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Relationship between Stress Level and Reworks for Construction Professionals

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Abstract:
This paper presents a study investigating the relationship between stress level and reworks for construction professionals. As employees' work-life balance (WLB) becomes more important nowadays, controlling the level of stress in the workplace becomes more important as occupational stress has negative impacts on WLB. Reworks can be one severe occupational stressor as people suffer from stress when they need to redo their works. This study hypothesizes that there is a positive correlation between reworks and level of stress, meaning that people tend to show high level of stress when they need to redo their works. The hypothesis will be tested by checking the stress level when engineers redo their works because of changes or errors. An electroencephalography (EEG) sensor will be used to measure the stress level of engineers when they redo their works. For more accurate measure of stress, the stress level will also be measured by the galvanic skin response (GSR). This experiment is expected to prove that rework process is a severe stressor for construction professionals, which will contribute to lower productivity and poorer WLB. The finding will emphasize the importance of managing reworks in the construction industry, which will eventually help construction managers to control the level of employees' stress successfully.
Key words: Stress, Rework, EEG sensor, GSR sensor

1. INTRODUCTION

Occupational stress is one important factor to be managed for the successful delivery of construction projects. It is because occupational stress has negative impacts on individuals' performance in terms of productivity and safety [1]. Managing the occupational stress is particularly important for the construction industry as the industry is heavily labor-intensive [2, 3].

There have been various studies investigating the occupational stress. For example, by using a survey, Love et al. (2010) found that construction professionals working for a contracting organization on-site had higher levels of poor mental health and greater work stress than consultants [4]. Bell et al. (2012) argued that perceived job stress is associated with poorer work-life balance as occupational stress is related to adverse effects on employees' psychological and physical health [5]. Physical work requirements and psychological aspects of job demands can cause occupational stress, which affects welling-being of employees and organization performance [6].

The negative correlation has been reported between the stress level and performance, meaning that high level of stress is associated with poorer performance. Based on a survey, Imtiaz and Ahmad (2009) found negative correlation between stress and job performance [7]. Halkos and Bousinakis (2010) also found that increased stress leads to reduced productivity [1].

There can be many different types of stressors. Leung et al. (2009) classified stressors into four categories: task stressors (e.g., work overload, role conflict, role ambiguity), organizational stressors (e.g., presence of bureaucracy, hierarchies, omnipotence of rules, unfair treatment), physical stressors (e.g., work environment, home environment), and personal stressors [8]. For construction workers' job stress, Leung et al. (2016) presented five types of stressors, including safety equipment, supervisor support, co-worker support, job certainty, and job control [9].

Among the various stressors, this study focuses on rework. Rework is defined as "doing something at least one extra time due to non-conformance to requirements" [10]. Rework causes negative impacts on project performance. There have been many studies reporting that the costs of rework are substantial, ranging from 2.4% to 5% [11, 12].

This study investigates the relationship between stress level and reworks for construction professionals. Specifically, this study hypothesizes that there is a positive correlation between reworks and level of stress. When people need to redo their works, they tend to show high level of stress, which causes lower productivity and poorer work-life balance (WLB).

This paper consists of four sections. After the Introduction, the next section presents the literature review about stress, impact of stress in terms of productivity and WLB, and rework. The research hypothesis is provided based on the literature review in the same section. The third section, research methodology, presents how the stress level is measured. Electroencephalogram (EEG) and Galvanic Skin Response (GSR) sensors are introduced in this section. The data processing procedure including how filtering is conducted to remove noises from raw data and how the stress level is measured from the filtered data is presented as well. The last section briefly describes the experiment design and expected findings.

2. LITERATURE REVIEW

This section consists of four sub-section. The first sub-section presents the definitions of stress. The second sub-section provides the impact of stress on productivity and WLB. After the third sub-section describes rework, the last on presents the research hypothesis as well as research model.

2.1. Definition of Stress

Table 1 summarizes the definitions of stress. As shown in the table, stress has been defined in various ways. In general, most of the definitions describe stress as peoples' psychological, cognitive or behavioral reaction or response to any environmental, social or internal demand. Cannon (1929) suggested "fight or flight" concept to explain stress and its effects [20]. Also known as acute stress response, it is the concept that when the animal faces threats, it chooses to fight or run (flight) by activating sympathetic nervous system. The activation of a system stimulates the adrenal medulla, which secretes catecholamines such as epinephrine and norepinephrine. The secretion of these hormones induces increasing of heart rate and blood pressure, sweating and other physiological reactions. If these processes become chronic, it can lead to negative symptoms such as backache, headache, gastrointestinal problems. Anxiety, frustration, and burn-out are common psychological symptoms of excessive stress [21].

Table 1. Definitions of stress

Author	Stress Definition	Remarks
Lazarus (1993) [13]	Three categories of stress ● Harm: Psychological damage that has already been done ● Threat: The anticipation of harm that has not yet taken place but maybe imminent ● Challenge: Difficult demands people feel confident about overcoming by effectively mobilizing and deploying their coping resources	
Selye (2016) [14]	Nonspecific response of the body to any demand	
Sharma and Gedeon (2012) [15]	Complex reaction patterns that often has psychological, cognitive and behavioral components	

Thoits (1995) [16]	Any environmental, social, or internal demand which requires the individual to readjust his/her usual behavior patterns	
The Health and Safety Commission (1999) [17]	Reaction that people have to excessive pressures or other demands placed on them	
Brough and Williams (2007) [18]	Harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources, or needs of the worker.	Workplace Stress
Australian Government Comcare (2008) [19]	A form of strain, a state of negative emotions, and arousal experienced in relation to the work role	Job Stress

2.2. Impact of Stress on Productivity and WLB

Chronic stress not only adversely affects health but also lowers personal working efficiency, which eventually affects the organizational performance. High level of stress in the workplace is perceived as a problem by management because it causes low productivity, high absenteeism, alcohol problems, drug abuse, and high blood pressure, which adversely affect organizational performance [7]. Tarafdar et al. (2007) stated that stress results in low productivity, dissatisfaction at work, lack of job involvement, and poor job performance [22]. High level of stress is also related to high level of dissatisfaction, which leads to employee turnover and this causes company costs in terms of recruitment, selection and training of new employees [1, 23].

High level of stress also leads to lower work-life balance (WLB). WLB is a way to tune life in the workplace and personal life. WLB is defined as the absence of conflict between work and family or personal roles [24, 25]. Hill et al. (2001) describes it as the degree to which an individual can simultaneously balance the emotional, behavioral and time demands of work, family and personal duties [26]. The absence of WLB causes poor performance and more absenteeism of employees [27]. It also has a significant relationship to other organizational outcomes such as turnover intention [28]. Regarding the relationship between stress and WLB, Bell et al. (2012) found that perceived job stress is associated with poorer WLB [5]. Ross and Vasantha (2014) argued that one signs of unhealthy WLB is work load increase which is one typical job stressor [29]. In addition, Chiang et al. (2010) showed that high WLB can decrease job stress [6].

2.3. Rework

Rework is defined as “doing something at least one extra time due to non-conformance to requirements” [10]. Another definition of rework is “the process by which an item is made to conform to the original requirement by completion or correction” [30]. There can be various causes of rework, including errors, omissions, failures, and damage [11, 31]. A change order can be another cause of rework [11, 31, 32].

Rework worsens construction project performance. Love and Li (2000) found that the costs of rework for residential and industrial buildings are 3.15% and 2.40% of contract value, respectively [11]. CII (2005) found that the direct costs caused by rework average 5% of total construction costs [12]. In addition to the project-level impact, rework also has negative impacts on individuals. Love (2002) reported that the architect and structural engineers’ morale is adversely affected when they need to constantly revise their documentation [31].

2.4. Research Hypothesis

This study investigates the relationship between stress level and reworks. Leung et al. (2010) classifies the task stressors into three categories [33]. Definitions of the three task stressors are summarized in Table 2. When reworks or change orders occur, people need to redo their works. Since they spend their time for the same scope of work, it is likely that they become overloaded. In addition, the decisions about reworks and change orders are not typically made by the employees who are responsible for redoing the works. Thus the level of autonomy should be low. In summary, it is reasonable to assume that reworks and change orders are related to work overload and lack of autonomy.

Based on the rationale, this study hypothesizes that there is a positive correlation between reworks and level of stress, meaning that people tend to show high level of stress when they need to redo their works.

Table 2. Definitions of Task Stressors

Task Stressor	Definition	Source
Work overload	the extent to which the job performance required in a job is excessive	Iverson and Maguire (2000) [34] pg. 814
	the job demands are too great for one individual	Leung et al. (2010) [33] pg. 1094
Role ambiguity	A lack of clarity about the expectations of the work role and about the scope and responsibilities of the job	Leung et al. (2010) [33] pg. 1094
Lack of autonomy	the degree to which the job provides substantial freedom, independence, and discretion in scheduling the work and in determining the procedures to be used in carrying it out	Hackman and Oldham (1975) [35] pg. 162

Figure 1 shows the research model of this study. As mentioned previously, stress results in low productivity and WLB, which lead to worsen the organizational performance. In addition, as there are higher numbers of dual-earner couples and single parents, demand for workplace flexibility to take care of children and elders has increased substantially nowadays [36]. This kind of environmental shifts leads employees to desire more for WLB and employers began to offer more supports for their employees' WLB [37]. As a result, organizations should consider the level of employees' stress more carefully nowadays.

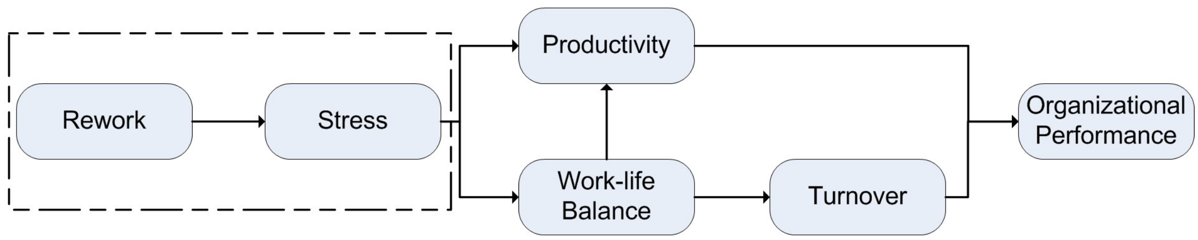


Figure 1. Research Model

For the research model shown in Figure 1, this study investigates the relationship between rework and stress which is shown in the dotted box in Figure 1.

3. RESEARCH METHODOLOGY

In order to study the relationship between rework and stress, this study uses two sensors measuring electroencephalogram (EEG) and galvanic skin response (GSR). This section introduces them and presents how stress can be measured by them quantitatively.

3.1. Electroencephalogram (EEG)

EEG is an electrical signal generated by the activation of neurons in the brain. It can be measured by attaching electrodes along the scalp. As EEG is a non-invasive measure technique of the brain's activation, it is widely used across neuroscience and medical fields [2,15,38]. EEG signals can be classified by frequency, such as delta (0.5-4 Hz), theta (4- 8Hz), alpha (8-13 Hz), beta (13-30 Hz) and gamma (> 30 HZ) [39,40]. Each frequency region represents specific states. For example, delta frequency range is occurred during deep sleep [41]. In this study, beta frequency will be used to measure the level of stress. There have been many studies using beta frequency to measure the level of stress as there is a positive correlation between beta frequency range and the level of stress [41,42,43,44,45].

The wireless EEG measure device EPOC+ by EMOTIV shown in Figure 2(a) is used to measure the EEG signals. The device provides 14 electrodes as shown in Figure 2(b). Jebelli et al. (2018) and Hwang et al. (2018) well describe the process to measure stress from the raw data generated from the device [39,40]. After the raw data are extracted from the EEG measure device, they need to be processed to remove extrinsic and intrinsic artifacts. Extrinsic artifacts are the noises which are not generated by physiological reasons. Examples of extrinsic artifacts are electrode popping or mechanical noises. Intrinsic artifacts are the noises generated by body changes. Eye blinking, eye movement, and facial muscle movement are examples of intrinsic artifacts. Such noises can be filtered via EEG signal processing tools [40]. In this research, EEGLab will be used to process the EEG signals. EEGLab is an open-source software made by Swartz Center for Computational Neuroscience(SCCN) of the University of California San Diego. It was made for EEG data analysis tools for MATLAB. EEGLab has been widely used for research and recognized as the software most widely used for electrophysiological data analyses [46]. As the frequencies of extrinsic artifacts are different from EEG signals, it is necessary to filter the higher or lower than the frequencies of EEG signals. As this study focuses on the measurement of beta frequency which ranges 13 to 30 Hz, the high and low frequency cutoff in this study were determined as 30Hz and 0.5Hz, respectively. The intrinsic artifacts have similar frequencies to EEG signals. Independent component analysis (ICA) will be applied to remove the intrinsic artifacts. ICA is a method for signal processing and data analysis and have been widely used to remove intrinsic artifacts in EEG signals [47,48,49]. In this method, it is assumed that the recorded EEG signal can be analyzed as the sum of independent components, and also can be decomposed as independent components. After decomposing EEG signal in to independent components, unwanted noises such as eye-blinking or muscle movement can be removed. After the extrinsic and intrinsic artifacts are removed, the beta frequency will be presented in the time domain form. While the beta frequency can be measured by various locations in Figure 2(b), this study specifically uses the frequency values at FC5 and FC6 as the beta frequency values measured at these locations have been used to represent the level of stress [50,51]

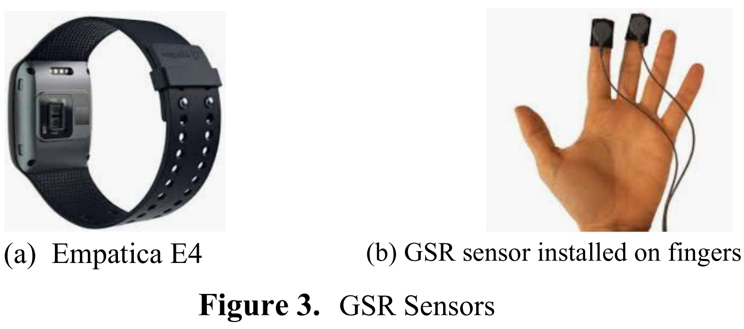
(a) EEG Sensor (EPOC+) (b) Location of electrodes on the scalp

Figure 2. EEG Sensor and Location of Electrodes

3.2. Galvanic Skin Response (GSR)

GSR is the method of measuring change of skin conductance at surface [52]. As mentioned previously, in a stressful situation, sympathetic nervous system is activated. Activation of sympathetic nervous system leads to sweating, which changes the skin conductance. Therefore, in a controlled situation, increasing GSR means increasing stress [53]. As GSR is only affected by sympathetic nervous system, there is few intervening variables between stress and GSR. Thus GSR can be a good indicator to measure stress [52].

Empatica E4 wristband will be used to measure the GSR signal. It has been widely used to measure GSR [54,55,56,57]. As it is a wristband as shown in Figure 3(a), subjects feel more comfortable to use this equipment than other types of equipment installed on their fingers as shown in Figure 3(b).



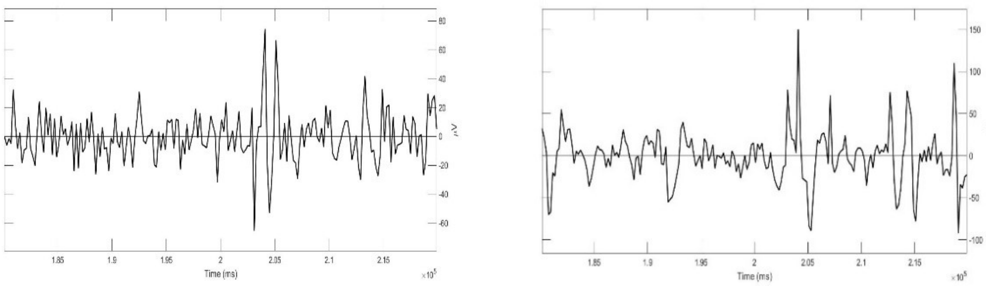
(a) Empatica E4 (b) GSR sensor installed on fingers

Figure 3. GSR Sensors

Recorded GSR signals will be processed by Ledalab. Ledalab is open source software for analyzing the skin conductance data in MATLAB. It helps users to filter their skin conductance data, and decompose for analyses [58,59,60,61]. Similar to the EEG sensor, GSR signals will be presented in the time domain.

4. EXPERIMENT DESIGN and PRELIMINARY FINDINGS

This study will investigate the relationship between stress level and reworks as shown in Figure 1. A preliminary test was conducted. A subject was asked to draw 3 simple drawings for a minute each and told to redraw them. He was told to stay calm for 20 seconds at the beginning of experiment, and the rework order was given at 200 seconds. Figure 4 shows the beta frequency from the preliminary test. They were obtained in FC5 and FC6 where the beta frequency can be measured. As shown in the figure, the beta frequency fluctuated substantially when they were asked to redo the work, indicating that the subject felt stress.



(a) Beta frequency recorded in FC5 (b) Beta frequency recorded in FC6

Figure 4. Preliminary EEG data

Figure 4 show that beta frequency of FC5 and FC6 was increased when rework order was given. Likewise figure 6 show that GSR value increase right after the rework order. Figure 5 represent the mean PSD value at certain situation such as stable, normal and stressed. Stable is the period when subject stay calm at the beginning of experiment and normal situation is the period when subject draw the plan. Stressed means the period when rework order was given. As can be seen at figure 5, mean PSD value of FC5 increased sequentially from stable to stressed situation. Contrary, mean PSD value for FC6 behave different. Mean PSD value of FC6 at stable situation is bigger than Normal one. But as mean PSD value at stressed is bigger than the others, it's possible to say that stress is detected. As bigger mean PSD value means more stress, we can say that current experiment set up can detect the stress from rework.

Figure 5 compares the mean power spectral density (PSD) values at different conditions such as stable, normal and stressed. The stable condition is the period when a subject stays calm at the beginning of experiment. The normal condition is the period when a subject works on the drawings. The stressed condition means the period when rework order was given. As can be seen in figure 5, the mean PSD values at FC5 and FC6 show were the highest in the stressed condition. As the bigger mean PSD value means higher level of stress, it can be concluded that rework causes stress.

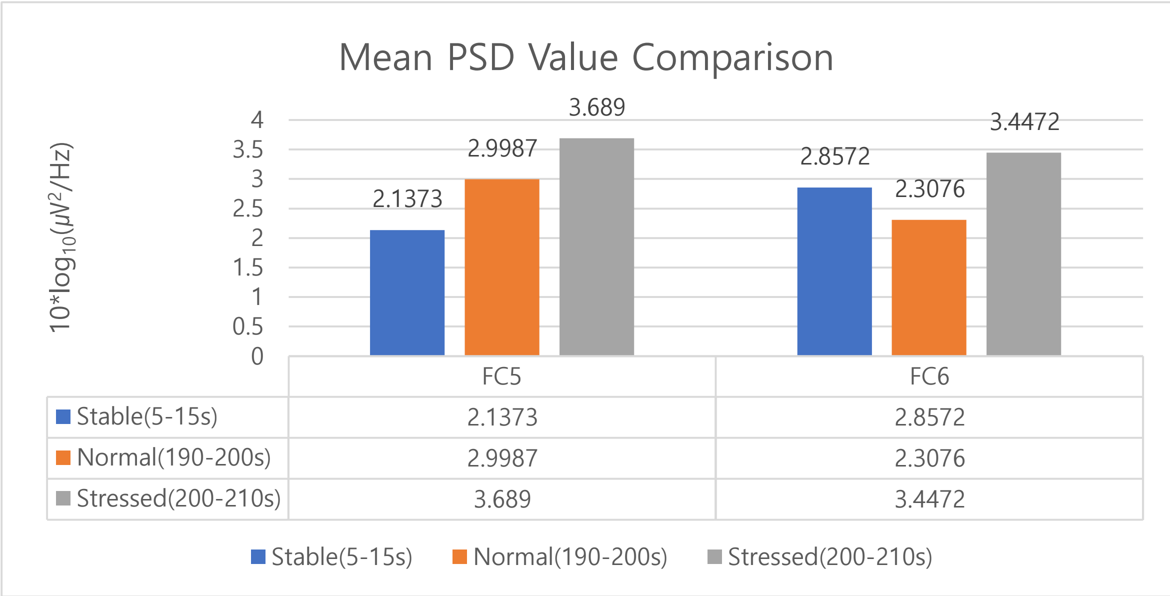


Figure 5. Mean PSD Value

Figure 6 shows the preliminary GSR data. As shown in the figure, when rework was assigned, the level of skin conductance increased significantly. As increasing GSR means increasing stress, the result also shows that the subject felt stress when rework order was given.

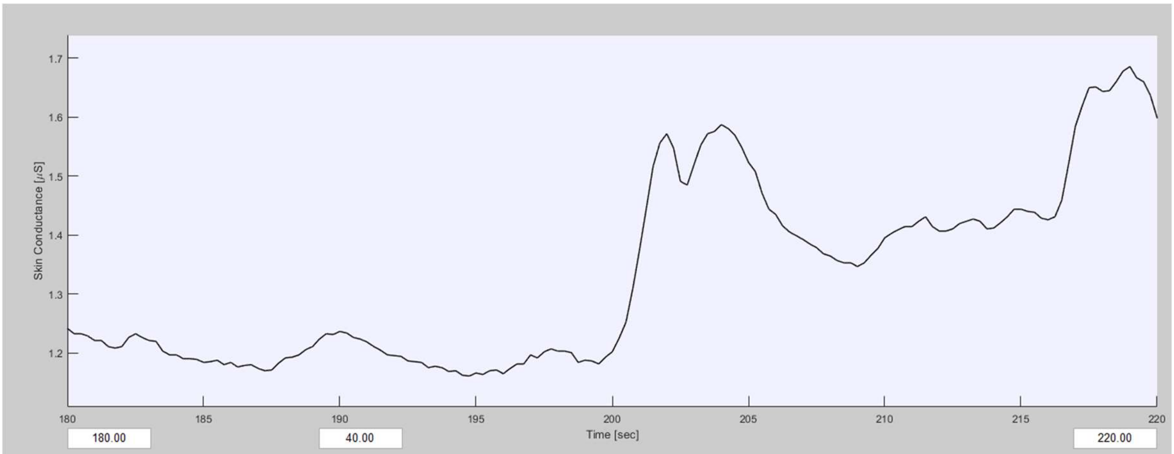


Figure 6. Preliminary GSR data

As presented in the previous section, there have many studies asserting that high level of stress reduces productivity [7,22]. Thus if the hypothesis is validated, it can be argued that reworks contribute to lowering productivity. This can be an interesting finding especially to practitioners. There has been a practice that companies award a contract at bids below a reasonable price and then

try to recover their compensation by making change orders. Some researchers described this as change order abuse [62,63,64]. As a change order can be another cause of rework, employees feel stressed when they are directed to work change orders. In addition, this kind of practice will lower the employees' WLB, which will lead to turnover as people pay more attention on WLB. Thus it is possible that companies' short-term profits will increase with the practice but their long-term profits may decrease. Future studies will try to validate these statement by testing the relationships in Figure 1.

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