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Effects of Stress, Repetition, Fatigue and Work Environment on Human Error in Manufacturing Industries

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Abstract: Safety and health at work are extremely important yet they still appear to be one of the most neglected factors in the industry. Almost 90% of accidents that occur in the workplace are due to human errors. While studies suggest that the lack of skills and experience among workers can significantly increase the prevalence of human errors, few studies actually investigate how stress, repetition, fatigue and environment can affect human error. Hence, this study aims to explore the significances of the effects of stress, repetition, fatigue and work environment on human error in manufacturing industries. Questionnaires were constructed and distributed to several manufacturing firms across Peninsular Malaysia. A total of 200 questionnaire responses were collected back. The responses were analysed using descriptive, reliability, correlations and multiple linear regression analyses. It was found that human error is significantly affected by the 4 major factors explored in this study. A total of 48.8% of the variance in human error can be explained by stress, repetition, fatigue and work environment. The results of this study can act as useful protocols for manufacturing managers and policymakers in identifying critical factors to iron out problems such as human error and accidents at the workplace.

Key words: Repetition, fatigue, stress, work environment, human error, manufacturing industry

INTRODUCTION

Currently, the manufacturing sector of Malaysia is expected to expand as a result of increased investments by foreigners and the consumption of natural resources. The growth of manufacturing industries in Malaysia is expected to help create employment opportunities and improve the economy towards developing a high income nation. However, this rapid development also means that there can be an even bigger risk for workplace injuries and accidents to occur.

Manufacturing industries are complex organisations that require a lot of human-machine interactions. Hence, human errors that come from the mishandling defective products and machine failures can become dreadfully prevalent in manufacturing industries. An organisation that does not have an ergonomic system or process may have allowed a gap to exist between the worker's characteristics and the functional requirements of their job. Ergonomics is undoubtedly an important social and technological proponent for people to improve their quality of work, work satisfaction and safety.

According to the Malaysia Social Security Organisation, the number of workplace accidents has increased from the year 1996-2011. During that time, it was found that human error was the major cause of more than 90% of these workplace accidents (DiDomenico and Nussbaum, 2008). According to Liu *et al.* (2009), human error can be defined as any unsafe act carried out by a person that can significantly bring negative impacts to the workplace. Human error is prominently researched in areas such as the aircraft industry (Allen and Marx, 1999), nuclear power industry (Huang and Zhang, 1998), medical industry (Lee *et al.*, 1997) and mining industry (Mason, 1996). However, according to Kumar and Madhu (2012), the manufacturing industry presents the highest total claim on accident costs. Despite this, some researchers believe that the study of human errors in the manufacturing industry falls under the category of miscellaneous studies (Dhillon and Liu, 2006).

Ionides (2008) stated that in the year of 2007, Indonesia Adam Air flight 574 disappeared with more than 100 passengers during a domestic flight. Authorities found that the pilots lost control after being preoccupied

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with the malfunctioning of the navigational equipment (Ionides, 2008). The preceding scenario is an example of a serious accident caused by human error. Besides that, there was also a case of a factory explosion in Johor, Malaysia where millions of dollars were lost just because a worker forgot to switch off a certain machine (The Star, 2012).

The preceding studies beg the need for an investigation to be carried out on factors that influence human error in the manufacturing industry. Therefore, this study aims to explore the effects of stress, repetition, fatigue and work environment on human error in manufacturing industries with a special emphasis on the manufacturing industries in Malaysia. In this study, a framework was created based on the literature review on human error and ergonomics factors such as stress, repetition, fatigue and work environment. A survey is conducted among manufacturing workers and supervisors. The surveys are analysed using descriptive, reliability and multiple linear regression analyses. From the multiple linear regression analysis, the effects of stress, repetition, fatigue and work environment on human error can be determined. Last but not least, by using theoretical support, the mechanisms of these effects are explained.

Inspite of numerous studies on the general causes and effects of human error in selected industries Gilad (1994) and Kumar and Madhu (2012) suggest that the manufacturing industry has the highest total of claims on accident costs. However, it appears that studies on human error in the manufacturing industry still fall under the category of miscellaneous studies (Dhillon and Liu, 2006). The knowledge of human error in the manufacturing industry is very important for manual workers in order for them to avoid hazardous situations. An improved condition of the workplace through improved knowledge and awareness on human error may reduce the time and cost resources of an industry and increase productivity (Ng and Jee, 2013). Therefore, enhancing the knowledge of human error among manual workers is important without a doubt.

The revenue of Malaysia's economy is mainly driven by the tourism and manufacturing industries. Hence, the focus of this study covers the manufacturing industry of Malaysia which plays an underlying role in the growth of Malaysia's economy. According to Malaysia's occupational safety and health statistics on accident rates by sectors in 2013, there were 58 deaths, 1469 non-permanent disabilities and 128 permanent disabilities among manual workers in manufacturing firms. According to Lansberg (1999), small and medium enterprises normally have more complex business management processes which can potentially cause conflicts and accidents to happen at the workplace. There is a possibility that these organisations lack certain safety procedures and health policies at the workplace.

According to the chairman of the National Institute for Occupational Safety and Health of Malaysia (NIOSH) in the year of 2012, work-related accidents increased by 38% in the past five years (The Star, 2013). The chairman added that there were three work-related deaths every day in 2011 which indicated that workplace accidents need to be taken seriously in Malaysia (The Star, 2013).

According to the Talsico Categories of Human Error, there are six main categories of human error that are normally encountered in the workplace. These include the learning gap, memory gap, inconsistency, application, omission and decision. Besides that (Reason, 1990) suggested that the usage of the generic modelling system should be a basis for the taxonomy of human error which are based on skills, rules and knowledge. Reason (1990) added that the lack of any one of these bases may cause human errors to occur in the workplace.

According to Hollnagel (1998), human error is the context of cognitive error that underlies the causes of action. Hollnagel (1998) indicated that error can be classified into three definitions. Firstly, an error can refer to a real action being performed incorrectly. Secondly, an error can refer to the visible consequences of improper action. Thirdly, an error can refer to the abstract caused due to the improper action or visible consequences of this. In addition, using the Hazard and Operability Study (HAZAOP) and Cognitive Reliability and Error Analysis Method (CREAM) (Wang and Zhao, 2010) managed to identify some of the root causes of human error. However, Whittingham (2004) highlighted that knowing the causes of human error are important before determining the appropriate method or model to use. He added that accidents happen due to a combination of workload, design and job deficiencies as well as the violation of rules.

In short, there have been many studies on human error. However, these studies are not fundamentally correlated to any particular factor especially under the circumstances of manufacturing industries. Therefore, it is crucial for researchers to highlight the effects f several factors on human error in the manufacturing industry. The factors that possibly affect human error may include stress, repetition, fatigue and work environment.

STRESS

Stress can be defined as the non-specific response of the human's body to any demand for change (Lazarus and

Folkman, 1984). If an individual whose work demands have gone over the limit, it is likely that they are unable to mobilise their work effectively. They are bound to face emotional stress such as mental strain, tension and pressure. Minor stress tends to occupy worker's minds with accumulated worries and distractions while major stress tends to divert workers' attention, causing them to be in an uncomposed state of mind (Wegner, 1988). In another study, it was found that stress can function like poison as it is a physical and mental condition which can affect the effectiveness, health and quality of one's work (Lawson *et al*., 2001). Lazarus and Folkman (1984) also found that stress can be associated with an individual's ability and performance. Hinkle (1973) mentioned that stress can endanger an individual that is going through many of psychological, social and emotional problems.

According to a study conducted by CCOHS (2005), over 50% out of 500 workers face stress problems a few times per week. Adams (1980) stated that there is a plausible relationship between human error and worker stress in the workplace. However, there appears to be a lack of evidences to suggest that a significant correlation exists between stress and human error among workers in manufacturing firms. Hence, this study proposes the following hypothesis:

H1: There is a significant correlation between stress and human error in the manufacturing industry

REPETITION

Repetition can be defined as a monotonous job with close exertion patterns repeated at an excessive level of frequency in a given period of time. According to Kilbom (1994), repetitions are conditional and are mainly based on the length of single work cycles. An employee who repeatedly works with repetitive motion within a single cycle time duration is less than 30 sec of the average work cycle time is considered to have performed high repetitions in his/her work (Ketola *et al*., 2001). According to Colombini and Occhipinti (2004), tasks which are repeated for a minimum of 60 min can be considered as repetitive work as well. A worker could perform awkward movements or high frequency motions repetitively if they utilise more than ten movements using their wrist and elbow within 1 min (Keyserling *et al*., 1993).

Manufacturing workers who are accustomed to performing repetitive tasks with the same movements over a long period of time can still make mistakes when pressured by the production manager to perform their tasks faster for higher production outputs (Armstrong *et al*., 1989). According to Ranney *et al*. (1995), workers often face problems concerning neck and muscle pain since they continuously perform the same movements over a long period of time. A manufacturing worker who is required to perform repetitive motions for long periods of time is likely to feel tired and fatigued (Wick *et al*., 1994). However, according to Escorpizo and Moore (2007), studies on repetition are still at an exploratory stage. Hence, this study proposes to use repetition as a predictor to determine whether a significant correlation exists between repetition and human error in the manufacturing industry. Based on the preceding justifications, the following hypothesis is proposed:

H2: There is a significant correlation between repetition and human error in the manufacturing industry

FATIGUE

According to Noor and Ibrahim (2008), fatigue can be described as a type of distress generally conditioned by the exhaustion of one's muscles due to work. For instance, according to (Zhang *et al*., 2008), mental fatigue involves the depravation of mental performance due to an overload of both mental and physical activities. Wang and Zhao (2010) suggest that fatigue can be considered as one of the reasons that cause human errors at the workplace. According to Sarter and Amalberti (2000), fatigue can result in human errors in production as well which indirectly impacts the productivity of the workers and the firm. The preceding substantiations beg the need for researchers to uncover the significance of the correlation between fatigue and human error in the manufacturing industry. Hence, the following hypothesis is proposed:

H3: There is a significant correlation between fatigue and human error in the manufacturing industry

WORK ENVIRONMENT

A work environment includes reasonable working conditions such as normal temperature, odour-free, dust-free, uncongested and calm conditions (McGarth, 1978). According to Davis (1984), a work environment with poor working conditions are associated with job dissatisfaction and stress. Poor working conditions may negatively affect the individual performance of workers. In addition, workers get easily distracted with poor working conditions and lose concentration in working towards improving company performance (Yeow *et al*., 2012). Apart from the performance implications, workers may even get injured at

the workplace with the poor working conditions in their work environment (Knisley, 2005). Frequent occurrences of accidents in the workplace may affect a company's capital returns (Ng *et al*., 2013, 2014).

A study conducted in a Malaysian automotive manufacturing firm showed that the workers were working under poor working conditions with ergonomics issues such as machine vibrations and machine noise which were above the safety margins (Kvarnstrom, 1997). These poor working conditions may lead to the likelihood of increased human errors which in turn may lead to the prevalence of more work-related injuries.

In a study involving manufacturing workers, Parimalam *et al*. (2006) found that workers often complain of headaches and visual strains caused by the insufficient light at their workplace. The workers also complained of excessive noise from the machines and the lack of ergonomic furniture and chemical protection apparatus. An uncomfortable work environment has a significant influence on the performance since, the likelihood of human error occurrences is high (Knisley, 2005). Muchler (1991) concurs that the poor working conditions of a work environment can increase the number of human errors in manufacturing firms. Based on the preceding rationales, the following hypothesis is proposed:

H4: There is a significant correlation between work environment and human error in the manufacturing industry

MATERIALS AND METHODS

The dependent variable of this study is human error while the independent variables are stress, repetition, fatigue and work environment. The framework is presented in Fig. 1. In order to facilitate the data collection of this study, a survey was conducted using a questionnaire developed based on the literature review.

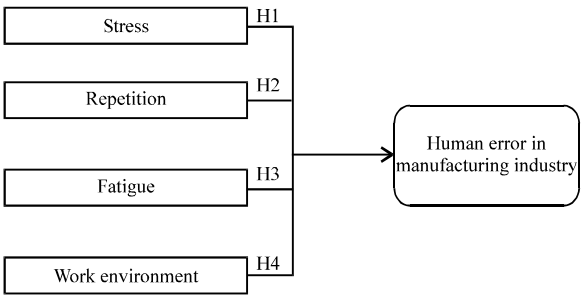

Fig. 1: Research framework for the effects of stress, repetition, fatigue and work environment on human error in the manufacturing industry

A total of 200 questionnaires were randomly distributed to workers in several manufacturing industries in Peninsular Malaysia, namely in Melaka, Johor, Seremban and Kuala Lumpur. The five-point Likert scale was adopted in the questionnaire development. The age range of the targeted respondents are from 18-55 years old. The responses were analysed using the Statistical Package for Social Science (SPSS) version 18 with analyses such as reliability, descriptive, Pearson's correlations and multiple linear regression analyses.

RESULTS

From the demographic profile in Table 1, it is found that about 107 male respondents (53.5%) and 93 female respondents (46.5%) participated in the survey. Most of the targeted respondents are mainly around 21-29 years old and consist of nearly half of the total participants in this study (48.5%). This is followed by the age group range of 30-39 years (25.5%). For the age groups below 20 years old, a total of 21% participated, whereas for the age group of 40 years old and above, only 5% participated. The majority of the respondents were Malay, with about 124 out of 200 respondents participating. This was followed by the Indian (42 people) and Chinese respondents (27 people). Only 7 respondents under the category of "others" participated in this study.

Based on the results in Table 2, the Cronbach's alpha ranges from 0.649-0.866. The alpha value for repetition is 0.649 which is also the lowest value among the variables. This value however, is still considered acceptable.

Table 1: Demographic profile of survey respondents

Demographic profile	Frequency	Percentage
Gender		
Male	107	53.5
Female	93	46.5
Age		
Below 20	42	21.0
21-29	97	48.5
30-39	51	25.5
40 and above	10	5.0
Race		
Chinese	27	13.5
Malay	124	62.0
Indian	42	21.0
Other	7	3.5

Table 2: Reliability analysis for the stress, repetition, fatigue, work environment and human error variables

Variables	No. of items	Cronbach's alpha
Independent variables		
Repetition	5	0.649
Stress	5	0.806
Fatigue	5	0.721
Work environment	5	0.866
Dependent variable		
Human error	4	0.651

Table 3: Pearson's correlations analysis to determine the correlations between the independent and dependent variable

	Independent variable				
Correlation	Repetition	Stress	Fatigue	Work environment	Human error
Dependent variable	0.405**	0.551**	0.510**	0.547**	1
Significant (2-tailed)	0.000	0.000	0.000	0.000	

**Correlation is significant at the 0.05 level (2-tailed)

According to Nunnally (1978), in order to obtain acceptable reliability, the minimum acceptance value of the Cronbach's alpha should be at 0.5. The variable with the highest alpha value in this study is the work environment variable with an alpha value of 0.866. The stress variable has the second highest alpha value (0.806) followed by the fatigue variable (0.721). The alpha value for the human error variable is 0.651 which is also considered acceptable for the study. Hence, it can be concluded that the internal consistency and reliability of the measurements used in this study are at acceptable levels.

Table 3 presents the correlations analysis between the independent and the dependent variables. It is found that all the independent variables have a positive and significant correlation with human error. Firstly, the correlation coefficient R that exist between repetition and human error ia 0.405 which indicates that there is a positive correlation between repetition and human error. The p-value is 0.000 which is less than 0.05 ($p<0.05$) and this shows that the correlation is significant.

Besides that, the correlation between stress and human error is also found to be positive and significant ($R = 0.551$, $p<0.05$). In addition, there is also a positive and significant correlation between fatigue and human error ($R = 0.510$, $p<0.05$). Lastly, the correlation between work environment and human error is also found to be positive and significant ($R = 0.405$, $p<0.05$). The preceding results show that H1, H2, H3 and H4 are not rejected. However, in order to support these results, further analysis is conducted with the multiple linear regression analysis.

Before the multiple linear regression analysis carried out, it is necessary to determine whether the data collected is normally distributed or not. Chambers *et al.* (1983) mentioned that the normal probability plot is a graphical method used to evaluate whether an observed data set follows a given distribution. The normality is considered reasonable when the observed data is nearer to the line. Otherwise the plot will fall outside from the line if the data are not normality distributed. Figure 2 shows the normality distribution of the data which is observed to be reasonable since the plot is approximately linear with the data points falling closer to the line. This assumption,

Table 4: Multiple linear regression analysis to determine the effects of stress, repetition, fatigue and work environment on human error

	Unstandardised coefficients			
Model	β	SE	t	p-value
Constant	0.395	0.268	1.48	0.140
Repetition	0.221	0.066	3.34	0.001
Stress	0.233	0.056	4.14	0.000
Fatigue	0.263	0.053	4.94	0.000
Work environment	0.175	0.049	3.55	0.000

Table 5: Coefficient of determination results

Model	R	R^2	Adjusted R^2
1	0.699	0.488	0.478

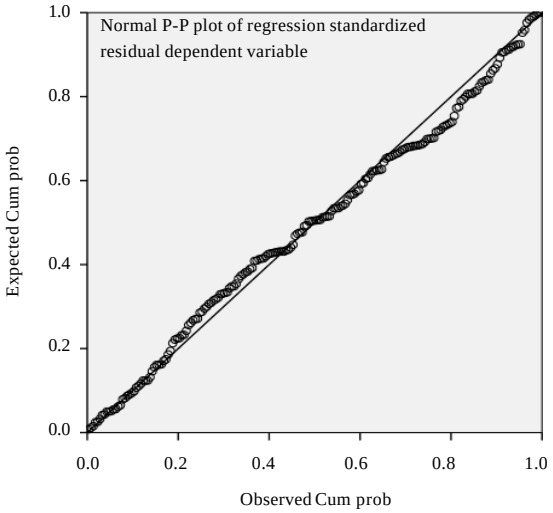

Fig. 2: Normality distribution of the data

hence, merits and supports the use of the multiple linear regression analysis which means that the outcome of the regression results can plausibly represent a larger population than this study.

Table 4 indicates that the effects of the four independent variables (repetition, stress, fatigue and work environment) on human error are significant since the p-values are less than 0.05 ($p<0.05$). Therefore, the hypotheses (H1-H4) are not rejected.

Table 5 shows the results of the multiple linear regression's coefficient of determination (R^2) which explains the variance between the dependent and independent variables. The R^2 value is 0.488 which means that 48.8% of the variance in human error can be explained by stress, repetition, fatigue and work environment.

DISCUSSION

Based on the results, there is a positive and significant correlation between repetition and human error

among workers in the manufacturing industry. Repetition can cause workers to feel tired and indirectly cause them to lose their concentration while performing the same movements over a long period of time. In the end, this will most likely lead to the prevalence of human error. According to You and Kwon (2005), the repetitiveness of hand tasks at the workplace can cause injuries and lead to poor performance and higher compensation costs. Researchers also suggest that workers usually face physical strain and musculoskeletal pain due to repetition (Israel *et al*., 2009). Manufacturing workers who are accustomed to performing repetitive tasks with the same movements over a long period of time, can still make errors when pressured by the production manager to perform their tasks faster for higher production outputs (Armstrong *et al*., 1989).

Apart from that, there is also a positive and significant correlation between stress and human error among workers in the manufacturing industry. For industrial workers, work stress can divert their attention from the company's main objectives and cause a person to be in a less composed state of mind. According to Yeow *et al*. (2012), stress is proven to have a significant effect on the effectiveness and work quality of workers. According to (Bhanarkar *et al*., 2005), stress has both positive and negative impacts on a person.

In addition, there is also a positive and significant correlation between fatigue and human error among workers in the manufacturing industry. Workers may not be able to reduce the quantity of defective products if they feel fatigued during working hours. This indirectly affects the stability of the worker's performance. Hopkin (1990) mentioned that although fatigue does not directly lower the overall performance of an operation, it can eventually cause poor organisational performance if not resolved for the long run.

There is also a positive and significant correlation between work environment and human error among workers in the manufacturing industry. According to DiNubile and Sherman (1999), poor working conditions in the work environment can disrupt the workers concentration and negatively affect their performance. Workers who constantly work in poor working conditions are exposed to ergonomics issues such as machine vibrations and machine noises that are above safety margins (Kvarnstrom, 1997). All these conditions can lead to the prevalence of human error.

CONCLUSION

The main objective of this study was to determine the effects of stress, repetition, fatigue and work environment on human error. Based on the results, the objective has been achieved. The outcome of this study can be useful for both human resource managers or manufacturing managers who aim to reinforce their workplace safety and health policies.

For future research, it is suggested that researchers include even more factors of potential influence to human error such as mental workload, workplace conflicts and work-rest duration. Researchers can also break down the category of the work environment variable and investigate smaller sub-variables such as noise, humidity, office layout and illumination. The sample size of the study can also be increased for a more detailed analysis.

Another suggestion for future research is to improve the limitation of the sample location by distributing the survey forms to different manufacturing areas. Besides that, researchers can receive different perceptions of respondents from different countries. Furthermore, researchers should also consider other data collection methods such as observations, personal interviews and experimentations. This will help to enhance the quality of the study on human error.

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