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Abstract

We conducted 3 studies to investigate how poor quality sleep relates to work injuries. First, using a sample of employed people living in the United Kingdom ($N = 4,238$; Study 1), we found that poor quality sleep was related to more frequent workplace injuries via negative affect rather than cognitive failures. Second, we again compared parallel pathways using a sample of U.S.A. employees ($N = 202$; Study 2): poor quality sleep was related to more frequent work injuries via work-related negative affect but not work-related cognitive failures. Third, we used a 2-wave sample of employees from the United Kingdom ($N = 71$; Study 3) finding that poor quality sleep was related to more frequent work injuries 7 weeks later via negative affect. Comparing high arousal and low arousal negative affect as competing pathways showed that there was a significant indirect effect of the former on the poor quality sleep-work injuries relationship but not the latter. Across 3 studies, we implicated the role of self-control failure stemming from poor quality sleep in predicting more frequent work injuries and suggested initiatives targeting high arousal negative affect as a way of reducing work injuries.

Keywords: cognitive failures; injuries; negative affect; safety; sleep; strain

Tired, strained, and hurt: The indirect effect of negative affect on the relationship between poor quality sleep and work injuries

Sleep has an important influence on safety performance at work (DeArmond & Chen, 2009; Williamson et al., 2011; Wong & Kelloway, 2016). Individuals who go to work sleepy or have chronic sleep disturbance are more likely to commit safety violations, engage in safety-compromising work behaviors, and sustain work injuries (Patterson et al., 2011; Rajaratnam et al., 2011). Even the loss of sleep from the one-hour switch to Daylight Saving Time is associated with increased occupational injuries (Barnes & Wagner, 2009). Research that looks into why poor sleep is associated with poor safety performance most often points to the role of cognitive impairments (e.g., Brossoit et al., 2019). From a practical perspective, organizations are investing in fatigue management programs to help mitigate human error from poor sleep (Dawson, Chapman, & Thomas, 2012). While these systems seem promising (Dawson, Searle, & Paterson, 2014), using them implies that the sole consequence of poor sleep is cognitive impairments (i.e., motor coordination, vigilance).

We propose that there is value in understanding *how* poor sleep leads to more frequent workplace injuries via mechanisms beyond cognitive impairment. Aside from the benefit of developing novel linkages between sleep and safety, exploring non-cognitive mechanisms calls for both academics and practitioners to re-evaluate the dominant focus of cognition in error management. In the current research, we conducted three studies that as a set compared negative affect against cognition as potential indirect effects in the poor sleep-work injuries relationship. Our first study compared an affective pathway to a cognitive pathway and found that only the indirect effect through negative affect was significant. Our second study extended the findings from the first study by exploring how work-specific operationalizations of cognitive failure and

negative affect worked as indirect effects of the poor sleep-work injury relationship. Our last study examined the nuances of the negative affective mechanism between sleep quality and workplace injuries across two time points. By elaborating on the indirect role of negative affect in three conceptual replications and methodological extensions, this research calls attention to the role of affect in linking poor sleep and work injuries (Haig, 2013; Spector, 2019).

Theoretical Background and Hypotheses

Self-regulation theory (Vohs & Baumeister, 2004) provides the conceptual motivation for exploring how sleep affects the regulation of cognition (e.g., alertness) and affect (e.g., experienced emotions; Barnes, 2012), and subsequently workplace safety. First, sleep deprivation results in depletion of resources and lack of resource recovery, which affects an individual's ability to monitor and exert control over one's affect and cognition (Barber, Grawitch, & Munz, 2013; Muraven & Baumeister, 2000), and as a consequence increases the likelihood of workplace injuries. Empirically, poor sleep does manifest as impaired cognition and negative emotions (Frone & Tidwell, 2015; Litwiller, Snyder, Taylor, & Steele, 2016). Yet, research has placed a stronger emphasis on understanding the cognitive basis of workplace injuries (Christian, Bradley, Wallace, & Burke, 2009). In this paper, we used the self-regulatory framework to compare the cognitive and affective pathways between sleep and safety. We reviewed the literature on different aspects and measures of sleep (e.g., insomnia, sleep deprivation, subjective sleep quality) to contribute towards a latent concept of poor sleep. Research examining daytime sleepiness and fatigue was excluded as they are the manifestations of poor sleep rather than characteristics of sleep itself.

Cognitive Failures Pathway

Self-regulation theory posits that one way that poor sleep can affect safety performance is by the depletion of the resources required to monitor and control cognition (Muraven & Baumeister, 2000). If this reservoir of resources are drained, the quality of cognitive processing decreases (Kahneman, Ben-Ishai, & Lotan, 1973). A meta-analysis reported that short-term sleep deprivation affects attention, working memory, and executive control of information processing (Lim & Dinges, 2010), and neurological imaging studies revealed that the lack of sleep affects brain activity in the areas that are important for memory, learning, and motor functioning (see Dawson, Noy, Härmä, Åkerstedt, & Belenky, 2011 for a review).

Correspondingly, the workplace safety literature posits that most work-related injuries are caused by unintended missteps in attention, memory, and actions (Baysari, Caponecchia, McIntosh, & Wilson, 2009; Hobbs, Williamson, & Van Dongen, 2010; Salminen & Tallberg, 1996). These missteps are considered to be cognitive failures, which are ‘malfunctions’ in performances that an individual is normally capable of executing under normal circumstances (Norman, 1981; Reason, 1990; Wallace, Kass, & Stanny, 2002). Work-related cognitive failures are associated with more unsafe behaviours, more injuries, more mishaps, fewer safety behaviours, poor use and storage of work tools, and less frequent use of personal protection equipment (Larson, Alderton, Neideffer, & Underhill, 1997; Wallace & Vodanovich, 2003a). More recently, Brossoit et al. (2019) found that the relationship between insomnia symptoms and minor workplace injuries was mediated by workplace cognitive failures. Therefore, we hypothesized that one pathway from poor sleep to work injuries exists through a decline in cognitive capabilities that materializes as attention, memory, and action failures.

Hypothesis 1.1: There is an indirect effect of cognitive failures on the relationship between sleep difficulties and workplace injuries.

Negative Affect Pathway

Sleep deprivation can also affect the regulation of affect by depleting the resources that are needed to control the display of negative affect (Barnes, 2012; Muraven, Tice, & Baumeister, 1998). According to self-regulation theory, regulating negative affect is considered a form of self-control exertion and depletion as individuals typically seek to get out of aversive emotional states (Muraven & Baumeister, 2000). Sub-clinical levels of poor sleep is associated with the expression of more frequent negative emotions and fewer positive emotions (Baglioni, Spiegelhalder, Lombardo, & Riemann, 2010; Barnes, Ghumman, & Scott, 2013; Scott & Judge, 2006). Poor sleep can also impair the processing of emotional experiences (Walker & Van der Helm, 2009), the accuracy of emotion recognition (Van der Helm, Gujar, & Walker, 2010), and the functional connectivity between the emotional center of the brain (amygdala) to the area for executive functioning (prefrontal cortex; Chuah et al., 2010), which further suggests that lack of sleep is related to emotion regulation failure.

The research that links negative affect to workplace safety is relatively limited compared to cognition and workplace safety. Two studies found that negative affect is associated with increased risk of injuries at work (Iverson & Erwin, 1997) and self-reported risky driving (Hu, Xie, & Li, 2013). However, looking broadly at how negative affect impacts self-control, sleep-deprived individuals are more likely to have lower self-control and more self-reported state hostility, which is associated with more self-reported workplace deviance and actual interpersonal deviance behaviours (Christian & Ellis, 2011). In the context of safety, the lack of sleep may result in more resources spent on negative affect regulation but less resources spent on regulating (i.e., underregulation) the impulse to perform work in more efficient but less safe ways (Christian & Ellis, 2011). In a slightly different context, Liu et al. (2017) found that work demands in the form of mistreatment from customers predicted employees' negative mood,

which in turn predicted overeating behaviours. The link between mood and unhealthy eating may be a process of misregulation, in which affect regulation prioritizes the return to positive mood (satisfaction from eating unhealthy food), and which may not be aligned with achieving long-term goals (healthy eating; see also Tice & Bratslavsky, 2000; Tice, Bratslavsky, & Baumeister, 2001). Similarly, the goal of adhering to safety procedures may be sacrificed in individuals with negative moods because of the behavioural choices associated with returning to positive moods (e.g., taking shortcuts). Therefore, we hypothesized that one of the pathways from poor sleep to work injuries exists through negative affect due to underregulation or misregulation of mood.

Hypothesis 1.2: There is an indirect effect of negative affect on the relationship between sleep difficulties and workplace injuries.

Study 1

Method

Participants responded to a postal survey carried out in the United Kingdom sent to 30,000 people selected at random from the 2001 electoral registers. In total, 7,979 people completed and returned a questionnaire, giving a response rate of 27%. The sample selected for this study were the 4,238 respondents (53%) who reported that they were employed. Over half (57%) of this sample were female and their average age was 39.61 years ($SD = 12.01$ years, range: 17 to 82 years). About a third (35%) had a university degree or higher educational or professional qualification, and 9% had no formal educational qualifications. Most were permanently employed (87%), worked full-time (76%), had non-manual jobs (75%) and described themselves as an employee with no supervisory or managerial responsibilities (64%).

Measures

Sleep difficulties. Participants were asked whether they had experienced any difficulty sleeping with “Have you had any of the following symptoms in the last 14 days: Difficulty

sleeping?” (1 = “Yes”; 0 = “No”; Marmot et al., 1991). Short sleep disturbance measures were found to correlate highly with longer sleep disturbance scales (Buysse et al., 2010).

Negative affect. Negative affect in the past 14 days was assessed using the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983; $\alpha = .88$). The scale consisted of 14 items, with seven items for the anxiety subscale and seven items for the depression subscale. Sample items were “Worrying thoughts go through my mind” (anxiety) and “I feel as if I am slowed down” (depression) and were answered on a 4-point Likert-type frequency scale (i.e., scored from zero to three from lowest to highest frequency, respectively). One item from the anxiety subscale and five items from the depression subscale were reverse-scored; a higher summed score across the two subscales indicated more negative affect experienced. This scale was widely used in medical studies to measure emotional distress in the general population (Bjelland, Dahl, Haug, & Neckelmann, 2002; Cosco, Doyle, Ward, & McGee, 2012).

Cognitive failures. Cognitive failures at work were measured using a single item “How frequently do you find that you have problems of memory (e.g. forgetting where you put things), attention (e.g. failures of concentration), or action (e.g. doing the wrong thing) at work?” answered on a 5-point Likert-type frequency scale, from 1 = “Not at all” to 5 = “Very frequently”), with higher scores indicating more frequently cognitive failures at work. This single item measure correlated .70 with Broadbent, Cooper, Fitzgerald and Parkes (1982) Cognitive Failure Questionnaire (Simpson, Wadsworth, Moss, & Smith, 2005).

Workplace injuries. Injuries at work in the past 12 months were assessed using a single item “Thinking about the last 12 months, have you had any accidents while you were working that required medical attention from someone else (e.g. a first aider, general physician, nurse or hospital doctor)?” Responses options ranged from “None” to “More than 6”, and responses were

recoded to 1 = “1 or more” and 0 = “None.” Past research showed a high correlation between self-reported injuries and records of injuries (e.g., Klen & Ojanen, 1998).

Analyses and Results

We tested our hypotheses using Preacher and Hayes’ (2008) two-part process: (1) operationalizing a partially-mediated model to test the total indirect effects, and (2) testing the contrast of individual indirect effects within the model. Our partially-mediated logistic regression model suggested that while sleep difficulties have a direct effect on workplace injuries, they also have indirect effects through negative affect and cognitive failures. Indirect effects in a parallel mediation correlate but do not causally influence each other (Hayes, 2013). Analyses were carried out using SPSS 24 (IBM, 2016) and Hayes’ (2013) PROCESS add-on with bias-corrected bootstrapping based on a sample of 10,000.

[Insert Table 1 about here]

A correlation matrix of study variables appears in Table 1. The total effect of the relationship between sleep difficulties and workplace injuries was significant ($B = .47$, $SE = .14$, $p < .01$, 95% CI = [0.19, 0.75], Nagelkerke $R^2 = .01$; Figure 1). The confidence intervals for the total indirect effect did not include zero ($ab_{total} = 0.15$, $SE = .06$, 95% CI = [0.04, 0.26]), suggesting that there was a significant indirect effect of both pathways combined. In comparing the two indirect effects, the confidence intervals for the indirect effect of negative affect did not include zero ($ab_{affect} = 0.15$, $SE = .06$, 95% CI = [0.04, 0.26]), whereas the confidence intervals for cognitive failures did include zero ($ab_{cognition} = -.004$, $SE = .03$, 95% CI = [-0.06, 0.06]). As a result, Hypothesis 1.2 was supported and Hypothesis 1.1 was not supported. As a post hoc test, the confidence intervals of the contrast comparing the two effects did not include zero ($ab_{contrast} =$

0.16, $SE = .07$, 95% CI = [0.02, 0.29]), which suggested that the effects differed significantly from one another.

[Insert Figure 1 about here]

Study 2

The second of our three studies attempted to conceptually replicate the phenomenon found in Study 1 using an independent sample and different measures of the constructs. In contrast to an exact replication study, this approach serves to explore the generalizability of Study 1's phenomenon (Haig, 2013). We examined *work-related* negative affect as an indirect effect of the relationship between sleep quality and workplace injuries and explore if the affective pathway significantly differs from the cognitive pathway.

Hypothesis 2.1: There is an indirect effect of negative work-related affect on the relationship between quality of sleep and workplace injuries.

Hypothesis 2.2: The negative work-related affect indirect effect significantly differs from the cognitive failures indirect effect.

Method

Participants. Two hundred and two (103 men, 98 women, 1 undeclared) full-time, non-white collar workers in the United States of America were recruited by Qualtrics to participate in a 30-minute online survey study in exchange for five US dollars. Participants self-identified their job titles as either blue- (manual labor), grey- (manual labor and office work; e.g., engineer), or pink-collar (manual labor in service industries). The average age of the sample was 39.78 years ($SD = 11.80$ years, range: 21 to 71 years). The majority of the participants identified as Caucasian (85.1%). Two percent of participants did not finish high school, while 36% had a high school diploma, 33.5% had a postsecondary college diploma, and 28.4% of them had a university

degree. The average tenure was 73.82 months ($SD = 78.27$ months, range: 1 to 420 months). The average hours worked per week was 56.48 hours ($SD = 12.35$ hours, range: 35 to 98 hours).

Measures

Sleep difficulties. Sleep difficulties in the past week were assessed using the insomnia index of the Karolinska Sleep Questionnaire (Kecklund & Åkerstedt, 1992; $\alpha = .87$). The subscale consisted of four items regarding characteristics of the night's sleep answered on a 5-point Likert-type frequency scale using 1 = "Never" to 5 = "Always." The mean item-level score was computed with a higher score indicating more sleep difficulties. A sample item was "Difficulties falling asleep." The Karolinska Sleep Questionnaire was validated to be related to behavioural and EEG indicators of sleepiness (Kaida et al., 2006).

Work-related negative affect. Negative affective reactions to work experiences in the past week were measured using the negative subscale of Van Katwyk, Fox, Spector, and Kelloway's (2000) Job-related Affective Well-being Scale ($\alpha = .90$). The scale consisted of 10 items answered on a 5-point Likert-type frequency scale using 1 = "Never" to 5 = "Extremely often." A sample item was "My job made me feel angry." Mean item-level scores were computed, with a higher score indicating more work-related negative emotions experienced. The negative affect subscale of the Job-related Affective Well-being Scale was used in studies examining emotions in the workplace (e.g., Schaufeli & Van Rhenen, 2006).

Work-related cognitive failures. Daily work-specific cognitive failures in the past week were measured using Wallace and Chen's (2005; $\alpha = .91$) Workplace Cognitive Failure Scale, which consisted of 15 items regarding memory, attention, and action failures answered on a 5-point Likert-type frequency scale using 1 = "Never" to 5 = "Very often." A sample item for memory failures was "Fail to recall work procedures," for attention failures were "Do not fully

listen to instruction,” and for action failures was “Throw away something you meant to keep.” Mean item-level scores were computed and a higher score indicated more cognitive failures committed. The Workplace Cognitive Failures measure was found to be predictive of automobile and workplace accidents (Wallace & Vodanovich, 2003b).

Workplace injuries. Injuries experienced in the past week were assessed by asking the two questions “Have you had a minor injury (e.g. cut, scrape or bruise) that did not require medical or first aid attention at work?” and “Have you had an injury that required medical or first aid attention at work?”, both answered dichotomously (1 = “Yes”; 0 = “No”). Due to the rare occurrence of injuries at work in the timeframe, the two types of injuries were summed together.

Analyses and Results

Similar to Study 1, we tested our hypotheses using Preacher and Hayes’ (2008) two-part process, using SPSS 24 (IBM, 2016) and Hayes’ (2013) PROCESS add-on with bias-corrected bootstrapping based on a sample of 10,000. Our partially-mediated logistic regression model suggested that while sleep difficulties has a direct effect on workplace injuries, it also has indirect effects through work-related negative affect and work-related cognitive failures. A correlation matrix of study variables appears in Table 2. The total effect of the relationship between sleep difficulties and work injuries was significant ($B = .52$, $SE = .16$, $p = .001$, 95% CI = [0.21, 0.82], Nagelkerke $R^2 = .17$; Figure 2). The confidence intervals for the total indirect effect did not include zero ($ab_{total} = 0.29$, $SE = .12$, 95% CI = [0.08, 0.54]), suggesting that there was a significant indirect effect of both pathways combined. In comparing the two indirect effects, the confidence intervals for the indirect effect of work-related negative affect did not include zero ($ab_{affect} = 0.33$, $SE = .12$, 95% CI = [0.13, 0.58]), whereas the confidence intervals for work-related cognitive failures did include zero ($ab_{cognition} = -0.03$, $SE = .10$, 95% CI = [-0.25,

0.15]). Moreover, the confidence intervals of the contrast comparing the two effects did not include zero ($ab_{contrast} = -0.37$, $SE = .19$, 95% CI = [0.03, 0.77]), which suggested that the effects differed from one another. As a result, Hypothesis 2.1 and 2.2 were fully supported.

[Insert Table 2 and Figure 2 about here]

Study 1 & 2 Discussion

In the first two cross-sectional studies, we established covariation among poor sleep, general and work-related negative affect, and work injuries while controlling for the spurious explanation of impaired cognitive functioning. The contrast tests that compared the two indirect effects showed the same pattern of results across the two studies, with the negative affect pathway as a significant indirect effect rather than cognitive errors. While the different measures of negative affect compromised the direct comparison of Study 1 and 2's findings, to show that this phenomenon held true for general and work-specific negative affect suggested that the influence of sleep on emotions and injuries is not domain-bound and is thereby pervasive.

We acknowledged that the timeframe of Study 1's injury measure is problematic in teasing apart the temporal occurrence of sleep and negative affect, and that Study 2 partially remediated this by setting all measures to a 1-week recall timeframe. Yet, the use of cross-sectional data did not allow us to make unbiased causal inferences about the mechanism of interest (Maxwell & Cole, 2007). We partially overcame this limitation with a two-wave design in Study 3, which separated out sleep at one time point and negative affect at a later time point, and were able to address common method bias and tease out the temporal precedence between sleep and negative affect (Spector, 2019). In this final study, we focused on negative affect as the sole indirect effect and compare the parallel pathways of high and low arousal negative emotions. Negative emotions from poor sleep can range from low to high arousal (Ford &

Kamerow, 1989; Waters, Adams, Binks, & Varnado, 1993), yet only high arousal negative affect appears to increase impulsive risk-taking behaviours through depletion in self-regulatory resources (Leith & Baumeister, 1996). As well, partially sleep-deprived individuals are more likely to have lower self-control and more self-reported state hostility (a high arousal negative state), which is associated with more self-reported workplace deviance and actual interpersonal deviance behaviours (Christian & Ellis, 2011). Therefore, we hypothesized that:

Hypothesis 3: There is an indirect effect of high arousal negative affect at T2 on the relationship between sleep quality at T1 and workplace injuries at T2.

Study 3

Methods

Participants. Seventy-one shift workers (49 men, 22 women) at a chocolate manufacturing plant in the north of England were recruited to participate in the study that consisted of two surveys administered seven weeks apart (“T1” and “T2”). The two time points were chosen because seven weeks constitute a full cycle of the participants’ shiftwork schedule. The average age of the sample was 45.28 years ($SD = 8.31$ years, range: 19 to 60 years). Most of the participants were process workers ($n = 69$), while two participants were fitters. The average tenure was 14.06 years ($SD = 8.33$ years, range: 0.58 to 30 years). The average shift hours worked per week was 38.20 hours ($SD = 1.74$ hours, range: 35 to 45 hours).

Measures

Sleep quality. Sleep quality in the past four weeks was measured at T1 across each of the morning, afternoon, and night shifts using a single item (“How well do you sleep?”) from the Standard Shiftwork Index (Barton et al., 1995). Participants answered on a 5-point Likert type scale using 1 = “Extremely well” to 5 = “Extremely badly”. We took the average of the items across the three shifts, with a higher score indicating poorer sleep quality.

Negative affect. Negative affect at T2 was measured using two items from the General Health Questionnaire (GHQ; Goldberg & Williams, 1988). Participants answered on a 4-point Likert-type frequency scale using 0 = “Not at all” to 3 = “Much more than usual” about the past four weeks. The two items were chosen from Shevlin and Adamson’s (2005) Anxiety-Depression dimension of the three-factor model of the GHQ ($\alpha = .80$). The items were “Constantly under strain?” to represent high arousal negative emotion and “Unhappy and depressed?” to represent low arousal negative emotion. Although the items “Lost sleep over worry” and “Could not overcome difficulties” are a part of the Anxiety-Depression dimension (Shevlin & Adamson [2005], p. 234), we did not use the former because it contained the word “sleep” which confounded the sleep quality measure, and the latter because it captured the behavioural manifestation of negative affect rather than negative affect itself.¹

Work injuries. Minor injuries at work at T2 were assessed using Hemingway and Smith’s (1999) scale of occupational injuries adapted for the manufacturing industry (the original scale reflected frequent occupational injuries for nurses). The current scale consisted of 10 items answered on a 5-point Likert-type frequency scale using 1 = “Never” to 5 = “More than five times” about the past four weeks. A sample item was “During the last four weeks, how frequently have you sustained the following types of work-related injuries whilst at work - strain or sprain?” A higher summed value indicated more frequent work injuries. Due to the low frequency of injuries (i.e., negatively-skewed distribution), a natural log transformation of the injury outcome variable was used in model testing.

Analyses and Results

¹ Analysis was conducted with all four GHQ negative affect items as four parallel indirect effects, and the CI for “Constantly under strain” was the only indirect effect that did not include zero. We decided on the two parallel indirect effects model for a more succinct result section.

Similar to Studies 1 and 2, we tested our hypotheses using Preacher and Hayes' (2008) two-part process, using SPSS 24 (IBM, 2016) and Hayes' (2013) PROCESS add-on with bias-corrected bootstrapping based on a sample of 10,000. Our partially-mediated regression model suggested that while sleep quality at T1 has a direct effect on workplace injuries at T2, it also has indirect effects through high and low arousal negative affect at T2. A correlation matrix of study variables appears in Table 3. The total effect of the relationship between sleep quality at T1 and workplace injuries at T2 was not significant ($B = -.02$, $SE = .02$, $p = .39$, 95% CI = [-0.05, 0.02]; Figure 3).² The confidence intervals for the total indirect effect did not include zero ($ab_{total} = 0.02$, $SE = .01$, 95% CI = [0.001, 0.04]), suggesting that there was a significant total indirect effect of high and low arousal negative emotions. In comparing the two indirect effects, the confidence intervals for the indirect effect of high arousal negative affect at T2 did not include zero ($ab_{strain} = 0.02$, $SE = .01$, 95% CI = [0.01, 0.05], $r_{standardized} = .16$, 95% CI_{effect size} = [0.06, 0.24]), whereas the confidence intervals for low arousal negative affect did include zero ($ab_{depression} = -.01$, $SE = .01$, 95% CI = [-0.02, 0.001], $r_{standardized} = -.06$, 95% CI_{effect size} = [-0.18, 0.01]). Moreover, the confidence intervals of the contrast comparing the two effects did not include zero ($ab_{contrast} = -0.03$, $SE = .01$, 95% CI = [-0.06, -0.01]), which suggested that the effects significantly differed from one another. The coefficients of the indirect effects suggested that the high arousal negative affect pathway was significantly different than the low arousal negative affect pathway.

General Discussion

² According to modern perspectives on indirect effect analyses, the predictor variable need not be significantly associated with the criterion variable to proceed with testing for indirect effects (Hayes, 2009; Preacher & Hayes, 2008). The total effect encompasses paths of influence not included in the tested model, some of which may be opposite in sign of the indirect effect being tested, thus cancelling out each other in the summation of the total effect.

In summary, we determined over a set of three studies that negative work-related affect plays a role in the relationship between sleep quality and work injuries. The first study showed that difficulty sleeping was associated with more workplace injuries resulting via negative affect but not cognitive failures. The second study conceptually replicated the first study using a different sample and more robustly measured scales (i.e., work-related negative affect, one-week timeframe recall). The third study demonstrated that high arousal negative affect (i.e., strain) rather than low arousal negative affect (i.e., depression) was the significant indirect pathway between sleep quality and workplace injuries. Therefore, high arousal negative affect from poor sleep may affect impulsive and risky decisions and behaviours, which in turn might put individuals at higher risk for work injuries. The two-wave design in Study 3 temporally separated sleep and negative affect, and partially controlled for the common method bias. Taken together, these findings established the relationship between poor sleep and more frequent work injuries via negative affect, and supported an alternative self-regulation basis of sleep-work injuries relationship other than through impaired cognition. Our studies aligned with past work demonstrating a self-regulatory basis of high arousal negative affect expression and decline in self-control (Christian & Ellis, 2011; Leith & Baumeister, 1996), but explored in a novel context of sleep and safety. Our findings answered Beus, McCord, and Zohar (2016)'s call for expanding workplace safety theory by providing a novel linkage to their model of workplace safety.

Our findings suggested that the affective pathway between poor sleep and work injuries is feasible and justifies more robust, time- and cost-intensive research designs. However, several limitations should be considered. First, while we used different measures of sleep, negative affect, and work injuries over the three studies to conceptually replicate the affective pathway, we acknowledge that true replications of identical measures are required to confirm the presence

of this phenomenon (Haig, 2013). Also, the lack of work injuries does not mean there is a presence of safety (Beus et al., 2016), nor does poor sleep equate to daytime fatigue. Future conceptual extensions should examine the affective pathway model using related constructs over a variety of research designs (e.g., sleep, fatigue, and safety behaviours using diary studies) and sources (e.g., informant-reports of safety) to determine further temporal precedence and rule out common method bias, respectively.

Second, the current research presented one interpretation of the order of relationships among the constructs in Study 1-3, while alternative models are plausible. We are aware that emotions and cognition are intricately connected. Anxiety is associated with the attentional bias of heightened vigilance to initial threat stimuli processing (Macleod & Mathews, 1988). As well, the association between sleep and high arousal emotions is bidirectional (Bonnet & Arand, 2010; Kahn, Sheppes, & Sadeh, 2013), and recent work injuries may also be the cause of poor sleep. To test properly for these alternative models, at least a three-wave panel design with a meaningful timeframe is needed to support the assumption of stationarity (Cole & Maxwell, 2003), or an experimental design can be used (Spector, 2019). Future research exploring the affective determinants of work safety should use multi-wave research designs to investigate if the maladaptive allocation of regulatory resources from high arousal emotions is self-control failure in action, as well as the aforementioned alternative models.

Finally, we omitted positive emotions in the research models because promotion-focused positive emotions have a weaker relationship to safety behaviours than prevention-focused negative emotions (Wallace & Chen, 2006). Yet, positive emotions can be experienced concurrently with negative emotions, and positive emotions have their own specific influence on self-regulation. For example, positive moods restore self-regulatory resources that have been

previously drained (Tice, Baumeister, Shmueli, & Muraven, 2007). Future research can also consider testing models that include both positive and negative emotions to examine if positive affect can buffer the effect of high arousal negative affect on workplace injuries.

The current results have two main implications for practice. First, workplaces typically have several layers of defense in place to reduce human error from escalating into injuries (Wagenaar, Hudson, & Reason, 1990). For example, successful standards in work design (e.g., autonomy to manage uncertainty at source; Grote, 2009) and technologies that accommodate the limits of human capacity (e.g., shift work hours and schedules, equipment display design; Wickens, Lee, Liu, & Gordon-Becker, 2004) help reduce workplace injuries. We recommend one more addition to the system defenses. Our findings suggest that organizational practitioners and researchers need to consider the affective consequences of poor sleep. Organizational initiatives that address negative affect directly (i.e., relaxation training, mental health awareness) or improve psychological well-being (i.e., reducing job insecurity, increasing job control, regulations on work intensity and shift patterns) may be helpful in reducing work injuries alongside more cognitive-specific interventions. Second, the widespread consequences of poor sleep extend beyond cognition to emotions, and suggest that directly addressing employees' sleep rather than mitigating its consequences is the ideal strategy for injury prevention at work.

Conclusion

Findings from our three studies determined that there is an indirect effect of negative affect on the relationship between poor sleep and work injuries. We speculated on the role that self-control failure plays in relation to sleep and work injuries. Given that emotions are a plausible mechanism linking sleep and safety performance, we suggest that initiatives which enhance affective well-being can be integrated into workplace injury prevention programs.

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Table 1. Means and correlations of Study 1's variables ($N = 4,238$)

Variable	<i>M</i>	<i>SD</i>	1	2	3
1 Sleep difficulties	0.34	0.47			
2 Negative affect	10.32	6.48	.35***	.88	
3 Cognitive failures	1.30	0.99	.18***	.35***	
4 Workplace injuries	0.05	0.22	.05**	.06***	.02

Note: Cronbach's alpha is reported in the diagonal. ** $p < .01$, *** $p < .001$. All correlations aside from negative affect and cognitive failures are point-biserial. The correlation for sleep difficulties and workplace injuries is phi.

Table 2. Means, correlations, and Cronbach's alphas of Study 2's variables ($N = 202$)

Variable	<i>M</i>	<i>SD</i>	1	2	3
1 Sleep difficulties	2.53	1.14	.87		
2 Work-related negative affect	2.11	0.83	.52***	.90	
3 Work-related cognitive failures	1.76	0.60	.53***	.60***	.91
4 Workplace injuries	0.22	0.42	.25**	.33***	.21**

Note: Cronbach's alphas are reported in the diagonal. ** $p < .01$, *** $p < .001$.

Table 3. Means, correlations, and Cronbach's alphas of Study 3's variables ($N = 71$)

Variable	<i>M</i>	<i>SD</i>	1	2	3
1 T1 sleep quality	2.87	0.83			
2 T2 high arousal negative affect	0.75	0.84	.31**		
3 T2 low arousal negative affect	0.63	0.80	.27*	.65***	
4 T2 workplace injuries (natural log)	2.39	0.12	-.11	.33**	.08

Notes: T1 = Time 1. T2 = Time 2. * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure Captions

Figure 1. Direct and indirect effects of sleep difficulties on workplace accidents through negative affect and cognitive failures. The negative affect pathway was a significant indirect effect ($ab_{affect} = 0.15$). The contrast comparing the two indirect effects indicated that the negative affect pathway is significantly larger than the cognitive failures pathway ($ab_{contrast} = 0.16$). ** $p < .01$; *** $p < .001$.

Figure 2. Direct and indirect effects of sleep difficulties on workplace injuries through work-related negative affect and work-related cognitive failures. The negative affect pathway was a significant indirect effect ($ab_{affect} = 0.33$). The contrast comparing the two indirect effects indicated that the negative affect pathway is significantly larger than the cognitive failures pathway ($ab_{contrast} = 0.37$). ** $p < .01$; *** $p < .001$.

Figure 3. Direct and indirect effects of sleep quality at T1 on workplace injuries at T2 through high arousal negative affect and low arousal negative affect at T2. The high arousal negative affect pathway was a significant indirect effect ($ab_{strain} = 0.02$). The contrast comparing the two indirect effects indicated that the high arousal negative affect pathway is significantly larger than the low arousal negative affect pathway ($ab_{contrast} = -0.03$). * $p < .05$; ** $p < .01$.





