participation).

1.3. The incremental effect of mindfulness over conscientiousness

The above analyses are useful to understand how mindfulness relates to safety behaviors with regard to its additive power over other trait-like variables such as conscientiousness. Since the effect of conscientiousness results from a higher level of effortful control over one's behavior (Evans, 2008) which is also a function of being mindful (Giluk, 2009), it must correlate with dispositional mindfulness and this shared variance can in turn predict safety behaviors through its effect in reducing cognitive failures (Herndon, 2008; Wallace and Vodanovich, 2003). However, as being mindful also has benefits related to improved attention and decision making, theoretically speaking, it should cast more influence on operators' safety performance even if the effect of conscientiousness is statistically controlled.

Empirical research has proved the first assertion that dispositional mindfulness and conscientiousness are mutually correlated (Giluk, 2009). However, studies of its influence on real world performance are limited, producing mixed results. In an investigation of service workers, Dane and Brummel (2013) found that the influence of mindfulness on task performance diminished when conscientiousness is entered into the regression. However, by investigating workers in two newly built nuclear power plants, Zhang et al. (2013) found dispositional mindfulness was capable of predicting safety performance even after controlling for conscientiousness. However, this effect was only found among high-complexity task holders (control room operators), not less complex task holders (field operators). Although these results were only preliminary, it seems that the effect of mindfulness relies partly on task requirements. Compared with service workers, control room operators' tasks in nuclear power plants are not only dynamic, but also complex and error-intolerant. In such an environment, it is not enough to be merely conscientious: operators need to be very alert to all external stimuli and make intensive use of their knowledge and reasoning abilities. In this situation, the effect of mindfulness can be predicted as higher. We therefore postulate Hypothesis 2:

H2. Dispositional mindfulness adds more explanatory power in predicting safety behaviors (compliance and participation) after controlling for conscientiousness.

1.4. The boundary conditions of mindfulness: experience and intelligence

In addition to the task requirement factor, the mindfulness-performance relationship must be dependent, from the dual system perspective, on two other important characteristics of individuals: experience and intelligence.

First, from the associative and experiential nature of system 1, it can be reasoned that the benefit of increased awareness over one's automatic processes is dependent on one's work experience (Dane, 2011; Evans, 2008). This is because the latter determines the comprehensiveness and accuracy of domain specific intuitions (Kahneman and Klein, 2009). Whereas novices' intuitions are more likely to arise from relatively simple and bias-prone heuristics, experts' intuitions tend to be formed through a set of refined, complex and domain-specific schemas (Dane and Pratt, 2007). While being mindful can expand one's internal attentional breadth and thus attunes individuals to their intuitions, it might be even more beneficial for those with more experience to use their intuition to guide their decisions and behaviors (Rerup, 2005). On the other hand, for a novice who lacks expertise within the task domain, attending to these inadequate intuitions may hinder his/her performance by triggering an action that seems right but is erroneous. This was raised by Dane (2011) but it was not confirmed in subsequent research on service workers (Dane and Brummel, 2013). One explanation is that the low task complexity of the service workers and the relatively small experience range in their research may have restricted the observability of such an effect. In the present research, as we investigate workers with a higher task complexity with a broader range of experience, the interaction between experience and dispositional mindfulness may have a higher chance of occurring. As a result, we postulate the effect of mindfulness on operators' safety behavior is moderated by their work experience as in Hypothesis 3:

H3. The relationship between mindfulness and safety behaviors is more positive among experienced than less experienced operators.

Finally, an often overlooked fact is that the amount of information processed by a mindful individual and the difficulty of processing such information is greater compared to those are less mindful. Although mindfulness can improve the efficiency of system 2 by reducing interference from irrelevant sources, the information flow from a broadened attentional breadth, coupled with the reluctance to simplify, lead unavoidably to an increase in the input to system 2 and the overall demands placed upon it. One manifestation of this is that the practice of mindfulness is generally highly time-consuming (Weick et al., 2008; Zhang et al., 2013). However, since some complex problems cannot be resolved even if more time is spent–and in many situations, time is under pressure–the processing speed of system 2 can be a bottleneck. As one's intelligence can be seen as a measurement of the ability to use system 2 (Gottfredson, 1997; Stanovich, 1999), it can be argued that an individual's intelligence could be the moderator of the mindfulness-performance relationship. As a result, we further propose a fourth hypothesis:

H4. The relationship between mindfulness and safety behaviors is more positive among more intelligent than less intelligent operators.

1.5. Overview of the present research

In this study, we focused on the influence of dispositional mindfulness on safety behaviors of control room operators in nuclear power plants. We chose this special group of workers because, in such a dynamic, complex and safety-oriented environment, the benefit of being mindful is more likely to be witnessed (Weick et al., 2008). We first examined whether trait mindfulness could predict safety behaviors and add more predictive power when the effect of conscientiousness was accounted for. We further investigated whether the influence of mindfulness is moderated by operators' individual differences in their experience and intelligence.

2. Methods

2.1. Participants and procedure

Approved by the Chinese National Energy Administration and our institution level ethics review board, this research was part of a large project dedicated to improving current personnel selection standards in the nuclear industry. Our research, focused on experienced control room operators from plants that have been safely running for years. With the help of plant managers, we organized surveys (on mindfulness, personality, self-reported safety behaviors and background information) as well as cognitive tests (on intelligence) during the plants' regular training sessions. All participating operators were told that their participation was important for the future nuclear safety management and their responses would not be used for their promotion and other human resource decisions. In total, 212 control room operators from two major nuclear energy corporations in mainland China agreed to participate in this research on an anonymous basis. All participants were male between 25 and 40 years old (M = 30.4, SD = 2.57).

2.2. Measurement

2.2.1. Dispositional mindfulness

The Chinese version of the 14-item Freiburg Mindfulness Inventory (FMI-14) originally developed by Walach et al. (2006) and validated in a Chinese context by Zhang et al. (2013) was used in our study to measure dispositional mindfulness. As the measure does not require the respondents to have any previous knowledge of mindful meditation, FMI-14 has been proved to be reliable in previous research (Walach et al., 2006). Participants were asked to rate how often they had experiences such as "I pay attention to what is behind my actions" in the recent month (1: never – 4: very often). The overall α was .86.

2.2.2. Conscientiousness

The 12-item Conscientiousness scale from the Chinese version of the NEO Five Factor Inventory was used in our study (Costa and McCrae, 1992). The participants rated each statement on a 5-point Likert scale (0: strongly disagree – 4: strongly agree). Sample items included "I'm pretty good about pacing myself so as to get things done on time" and "I waste a lot of time before settling down to work" (reverse coded). In the current sample, the alpha coefficient was .80.

2.2.3. Work experience

The experience level of operators was collected through self-reports by asking how many years the operators had worked in their current positions. This ranged from 4 to 18 years (M = 7.75, SD = 2.69).

2.2.4. Intelligence

The operators completed the Raven's Standard Progressive Matrices (SPM) during training. The SPM is the most widely used nonverbal tests of intelligence (Raven et al., 1998; Raven, 2000). For the current research, the testing was conducted with a 40-minute time limit. The raw scores were transformed into standard scores based on age-related norms (Zhang and Wang, 1989). The average score was 113.1 for this sample (SD = 8.32).

2.2.5. Safety performance

Safety compliance and participation were measured by two three-item scales adapted from Neal and Griffin's (2006) original scales (see Table 2 for detailed wording). The operators were asked to rate their own safety behaviors in the past three months on a 5-point Likert scale (1: almost never – 5: almost always). Sample items can be found in Table 2. The Cronbach's alpha coefficients for safety compliance and safety participation were .84, and .85, respectively.

2.2.6. Measurement model

The measurement model was first validated. As suggested by Little et al. (2002), we used item parcels instead of original items to represent contentiousness and mindfulness scales because it has many psychometric advantages given the quantity of items in each scale. In doing so, an exploratory factor analysis was first conducted using all 32 items (14 for mindfulness, 12 for conscientiousness, 3 for safety compliance and 3 for safety participation) to check whether each scale is uni-dimensional (a prerequisite for using item parcels). Following O'Connor's (2000) recommended procedure, results of parallel analysis (PA) showed that the first four factors explaining 47% of total variance should be maintained. Using maximum likelihood extraction and promax rotation, it was found that all items were properly loaded on their expected factors.[2] This result suggests that each scale is uni-dimensional and the four-factor measurement model is generally valid.

Next, we followed the item-to-construct procedure (Little et al., 2002) to build four parcels for mindfulness and four parcels for conscientiousness. We balanced high loading items with low loading items and distributed the reverse coded items evenly. By conducting confirmatory factor analysis (CFA), we examined the model fit of several alternative measurement models (summarized in Table 1). The results suggest that the four factor solution (mindfulness, conscientiousness, safety compliance and participation loaded on separate latent variables) is an acceptable solution (Hu and Bentler, 1999). It outperforms all other alternative models including the best three-factor solution in which all 6 items of safety behaviors are loaded on one latent variable, $\Delta\chi^2$ (1, N = 212) = 158.2, p < .001, as well as the best two factor solution in which 8 parcels of conscientiousness and mindfulness are further combined, $\Delta\chi^2$ (5, N = 212) = 337.0, p < .001, and in addition, the single factor solution, $\Delta\chi^2$ (6, N = 212) = 696.7, p < .001. For the four factor solution, all factor loadings were at acceptable levels (see Table 2). Taken together, the expected measurement model is validated.

[2] For conciseness, detailed information about the parallel analysis and the item loading table of this exploratory factor analysis are not shown, but interested readers can contact the corresponding author to get this information.

Table 1
Assessment of alternative measurement models ($N = 212$).

Model types	*df*	χ^2	CFI	NNFI	RMSEA
One factor model	77	820.8	.50	.41	.21
The best two-factor model (1: FMI + C; 2: SC + SP)	76	461.1	.74	.69	.16
The best three-factor model (1: FMI; 2: C; 3: SC + SP)	72	282.6	.86	.83	.12
Four-factor model (expected model)	71	124.1	.96	.95	.06

Note: C = contentiousness scale of NEO Five Factor Inventory; FMI = Freiburg Mindfulness Inventory; SC = Safety Compliance; SP = safety participation.

3. Results

3.1. Initial analysis

Among the nuclear plants investigated, operators from organization 1 ($N = 111$) were lower in conscientiousness ($M_{difference} = 2.23$, Cohen's $D = .40$) and intelligence ($M_{difference} = 3.05$, Cohen's $D = .37$) than those from organization 2 ($N = 102$). To control for any difference between them, a dichotomous variable named 'Organization' was created for further analysis. In terms of zero-order correlations, safety compliance was correlated with younger age, less work experience, higher conscientiousness and dispositional mindfulness, whereas safety participation was correlated with higher intelligence, conscientiousness and dispositional mindfulness. There was also a significant correlation between dispositional mindfulness and conscientiousness ($r = .46$, $p < .001$). These patterns were consistent with previous research when the sample included a wide range of workers' experience in which a decline in safety performance among older operators can be observed (Ng and Feldman, 2008). Table 3 presents the descriptive statistics and inter-correlations among all variables.

3.2. Hierarchical regression analyses

In order to test our hypotheses, a series of multiple hierarchical regression analyses were conducted following the recommendations of Aiken and West (1991). The summed item scores of safety compliance and participation were treated as dependent variables and all other variables were standardized before entering the regression models.

In order to test H1, age, organization, work experience, and intelligence were entered as control variables in step 1. In step 2, dispositional mindfulness was entered (see Table 4). In the regression model predicting safety compliance, adding dispositional mindfulness into the model significantly increased the model fit ($\Delta R^2 = .10$, $F_{(1,206)} = 23.67$, $p < .001$) and the beta coefficient of mindfulness was positive ($\beta = .32$, $p < .001$). A similar pattern was found for safety participation where the model fit was also improved ($\Delta R^2 = .06$, $F_{(1,206)} = 13.50$, $p < .001$) and the beta coefficient was significant ($\beta = .25$, $p < .001$). These results indicate a positive relationship between dispositional mindfulness and safety performance, thus H1 is confirmed.

In order to test H2–H4, age, organization, work experience, intelligence and conscientiousness were entered as control variables in step 1. Dispositional mindfulness was entered at step 2. In step 3, the interaction terms between mindfulness and work experience, as well as mindfulness and intelligence were entered into the model (see Table 5). In both models, the coefficients of conscientiousness were significant in predicating safety compliance ($\beta = .30$, $p < .001$) and participation ($\beta = .20$, $p < .001$) at step 1. Moreover, the coefficients of mindfulness added at step 2 were all significant for both criteria. Meanwhile, the coefficients of conscientiousness dropped. Using the Sobel's tests of mediation (Baron and Kenny, 1986), it was found that mindfulness partially mediates the influence of conscientiousness in both facets of safety performance. Beyond simply confirming H2, this finding also suggests that mindfulness is a more proximal predictor of safety behaviors than contentiousness.

In step 3 of both models, adding the two interaction terms significantly improved the model fit, and the coefficients were also positive and significant (though the term between mindfulness and intelligence was only marginally significant in predicting safety participation, $\beta = .13$, $p = .053$). We further tested and depicted the simple slope tendency following Aiken and West's (1991) suggested procedure. By comparing more experienced operators (one standard deviation above the average) with less experienced (one standard deviation below the average), it can be seen that the effect of mindfulness in predicting safety compliance was more positive for the former ($\beta = .48$, $p < .001$) but insignificant ($\beta = .03$, *ns.*) for the latter. A similar pattern was found for predicting safety participation: positive ($\beta = .36$, $p < .001$) for operators having more

Table 2
Factor loadings of all items and parcels for the four-factor solution ($N = 212$).

Variables and items (or parcels)	1	2	3	4
Safety compliance				
SC-1. I use all necessary means to guarantee work safety in my job	.68			
SC-2. I use the correct safety procedures for carrying out my job	.86			
SC-3. I ensure the highest levels of safety when I carry out my job	.86			
Safety participation				
SC-1. I promote the safety program within the organization		.68		
SC-2. I put in extra effort to improve the safety of the workplace		.84		
SC-3. I voluntarily carry out tasks or activities that help to improve workplace safety		.94		
Mindfulness				
Parcel 1 (mean of 3 items: FMI-9, FMI-5, FMI-11)			.83	
Parcel 2 (mean of 3 items: FMI-8, FMI-4, FMI-1)			.78	
Parcel 3 (mean of 4 items: FMI-7, FMI-6, FMI-14; FMI-13 [R])			.72	
Parcel 4 (mean of 4 items: FMI-10, FMI-12, FMI-3, FMI-2)			.85	
Conscientiousness				
Parcel 5 (mean of 3 items: NEO-FFI-60, NEO-FFI-50, NEO-FFI-45 [R])				.77
Parcel 6 (mean of 3 items: NEO-FFI-20, NEO-FFI-55 [R], NEO-FFI-5)				.74
Parcel 7 (mean of 3 items: NEO-FFI-35, NEO-FFI-10, NEO-FFI-30 [R])				.74
Parcel 8 (mean of 3 items: NEO-FFI-40, NEO-FFI-25, NEO-FFI-15 [R])				.66

Note: FMI = Freiburg Mindfulness Inventory; NEO-FFI: NEO Five Factor Inventory; number after scale name indicates its original item number; R = reverse coded.

Table 3
Descriptive statistics and zero-order correlations of all variables ($N = 212$).

	M	SD	1	2	3	4	5	6	7
1. Age	30.39	2.57	–						
2. Organization	.48	.50	−.06	–					
3. Work experience	7.75	2.69	.84**	.03	–				
4. Intelligence	113.13	8.32	−.10	−.18*	−.10	–			
5. Conscientiousness	46.58	5.64	−.06	−.20*	−.05	.12	–		
6. Mindfulness	45.77	6.44	−.15*	−.06	−.11	.09	.46**	–	
7. Safety compliance	14.37	1.23	−.15*	−.07	−.15*	.11	.32**	.34**	–
8. Safety participation	13.04	2.17	−.05	−.05	−.02	.14*	.21**	.26**	.54**

* $p < .05$.
** $p < .01$.

Table 4
Hierarchical multiple regression predicting safety performance to test H1 ($N = 212$).

Independent variables	Safety compliance		Safety participation	
	Step 1	Step 2	Step 1	Step 2
1. Age	−.10	−.04	−.09	−.05
2. Organization	−.06	−.04	−.03	−.02
3. Work experience	−.05	−.07	.07	.06
4. Intelligence	.09	.06	.14+	.12+
5. Mindfulness		.32**		.25**
Adjusted R^2	.02	.11**	.01	.06**
ΔR^2	.04	.10**	.02	.06**

+ Significant at .10 level.
** Significant at .01 level.

experience but insignificant ($\beta = .06$, *ns.*) for those with less (see Fig. 1). Therefore, H3 is fully confirmed.

Similar results were also found by comparing operators who were more intelligent (one standard deviation above the average) with those who were less (one standard deviation below the average). It was found that the effect of mindfulness in predicting safety compliance was stronger for the former ($\beta = .39$, $p < .001$) than the latter ($\beta = .11$, *ns.*). This was also true for predicting safety participation: stronger ($\beta = .34$, $p < .001$) for those with a higher level of intelligence but weaker ($\beta = .08$, *ns.*) for those with a lower level (see Fig. 2). Therefore, H4 is confirmed.

4. Discussion

The present study investigated the effect of dispositional mindfulness on operators' safety behaviors in the context of nuclear power plant control rooms. Based on its interaction with the dual process system, the research raised several falsifiable hypotheses. We found that dispositional mindfulness explained a unique ratio of variance in predicting safety compliance and safety participation behaviors even after accounting for the effect of conscientiousness. Moreover, work experience and intelligence were found to be moderators of such a link: namely, the effect of mindfulness is stronger among those who are more experienced and more intelligent.

The study provides several valuable pieces of information concerning the mindfulness-performance relationship based on the dual process framework. Firstly, the research suggests that the working environment is an important precondition for the effectiveness or otherwise of mindful people. On the one hand, a dynamic environment may not be enough to make dispositional mindfulness a more important predictor of performance than other trait-like factors (e.g. conscientiousness). In circumstances where errors can be prevented quite easily, people who are mindful may not necessarily perform better, especially when conscientiousness is controlled for. For example, in a mass-production factory, assembly line workers are working in a dynamic environment, but their tasks are repetitive, non-complex and efficiency-oriented (a certain number of errors can be tolerated). In doing such tasks, the benefit of having a larger attentional breadth encompassing complex information from both the external and internal environment (the unique property of being mindful) will not outweigh its drawbacks (being time-consuming) which can in turn undermine efficiency. However, a high capability of behavioral control (a function shared with being conscientious) is still important as workers need to concentrate on their work in a highly organized manner. This may be the reason why mindfulness cannot explain more variance in their performance over and above conscientiousness when in a less complex and efficiency-oriented environment as shown in the study by Dane and Brummel (2013). On the other hand, in a context that is not only dynamic but also complex and error-intolerant (nuclear power plants are a perfect case), the benefits of mindfulness are much clearer. Though being dynamic, complex and error-intolerant are characteristics of most high risk organizations (nuclear power plants, air traffic control, etc.), such traits are also required by many important occupations, from drivers (Feldman et al., 2011) to

Table 5
Hierarchical multiple regression predicting safety performance to test H2–H4 ($N = 212$).

Independent variables	Safety compliance			Safety participation		
	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
1. Age	−.07	−.04	.02	−.08	−.05	.00
2. Organization	.00	−.01	−.03	.01	.00	−.02
3. Work experience	−.06	−.07	−.13	.06	.06	.01
4. Intelligence	.06	.05	.08	.12+	.11	.14*
5. Conscientiousness	.30**	.20**	.17*	.20**	.11	.09
6. Mindfulness		.23**	.25**		.20**	.21**
7. Mindfulness × Work experience			.23**			.15*
8. Mindfulness × Intelligence			.14*			.13+
Adjusted R^2	.10**	.14**	.20**	.04*	.07**	.09**
ΔR^2	.12**	.04**	.07**	.06*	.03**	.04*

+ Significant at .10 level.
* Significant at .05 level.
** Significant at .01 level.

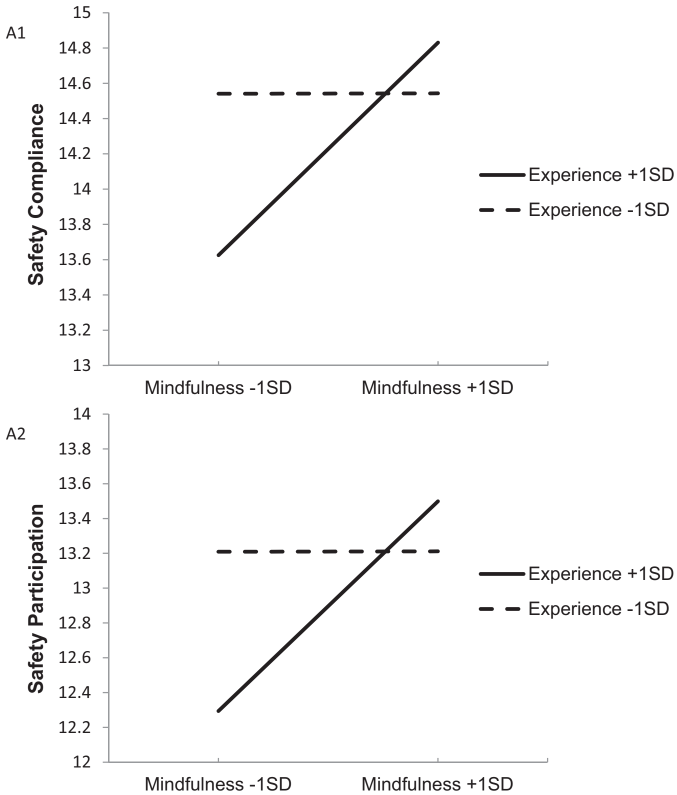

Fig. 1. The joint effect of work experience and dispositional mindfulness on safety compliance (A1), and safety participation (A2), controlling for conscientiousness.

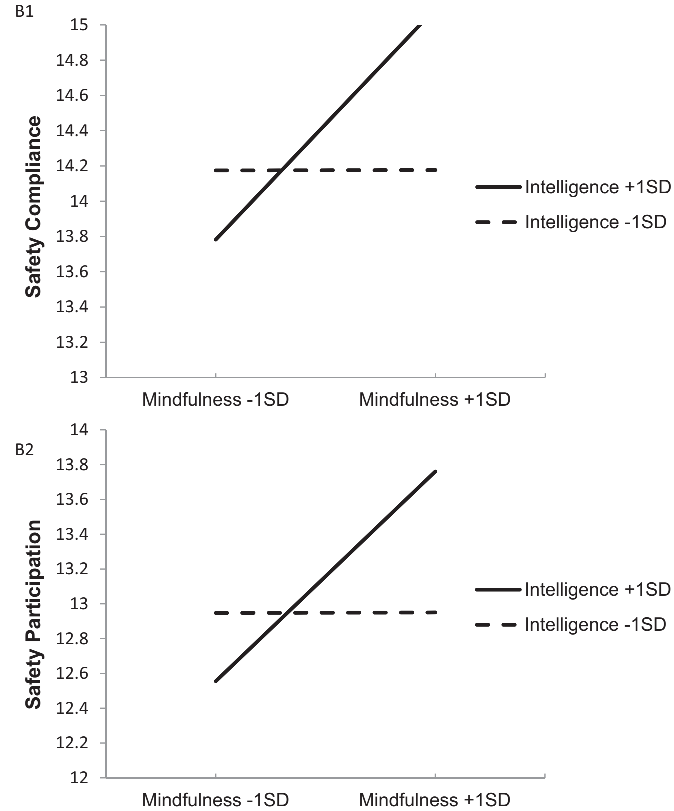

Fig. 2. The joint effect of intelligence and dispositional mindfulness on safety compliance (B1), and safety participation (B2), controlling for conscientiousness.

entrepreneurs (Rerup, 2005) or military personnel (Jha et al., 2010). Future studies may acquire valuable information by exploring the effect of mindfulness on the work performance of these groups of people.

Secondly, the present study found work experience to be a moderator of the mindfulness-performance relationship. Among more experienced operators, the link between mindfulness and both types of safety behaviors was stronger than those for less experienced workers. But a further examination of the data suggested that there was a negative effect of work experience on safety compliance behaviors (although only marginally significant). A possible explanation is that experienced workers generally have more confidence in their abilities so they may operate in a way that is not exactly prescribed in formal rules or regulations. Such confidence (or overconfidence) and deviation from normal operations may bring potential problems in the high risk industries. In other words, greater experience is not only related to an increase in correct schemas and heuristics but can also be coupled with bad habits and beliefs such as taking short cuts is harmless. However, our analyses suggested that only the experienced non-mindful operators are those who would fail to follow the rules. This suggested that mindful people cannot only draw upon the benefits of their experience but also avoid its potentially negative influences. This result has important practical implications suggesting that training people to be mindful might be even more valuable for experienced workers than novices.

The present study is also the first, to the best of our knowledge, that has found that mindfulness and intelligence interact to influence operator performance–something that was not incorporated in Dane's (2011) framework. As suggested by Brown and Langer (1990), new perspectives and insights are more likely to emerge since people in a mindful state can be "open to several ways of viewing the situation" and "create new categories to represent the reality". However, they did not mention whether the processing of these new views and categories is also dependant on one's intelligence (but see Sternberg, 1985). In addition, in many real world contexts, even the most innovative perspectives or insights still need effortful processing before being successfully fulfilled. In this way, we may consider intelligence as a bottleneck of mindfulness. It is worth noting that there is an alternative explanation beyond this information flow perspective in which mindfulness is treated as a protector of the intelligence-performance relationship. Its rationale is based on the fact that intelligent people are more sensitive to stress which mindfulness is helpful in reducing. However, as the present study is only correlational, it is hard to know which explanation is superior, therefore, further experimental research might be necessary.

Several limitations of the present study should also be considered. In the first place, we found the single factor solution of mindfulness best fit the current data which is consistent with some previous research (Walach et al., 2006). However, some other studies have found the scale to be two-dimensional (Kohls et al., 2009; Zhang et al., 2013). As these different may be caused by different sample properties, caution must be taken in using this scale for different occupational groups. Second, the cross-sectional nature of this study precludes any hasty conclusion about causality. It is possible that mindfulness and safety behaviors are simultaneously influenced by other unknown factors (e.g., safety training). However, our study has at least shown that conscientiousness, experience and intelligence were not among these factors. Future research may benefit from using a longitudinal and controlled experimental design to investigate whether mindfulness training may improve safety performance via the change of dispositional mindfulness.

Thirdly, the present study used operators' self-reports to measure both dispositional mindfulness and safety performance which may be biased due to the inaccuracy of self-evaluation and common method variance (Podsakoff et al., 2003). However, it should be mentioned that self-reported safety behavior has been proven to be a reliable measure in a great deal of safety research. Moreover, in the culture of nuclear power plants, there is an emphasis on self-monitoring and an open atmosphere encouraging people to freely report their errors and near-misses. In addition, anonymity was guaranteed in the current research to reassure the participants that they could freely express their honest opinions. As a result, such potential biases were minimized. As we also used another self-reported measure (conscientiousness) as a control variable and the moderators were measured in different ways (cognitive tests and objective time) to triangulate the analyses, it is less likely that the results were distorted from the common method bias. Nonetheless, future research might still benefit from using more objective behavioral records (e.g. video recorded behaviors and/or log-files of the system).

In addition, while all hypothesized relationships were found to be significant, we only found small to medium effect sizes as manifested in ΔR^2 (.05–.10). While these sizes are quite common in social psychological research, they are relative small by the standard of safety engineering. It should be nevertheless noted that the effects might have been underestimated in our research. Indeed, the additive effect of mindfulness over conscientiousness (the confirmation of H2) provides a very conservative estimation of the true relationship between mindfulness and safety behaviors because both common method variance and a substantive true variance have been partialled out (Neal and Griffin, 2006; also see Podsakoff et al., 2003; Richardson et al., 2009). In addition, the interactional effect between mindfulness and intelligence may also be underestimated in our research since our sample had a rather restricted distribution of intelligence (M = 113.13; SD = 8.32). Future research may observe a larger effect using samples with larger variations. In addition, subsequent research may improve the model fit by investigating more proximal predictors such as emotional experience, motivation and cognitive errors which have been proposed as possible mediating mechanism but not explicitly measured in the current study.

5. Conclusion

This study expands our understanding of the influence of dispositional mindfulness on safety behaviors in a dynamic, complex and error-intolerant work setting. In general, the dual process model seems to be a good framework to understand the effect of mindfulness in relation to real world performance. Specifically, the additive power over other classic individual difference factors suggests that dispositional mindfulness is a good predictor of safety performance. In addition, the boundary conditions that have been identified in this study can guide future research to rethink the interaction between mindfulness and the dual system of human cognition. In a practical sense, it is therefore worth trying to use individual level mindfulness training as a measure to improve workplace safety. However, our research suggests that more experienced workers may be in greater need of such training for it may help reduce some experience-related negative effects, while more intelligent workers are also more likely to benefit from such training as being mindful may help them fully utilize their abilities.

Acknowledgements

This work is supported by the National Basic Research Program of China (2011CB302201), the Natural Scientific Foundation of China (31300875, 31070915 and 71371179), the Key Research Program of the Chinese Academy of Sciences (KJZD-EW-L04) and the Youth Project of the Scientific Foundation of Institute of Psychology, Chinese Academy of Sciences (Y1CX333005).

We appreciate the comments from the anonymous reviewers for this paper. We also thank Magnus Wilson, Dr. Yongjuan Li, Dr. Feng Li and Dr. Xinwen Bai for their helpful comments and Lulu Wang and Yaoshan Xu for their effort in data collection.

References

Aiken, L.S., West, S.G., 1991. Multiple Regression: Testing and Interpreting Interactions. Sage Publications, Newbury Park, CA.
Baron, R.M., Kenny, D.A., 1986. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J. Pers. Soc. Psychol. 51 (6), 1173–1182.
Bishop, S.R., Lau, M., Shapiro, S., Carlson, L., Anderson, N.D., Carmody, J., et al., 2004. Mindfulness: a proposed operational definition. Clin. Psychol. Sci. Pract. 11 (3), 230–241.
Brown, J., Langer, E., 1990. Mindfulness and intelligence: a comparison. Educ. Psychol. 25 (3–4), 305–335.
Brown, K.W., Ryan, R.M., 2003. The benefits of being present: mindfulness and its role in psychological well-being. J. Pers. Soc. Psychol. 84 (4), 822–848.
Brown, K.W., Ryan, R.M., Creswell, J.D., 2007. Mindfulness: theoretical foundations and evidence for its salutary effects. Psychol. Inq. 18 (4), 211–237.
Burns, C., Mearns, K., McGeorge, P., 2006. Explicit and implicit trust within safety culture. Risk Anal. 26 (5), 1139–1150.
Chiesa, A., Calati, R., Serretti, A., 2011. Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. Clin. Psychol. Rev. 31 (3), 449–464.
Christian, M.S., Bradley, J.C., Wallace, J.C., Burke, M.J., 2009. Workplace safety: a meta-analysis of the roles of person and situation factors. J. Appl. Psychol. 94 (5), 1103–1127.
Costa, P.T., McCrae, R.R., 1992. Neo PI-R Professional Manual. Psychological Assessment Resources, Odessa, FL.
Dane, E., 2011. Paying attention to mindfulness and its effects on task performance in the workplace. J. Manage. 37 (4), 997–1018.
Dane, E., Brummel, B.J., 2013. Examining workplace mindfulness and its relations to job performance and turnover intention. Hum. Relat., 1–24 (online version).
Dane, E., Pratt, M.G., 2007. Exploring intuition and its role in managerial decision making. Acad. Manage. Rev. 32, 33–54.
Endsley, M.R., 1995. Toward a theory of situation awareness in dynamic systems. Hum. Factors 37 (1), 32–64.
Evans, J., 2008. Dual-processing accounts of reasoning, judgment, and social cognition. Annu. Rev. Psychol. 59, 255–283.
Feldman, G., Greeson, J., Renna, M., Robbins-Monteith, K., 2011. Mindfulness predicts less texting while driving among young adults: examining attention- and emotion-regulation motives as potential mediators. Pers. Indiv. Differ. 51 (7), 856–861.
Giluk, T.L., 2009. Mindfulness, Big Five personality, and affect: a meta-analysis. Pers. Indiv. Differ. 47 (8), 805–811.
Gottfredson, L.S., 1997. Why g matters: the complexity of everyday life. Intelligence 24 (1), 79–132.
Griffin, M.A., Neal, A., 2000. Perceptions of safety at work: a framework for linking safety climate to safety performance, knowledge, and motivation. J. Occup. Health Psychol. 5 (3), 347–358.
Herndon, F., 2008. Testing mindfulness with perceptual and cognitive factors: external vs. internal encoding, and the cognitive failures questionnaire. Pers. Indiv. Differ. 44 (1), 32–41.
Hu, L.T., Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct. Equ. Model. 6 (1), 1–55.
Hülsheger, U.R., Alberts, H.J.E.M., Feinholdt, A., Lang, J.W.B., 2013. Benefits of mindfulness at work: The role of mindfulness in emotion regulation, emotional exhaustion, and job satisfaction. Journal of Applied Psychology 98, 310–325.
Jha, A.P., Stanley, E.A., Kiyonaga, A., Wong, L., Gelfand, L., 2010. Examining the protective effects of mindfulness training on working memory capacity and affective experience. Emotion 10 (1), 54–64.
Johnson, R.E., Lord, R.G., 2010. Implicit effects of justice on self-identity. J. Appl. Psychol. 95 (4), 681–695.
Kahneman, D., Klein, G., 2009. Conditions for intuitive expertise: a failure to disagree. Am. Psychol. 64 (6), 515–526.
Kass, S.J., VanWormer, L.A., Mikulas, W.L., Legan, S., Bumgarner, D., 2011. Effects of mindfulness training on simulated driving: preliminary results. Mindfulness 2, 236–241.
Kecklund, L.J., Svenson, O., 1997. Human errors and work performance in a nuclear power plant control room: associations with work-related factors and behavioral coping. Reliab. Eng. Syst. Saf. 56 (1), 5–15.
Kiken, L.G., Shook, N.J., 2011. Looking up mindfulness increases positive judgments and reduces negativity bias. Soc. Psychol. Pers. Sci. 2 (4), 425–431.
Klein, G., 1999. Sources of Power. MIT Press, Cambridge, MA.
Kohls, N., Sauer, S., Walach, H., 2009. Facets of mindfulness-results of an online study investigating the Freiburg Mindfulness Inventory. Pers. Indiv. Differ. 46 (2), 224–230.

Kontogiannis, T., Malakis, S., 2009. A proactive approach to human error detection and identification in aviation and air traffic control. Saf. Sci. 47, 693–706.
Lakey, C.E., Campbell, W.K., Brown, K.W., Goodie, A.S., 2007. Dispositional mindfulness as a predictor of the severity of gambling outcomes. Pers. Indiv. Differ. 43 (7), 1698–1710.
Langer, E.J., 1989. Minding matters: the consequences of mindlessness–mindfulness. Adv. Exp. Soc. Psychol. 22, 137–173.
Levesque, C., Brown, K.W., 2007. Mindfulness as a moderator of the effect of implicit motivational self-concept on day-to-day behavioral motivation. Motiv. Emot. 31 (4), 284–299.
Little, T.D., Cunningham, W.A., Shahar, G., Widaman, K.F., 2002. To parcel or not to parcel: exploring the question, weighing the merits. Struct. Equ. Model. 9 (2), 151–173.
Mrazek, M.D., Franklin, M.S., Phillips, D.T., Baird, B., Schooler, J.W., 2013. Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. Psychol. Sci. 24 (5), 776–781.
Neal, A., Griffin, M.A., 2006. A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. J. Appl. Psychol. 91 (4), 946–953.
Ng, T.W., Feldman, D.C., 2008. The relationship of age to ten dimensions of job performance. J. Appl. Psychol. 93 (2), 392–423.
Ostafin, B.D., Kassman, K.T., Wessel, I., 2014. Breaking the cycle of desire: mindfulness and executive control weaken the relation between an implicit measure of alcohol valence and preoccupation with alcohol-related thoughts. Psychol. Addict. Behav. (in press).
O'Connor, B., 2000. SPSS and SAS programs for determining the number of components using parallel analysis and Velicer's MAP test. Behav. Res. Methods 32 (3), 396–402.
Podsakoff, P.M., MacKenzie, S.B., Lee, J.-Y., Podsakoff, N.P., 2003. Common method biases in behavioral research: a critical review of the literature and recommended remedies. J. Appl. Psychol. 88 (5), 879–903.
Raven, J., Raven, J.C., Court, J.H., 1998. Manual for Raven's Progressive Matrices and Vocabulary Scales. Pearson, San Antonio.
Raven, J., 2000. The Raven's progressive matrices: change and stability over culture and time. Cognit. Psychol. 41 (1), 1–48.
Rerup, C., 2005. Learning from past experience: footnotes on mindfulness and habitual entrepreneurship. Scand. J. Manage. 21 (4), 451–472.
Richardson, H.A., Simmering, M.J., Sturman, M.C., 2009. A tale of three perspectives examining post hoc statistical techniques for detection and correction of common method variance. Organ. Res. Methods 12 (4), 762–800.
Schmertz, S.K., Anderson, P.L., Robins, D.L., 2009. The relation between self-report mindfulness and performance on tasks of sustained attention. J. Psychopathol. Behav. Assess. 31 (1), 60–66.
Shao, R., Skarlicki, D.P., 2009. The role of mindfulness in predicting individual performance. Can. J. Behav. Sci. 41 (4), 195–201.
Stanovich, K.E., 1999. Who is Rational? Studies of Individual Differences in Reasoning. Lawrence Elrbaum Associates, Mahwah, NJ.
Sternberg, R.J., 1985. Beyond IQ. A Triarchic Theory of Human Intelligence. Cambridge University Press, Cambridge, MA.
Turner, N., Stride, C.B., Carter, A.J., McCaughey, D., Carroll, A.E., 2012. Job Demands–Control–Support model and employee safety performance. Accid. Anal. Prev. 45, 811–817.
Vicente, K.J., Mumaw, R.J., Roth, E.M., 2004. Operator monitoring in a complex dynamic work environment: a qualitative cognitive model based on field observations. Theor. Issues Ergon. Sci. 5 (5), 359–384.
Vidulich, M.A., Tsang, P.S., 2012. Mental workload and situation awareness. In: Salvendy, G. (Ed.), Handbook of Human Factors and Ergonomics. , 3rd ed. John Wiley & Sons, Inc., Hoboken, NJ, pp. 243–266.
Walach, H., Buchheld, N., Buttenmüller, V., Kleinknecht, N., Schmidt, S., 2006. Measuring mindfulness – the Freiburg Mindfulness Inventory (FMI). Pers. Indiv. Differ. 40 (8), 1543–1555.
Wallace, J.C., Vodanovich, S.J., 2003. Workplace safety performance: conscientiousness, cognitive failure, and their interaction. J. Occup. Health Psychol. 8, 316–327.
Warm, J.S., Parasuraman, R., Matthews, G., 2008. Vigilance requires hard mental work and is stressful. Hum. Factors J. Hum. Factors Ergon. Soc. 50 (3), 433–441.
Weick, K.E., Sutcliffe, K.M., Obstfeld, D., 1999. Organizing for high reliability: processes of collective mindfulness. In: Sutton, R.S., Staw, B.M. (Eds.), Research in Organizational Behavior, vol. 1. Jai Press, Stanford, pp. 81–123.
Weick, K.E., Sutcliffe, K.M., Obstfeld, D., 2008. Organizing for high reliability: processes of collective mindfulness. Crisis Manage. 3, 81–123.
Xie, B., Salvendy, G., 2000. Review and reappraisal of modelling and predicting mental workload in single-and multi-task environments. Work Stress 14 (1), 74–99.
Zhang, H., Wang, X., 1989. Standardization research on Raven's Standard Progressive Matrices in China. Acta Psychol. Sin. 2, 113–121.
Zhang, J., Ding, W., Li, Y., Wu, C., 2013. Task complexity matters: the influence of trait mindfulness on task and safety performance of nuclear power plant operators. Pers. Indiv. Differ. 55 (4), 433–439.
Zohar, D., Erev, I., 2007. On the difficulty of promoting workers' safety behaviour: overcoming the underweighting of routine risks. Int. J. Risk Assess. Manage. 7 (2), 122–136.