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ORIGINAL ARTICLE

The Role of Fatigue and Work Overload in Predicting Work Situation Awareness among Workers

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ABSTRACT

Important factor in the prevention of industrial accidents involve of the ability of employees to maintain awareness of the work situation, understand the information it holds, and predict how situations will develop. In this study, we examined the role of fatigue and work overload in predicting work situation awareness among workers. The current study was a cross-sectional study. The sample consisting of 180 employees in National Petrochemical Company in 2014 was selected according to the stratified random sampling method and responded to questionnaires about demography characteristics, work situation awareness, fatigue and work overload. The data were analyzed by correlation techniques and stepwise regression. There was internal correlation among fatigue, work overload and work situation awareness. In addition, the results of stepwise regression analysis revealed that fatigue and work overload significantly predicted, respectively, almost 33% and 14% of variances of work situation awareness among workers. Fatigue and work overload can predict work situation awareness. Therefore, considering these variables can be important to promoting the awareness of work situation among workers.

KEYWORDS: *Fatigue, Work Overload, Work Situation Awareness, Workers*

INTRODUCTION

After a number of catastrophic events (most notably the Piper Alpha disaster in 1988 in which 167 workers died; [1]), oil and gas companies are making every effort to ensure that their occupational accident rates are kept as low as possible [2]. In most occupational accidents, there is a causal chain of organizational conditions and person errors [3]. Reason [4] conclude that human-factor causes can be attributed to 70–80% of occupational accidents in high-hazard industries. One critical element in predicting occupational accidents is the ability of employees to maintain an adequate understanding of their work situation. This means having a high level of awareness of job duties and workplace conditions, and judging how these may change in the near future to predict how the situation will develop [2]. Cognitive psychologists have long been interested in attention [5], and the role of cognitive skills in safety issues is well-documented [6]. In industrial companies, the necessary attention skills are referred to as 'situation awareness' (SA). SA is defined by Endsley [7] as ''The perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future''. This

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SA has been further studied in aviation industry [8]; in recent years, the studies has performed in fields such as aircraft maintenance, the military, driving, anesthesia, the maritime industry, and nuclear power plants [9-10]. Cognitive skills such as work situation awareness are known to be susceptible to the elements of work-related conditions such as fatigue and work overload [11] which are common in many high-risk industries and organizations, for example in oil and gas exploration, where employees work on remote installations, often in high time-pressured, dangerous conditions [12]. Ongoing research of the causal events shows failures in situation awareness and risk assessment [13]. Therefore, it is important to identify factors reducing work situation awareness.

Fatigue causes damages to alertness levels and consequently increases the risk involved in the job injuries [14], as the cognitive resources required are depleted due to physical actions or sleep deprivation [15]. Dawson and Reid [16] concluded that defects in cognitive processing in persons with only moderate sleep deprivation and fatigue were similar to those experienced when blood alcohol levels are over the legal limit for driving. The effects of fatigue are to reduce the speed of cognitive processing, and therefore increase reaction times, tunnel vision, inattentiveness, and lower vigilance and concentration [17]. These effects have been also reported in the maritime industry [18], transportation [19], and have been reported for the oil and gas industry [2]. Current theories of the effects of fatigue on workers' awareness are based on the concept of the regulation of effort and that fatigue is related with a loss of task-directed effort. For example, the Compensatory Control model, which was developed to explain the adaptive effects of stressors on occupational tasks [20], has been extended to explain the effects of fatigue states. According to compensatory control theory, fatigue-inducing conditions like sleep deprivation affect the way that effort is regulated. Sleepiness produces fatigue and as a result, both decrease the operator resources available to the task, decreases situation awareness and whereby increases the effort required to perform the task [20, 2]. Similarly, task-induced fatigue due to high workload or long duration, monotonous tasks for example, is related with loss of task-directed effort and poorer performance awareness as a result [21]. Fatigue can also produce cognitive performance deficits equivalent to or greater than the impairment related with acute sleep deprivation and decrease situation awareness [22].

In addition, unusually high workloads can affect individuals' performance [23]. Work overload was defined by Hart and Staveland [24] as "a hypothetical construct that represents the cost incurred by a human operator to achieve a particular level of performance". If workload is high or the tasks are very complicated, it can mean that workers are involve by attending to particular tasks, or are distracted by other pressing issues to tackle, and so do not apportion adequate time to monitor their work situation. In doing so, their situation awareness will be damaged, as they may be unaware of situational changes, and may make improper decisions based on incomplete or incorrect data [25]. Consequently, they may also be unable to react quickly adequate should an unforeseen incident occur [2]. Although oil and gas industries try to maintain the correct balance between production pressures and safety [26], in todays' energy market, changing demand is an intrinsic characteristic of the oil-working environment and therefore work does not always occur at a constant rate. Low workload phases do occur (e.g. waiting on weather), but more typical are periods when workload sharply increases (e.g. due to production pressures, or when the number of workers on workplace is low). Studies indicate that increased workload has a detrimental effect on workers' psychological wellbeing [27].

The aim of current research was to investigate the relationship between fatigue and work overload with work situation awareness. So far, little research (particularly in Iran) has been done about work situation awareness and the current research is new.

MATERIALS AND METHODS

Participants: This cross sectional study was administrated between October and November 2014 at one petrochemical industry in Asalooyeh area. This area is located on the shore of the Persian Gulf some 270 km SE of the provincial capital of Bushehr and is best known as the site for the land based facilities of the large Pars Special Energy Economic Zone (PSEEZ) project [28]. In this study, in attention to the extent and distribution of the employees in the different parts of this company was used of stratified random sampling to select sample members. To determine the sample size, a pilot study was carried out in which 50 petrochemical employees participated. Based on the results of the pilot research, with confidence level of 95% and study power of 80%, sample size was calculated to be 190 workers. Participants in this research were randomly selected from the corresponding personnel list such that workers of important jobs and units (i.e. operation, engineering, security, HSE and firefighting, maintenance and office work) were included. In order to have enough samples in each job group, proportional to size methodology was applied [29]. All participants were man. Informed consent was obtained from participants and they were ensured that their responses would be confidential and

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responses by managers and supervisors will not see any way and the results will be evaluated collectively, not individually. Overall, 180 completed questionnaires were collected. This study approved and financially supported by research committee of faculty of psychology and educational sciences of Allameh Tabatabaei University and National Petrochemical Company.

Measurements: Validated instruments were used for data collection on work situation awareness, fatigue and work overload. At first, all questionnaires were translated from English into Persian and independently back translated into English by a second translator. The few discrepancies between the original English and the back-translated version resulted in adjustment in the Persian translation based on direct discussion between the translators. At next step, psychometric characteristics of instruments were examined. Linguistic validation was performed by three experts of psychology department and five experts of safety and health departments. Thus, the questionnaires were piloted and finalized with an advisory group of workers to ensure that the scales items were comprehensible and appropriate to the context. Moreover, conceptual analysis was confirmed the content validity of all instrument. The questionnaires were distributed to workers with the help of union steward. Participants were assured of confidentiality and informed consent in written format was acquired from each of them. The following questionnaires were used:

- Demographic factors. Six demographic factors, namely age, gender, marital status, education, years of working experience and shift were included. Marital status was classified as married or not married (including divorced and widowed).
- Work situation awareness (SA). SA with 20 items of Sneddon, Mearns, Flin [30] were measured. Respondents indicated the extent of agreement with each statement on a 5-point Likert-type scale (0=very often; 5=never). The questions of this scale consist of 5 positive questions such as: "I think ahead of my work to plan for different possible outcomes" and 15 negative questions such as: "I am easily distracted by my thoughts or feelings". Sneddon and et al. [30], in their study, calculated this scale have acceptable internal reliability (Cronbach's alpha=0.86) and good validity. Evidence of reliability of this scale, as administered to Iranian relevant populations, in this research, by Alpha Coefficient is 0.79 and by Split-half is 0.75. The validity coefficients of questions are between 0.25 and 0.79 that all the validity coefficients are significant at $P<0.0001$.
- Fatigue scale. This scale is a 14 items questionnaire [31] that measures the physical and mental symptoms of fatigue. It is made based on the frequency of fatigue symptoms that employees have experienced them in the past month. Scoring is based on a Likert style of five degrees from 0 (never) to 4 (very much). Sum of the scores given to items is reported as the total score of fatigues symptoms for a worker. Prior studies surveying many industrials and organizations provide evidence for high internal reliability and criterion validity of the scale [32]. Evidence of reliability of this scale, as administered to Iranian relevant populations, in this research, by Alpha Coefficient is 0.88 and by Split-half is 0.83. The validity coefficients of questions are between 0.22 and 0.84 that all the validity coefficients are significant at $P<0.0001$.
- Work Overload. This scale is with 4-items of Beehr, Walsh and Taber [33] was measured. The scale refer to general perceptions about whether there was work density (e.g., hours of work) in the job or not. Two samples of the questions of this scale were "I am so busy on the job that can't get to take normal breaks" and "There is too much work to do in my job for it all to be done well". Participants showed the extent of agreement with each statement on a 5-point Likert-type scale (1=strongly disagree; 5=strongly agree). Mantineau [34] reported the internal validity of this scale using Cronbach's alpha 0.83. In addition, she showed that this scale had good criterion validity. Internal consistencies (Cronbach's α) in this study in Iran were 0.79, which was good for this scale.

Statistical analyses: The SPSS version 15 (Chicago, IL, USA) was used to analyze the data. In addition, descriptive statistics was used to summarize and organize the data, and were analyzed by stepwise regression analysis.

RESULT

Demographic characteristics of participants of this study are presented in Table 1.

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Table 1. Demographic characteristics of the sample members (N=180)

		Frequency	Frequency Percentage
Age	18 to 29 years	49	27.5
	30 to 41 years	122	67.5
	42 to 53 years	9	5
Sex	Male	180	100
	Woman	-	-
Marital status	Married	162	90
	Single	18	10
Education	M.Sc. (M.A.) degree or higher	58	32.5
	B.Sc. (B.A.) degree	49	27.5
	High school graduates	73	40
	Primary school graduates and lower	-	-
Work experience	5 years and lower	63	35
	6 to 15 years	43	24
	16 to 25 years	43	24
	26 years and higher	31	17
Shift *status*	Shift	130	72.5
	Not shift	50	27.5

Mean, standard deviation and internal correlations of variables under study are presented in (Table 2).

Table 2. Mean, Error Standard and internal collections of variables

				Correlations		
		$\bar{X}$	SD	1	2	3
1	Fatigue	40.17	5.13	1		
2	Work overload	16.24	3.21	0.71	1	
3	Work situation awareness	64.65	6.22	-0.51	-0.23	1

As can be seen, there were significant relationships among fatigue, work overload and work situation awareness (P<0.01).

To assess the predictive power of work situation awareness by fatigues and work overload variables were used of the stepwise regression analysis. The results of model summary are presented inTable3.

Table 3. Summary of regression analysis model

	Variable	R	R^2	ΔR^2	ΔF^2	Sig.
Step 1	Fatigue	0.50	0.25	0.25	60.58	.000
Step 2	Fatigue and work overload	0.60	0.36	0.11	29.60	.000

The results of regression model for explaining work situation awareness based on fatigue and work overload indicated that F-statistic for both models is significant in P<0.001. Therefore, there was the explanation possible of work situation awareness based on both variables. In Table 4, the regression coefficients of stepwise regression analysis are presented.

Table 4. Summary of stepwise regression analysis to predict work situation awareness based on fatigue and work overload

Variable	β	B	SE B	t	R^2	Sig.
Fatigue	-0.97	-1.19	0.13	-9.25	0.33	.000
Work overload	0.57	0.89	0.16	5.44	0.14	.000

As can be seen, fatigue variable with β=-0.97 can significantly predict almost 33% of the variance of work situation awareness. Moreover, work overload variable with β=0.57 can significantly predict almost 14% of the variance of work situation awareness.

DISCUSSION

The result of the current research showed fatigue variable significantly predicted work situation awareness among workers. This is consistent with the findings of the previous studies [35-37] and can be interpreted based on the following possibilities:

Wallace et al [35], in their research, concluded that individuals who scored higher on daytime sleepiness and fatigue also experienced more cognitive failures. Fatigue due to sleep disruption in petroleum and chemical industries is part of working and these results show that this is detrimental to employees by decreasing their WSA levels [2]. Lorist et al. [36] concluded that mental and physical fatigue cause to impaired cognitive control and decreased situation awareness. McDonald et al. [37] in the simple tests of attention and concentration indicated that some impairment

in situation awareness was influenced by fatigue. Decreased attention and increased cognitive errors are an obvious result of physical and mental fatigue among employees. Therefore, tired workers lose their vigilance and alertness, and therefore cannot pay attention to the workplace conditions. Unfortunately, there were conditions and many factors in working environment that cause fatigue in individuals. One of these factors is the change in shift workers. Many employees work in a shift pattern (known as 'short change') which involves workers changing half-way through day-shift to night-shift or vice versa), that result to disrupting sleep patterns and increasing fatigue [38]. In addition, workplace conditions generally tend to be noisy due to machinery and equipment. Moreover, there are high numbers of workers living and working in a limited area, and workers may share an accommodation cabin, which can disturb relaxation time and sleep and increase fatigue among them [39]. Companies and industrials can consider altering the shift patterns that are in place to make them more stable, for example, allow employees to always work a day or night shift rather than switch shift patterns in the middle (split/swing shift), or installing extra sound proofing in cabins to allow workers to enjoy more undisrupted sleep and thus reduce fatigue among employees [30].

In addition, the results showed work overload significantly predicted work situation awareness among workers. This is consistent with the findings of the previous studies [40-43] and can be interpreted based on the following possibilities:

Several researches indicated how the concepts of workload, situation awareness, and safety performance relate to each other for individual operators [40-44]. These models generally indicate that work overload has a negative impact on work situation awareness, which in turn has a positive correlation with incidents among workers. That is, as workload increases, situation awareness decrease and subsequently safety performance worsens.

A Structural Equation Model (SEM) [45] indicate that the theoretical constructs of SA, workload, and safety performance are related and affect each other, so that the workload negatively affects the SA, a low SA enables disturb safety performance. In addition, work overload can result in increasing stress levels among workers that can cause to reduced working memory capacity and diminished attention [46]. Work overload can result in poor concentration/alertness due to an overload on the personnel's cognitive resources, and this can interfere with the primary perception of the situation and conditions, causing inattention to the available information [46, 2].

Sawaragi and Murasawa [47] concluded that the high workload of the task demands can affect much the decision maker's internal reasoning tasks, and the internal states of the cognitive processing within a decision maker and interaction complexity can affect his/her ability of work situation awareness. In other study, Hancock and Warm [48] show that performance is especially disturbed when a worker is cognitively overloaded. Workers seek to meet task demands but as demands become excessive, they become overloaded and performance decrements occur. Requiring workers to maintain awareness of their work situation and make efficient decisions while serving long and intense shifts could result to cognitive overload.

CONCLUSION

The findings of this research emphasize the importance of fatigue and work overload variables in predicting work situation awareness among workers. Safety intervention needs to focus on these variables, as well as on the prevention methods coping against them, and these concepts influence the increase of work situation awareness directly or indirectly. It is recommended that the future research examine the effects of safety interventions on increasing situation awareness. Further, with designing these interventions and with more attention to them, we can affect one of the most important influential variables in incidence of occupational accidents. The present study needs to be replicated in different populations and needs more support that is empirical. Until then, the findings of the study should be interpreted with caution. Further, the cross-sectional design of the study and participants (i.e., a group of employee) exert some limitations on the generalization of the findings. Finally, the problems and limitations on the use of self-repotting instruments should not be overlooked.

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