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Investigating Frontal Neurovascular Coupling in Response to Workplace Design-Related Stress

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ABSTRACT This research seeks to examine the impact of workstation types on the coupling of neural and vascular activities of the prefrontal cortex (PFC). The design of the workstations was found to impair the performance, physical and mental health of employees. However, the mechanism underlying cognitive activity involved during workstation design-related stress effects in the PFC has not been fully understood. We used electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS) to simultaneously measure electrical activity and hemoglobin concentration changes in the PFC. The multimodal signal was collected from 23 healthy adult volunteers who completed the Montreal imaging stress task in ergonomic and non-ergonomic workstations. A supervised machine learning method based on temporally embedded canonical correlation analysis (tCCA) was utilized to obtain the association between neural activity and local changes in hemoglobin concentrations to enhance localization and accuracy. The results showed deactivation in alpha power rhythms and oxygenated hemoglobin, as well as declined activation pattern of the fused data in the right PFC at the non-ergonomic workstation. Additionally, all participants at the non-ergonomic workstation experienced a substantial rise in salivary alpha-amylase activity in comparison with the ergonomic workstation, indicating the existence of high-stress levels. The proposed tCCA approach obtains excellent results in discriminating workstation types achieving accuracies of 98.8% and a significant improvement of 8.0% ($p < 0.0001$) and 9.4% ($p < 0.0001$) over EEG-only and fNIRS-only, respectively. Our study suggests the use of functional neuroimaging in designing the workplace as it provides critical information on the causes of workplace-related stress.

INDEX TERMS Electroencephalography (EEG), ergonomic, functional near-infrared spectroscopy (fNIRS), oxygenated hemoglobin, prefrontal cortex (PFC).

I. INTRODUCTION

Stress has progressively become a part of daily life and is one of the health and safety issues at work. It could affect the well-being of workers and contribute to health problems; it has been documented as the second most common workplace health issue in Europe [1], and more than half of all job absences are due to stress effects [2]. The consequences of stress, such as presenteeism, absenteeism, and staff turnover, lead to productivity loss and increase the cost burden of enterprises [3]. Consequently, it is necessary to determine the causes of stress in the workplace (for example, psychological and physical stressors) to eliminate the levels of stress as much as possible. This study highlights the workplace environment and psychosocial stressors, and their interactions and effects on the severity of mental stress. Evidence has emerged that uncomfortable working conditions could affect workers' comfort and increase their stress symptoms [4]–[6], resulting in disorders related to hypothalamic-pituitary-adrenal (HPA) axis activation, such as cardiovascular and hypertensive diseases [7]–[9].

The use of functional neuroimaging has contributed to a better understanding of the neural correlates of stress and other mental states. Recent studies have revealed

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