THU-SSS-CCT-20

STUDY THE EFFECT OF STRESS ON MENTAL STATES USING FUNCTIONAL NEAR INFRARED SPECTROSCOPY(FNIRS)

Abdualrhman Daw Abdalhadi, PhD Student
Department of Electrical and Electronics Engineering,
Universiti Teknologi PETRONAS, Perak, Malaysia
E-mail: abdualrhman_22005752@utp.edu.my

Nitin Koundal, PhD Student
Department of Electrical and Electronics Engineering,
Universiti Teknologi PETRONAS, Perak, Malaysia.
E-mail: nitin_22005110@utp.edu.my

Assoc. Prof. Mohamad Naufal B Mohamad Saad, PhD
Department of Electrical and Electronics Engineering,
Universiti Teknologi PETRONAS, Perak, Malaysia
E-mail: naufal_saad@utp.edu.my

Assoc. Prof. Nina Bencheva, PhD
Department of Telecommunications,
University of Ruse "Angel Kanchev"
E-mail: nina@uni-ruse.bg

Abstract: *The purpose of the current study was to determine the fact that stress and cognitive load can increase person's mental workload. Acute stress is generally characterized as being brief and often brought on by subconscious thinking because of "demands and stressors of the recent past and prospective needs and challenges of the future". We will achieve this by observing people's cognitive reactions to stressful situations using a computer-designed task and functional near-infrared spectroscopy (fNIRS). During the endeavour, three distinct situations were introduced: the standard situation, in which participants completed the task with no time-constrained; the second scenario, in which subjects completed the assignment under time pressure; and the final situation, in which subjects completed the task under time pressure and under the cognitive demands. The findings demonstrated that subjects' restricted cognitive abilities prevented them from fully processing the data, which caused them to misunderstand the possible assignment when faced with increased mental workload and time restraints. Managers and employees can manage stressful work environments with the aid of current research.*

Keywords: *Stress, Cognitive demand, functional Near-Infrared Spectroscopy, Cognitive neuroscience*

INTRODUCTION

Stress is defined by psychological sciences as a feeling of pressure and tension in the mind. Low amounts of stress may be desirable, practical, and even beneficial. Numerous definitions of psychological stress exist. One of the more widely accepted definitions of stress is "a particular connection between the person and the surroundings that are evaluated by the individual as demanding or exhausting the person's capabilities and jeopardizing his or her well-being," (Lazarus and Folkman, 1984) and this definition refers to the procedures that are thought to lead to the development and recurrence of a number of disorders associated with stress. Positive stress can enhance psychosocial well-being and boost productivity. Positive stress is also seen as a crucial component of inspiration, adaptation, and response to the surroundings. High amounts of stress, however, may cause people to experience major bodily, psychological, and social issues (Tucker *et al.*, 2008). Acute stress and chronic stress are the two main categories or forms of stress that the American Psychological Association (APA) distinguishes. The traits, duration, symptoms, and methods of therapy for these diverse forms of stress are each described in a different way. The most prevalent and typical type of stress is acute stress. This type of stress is typically described as being fleeting and is frequently brought on by reflexive thinking that results from "demands and stressors of the recent past and prospective needs and challenges of the future". Long-term stress is referred to as chronic stress. Feelings of pessimism and sorrow are characteristic of this type of stress (*Stress*, 2011).

Numerous people experience hardship in their daily lives as a result of the disruption of the prefrontal cortex (PFC) functions such as imagination, decision-making, problem-solving, memory retention, and others (Cho *et al.*, 2016). The activity of several psychophysiological systems, including the immune, endocrine, and brain systems, alters as a result of stress (Balconi and Vanutelli, 2016). Prolonged exposure to a stressful scenario can be harmful to one's health because the corticosteroid hormones that are released in response to stress may negatively impact one's immunity, making one more vulnerable to infection. Chronic stress can also raise the risk of developing diseases including diabetes, heart disease, or depression (Pruett, 2003).

Particularly in the fields of professional or clinical healthcare, such as oncology or the management of chronic diseases, stress examination is regarded as a vital component of medical inspections. Human responses that are both perceptual and physiological can be used to quantify stress (Seo *et al.*, 2010). To research the mental state during a series of demanding tasks across time, continuous measurements are needed (Pruessner *et al.*, 2008). It is being established that physiological data from the brain, such as electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS), are capable of being utilized to measure stress (Moghimi *et al.*, 2012; Vander Weele *et al.*, 2013; Roy *et al.*, 2016; Sabeti *et al.*, 2016; Wei *et al.*, 2018; Tiwari and Falk, 2019). The variability of heart rate (HRV) is another physiological indicator that is frequently used as a stress indicator. It is a measurement of the changes in the durations within heartbeats that the nervous system's autonomy regulates. This method has been used to measure stress separately and in conjunction with measures of the galvanic skin responses, blood pressure, skin temperature, and EEG (Minguillon, Lopez-Gordo and Pelayo, 2016).

In real-world situations, motion and/or physiological processes other than cerebral activity frequently corrupt the fNIRS signal (Mirbagheri *et al.*, 2020). The heartbeat's physiological artifact can be effectively removed from the raw fNIRS signal and added to the study as a new source of data (Hakimi and Setarehdan, 2018). Therefore, it would be feasible to extract both the systemic information and the physiological response of the brain using just one portable instrument.

In contrast to the more strictly regulated psychological tasks that are most frequently utilized in the literature, the present investigation employed fNIRS to evaluate the assessment of mental states in more realistic stress tasks. We looked into how well fNIRS might identify various mental states during stress in conditions that were both cognitively demanding and time-constrained. To find out whether fNIRS could identify the cognitive states, visualizations of a natural stressful setting were added to the tasks.

Through this work, we hypothesise that:

- Stress could lead to an imbalance in the transmission of information in the prefrontal cortex (PFC) and this could influence cognitive activity, which reflects in hemodynamic response.
- Acute stress may lead to a high cognitive load and increase the probability of error.
- The use of supervised machine learning should be able to classify different mental states under stressful conditions.

MATERIALS AND METHODS

Experimental procedure

Two healthy graduate students were enrolled in the current study. Subjects in the research had to be right-handed and not have any prior history of neurological diseases or head injuries as inclusion requirements. During the second and third phases of the study, individuals were subjected to stressors such as deadline pressure and mental effort. The National Aeronautics and Space Administration -Task Load Index (NASA-TLX) instrument was utilized to gauge the stress intensity of the individuals. As part of the Balloon Analog Risk Task (BART) Task, physiological measurements were taken at different intervals, including at the beginning, at time pressure, and during the cognitive load.

Data Acquisition Protocol

The OT-R40 instrument was used in the present study to track the hemodynamic response to the risky balloon analogy task. By measuring variations in blood oxygenated haemoglobin and deoxygenated haemoglobin on the outermost layer of the cerebrum at several places concurrently based on a variance in light absorption, OT-R40 aids in monitoring brain activation. The 10/20 system, the standard technique for placing the optodes (light sensors) on the head, was employed in the fNIRS configuration. The 10/20 system uses specific cranial features for dividing the head into parts.

Task sequence

Three separate elements make up this study's experimental layout. The BART, the first part, lasts for 120 seconds. The following element places a 25-second time limit on the BART task. The experiment's last step combines the BART problem with an N-Back task, each of which must be completed in less than 25 seconds. Figure 1 depicts the full experimental layout, with each trial lasting 260 seconds overall. Optodes are often arranged in a grid-like layout on the scalp, with 52 channels, 17 emitters, and 16 detectors being a typical setup.

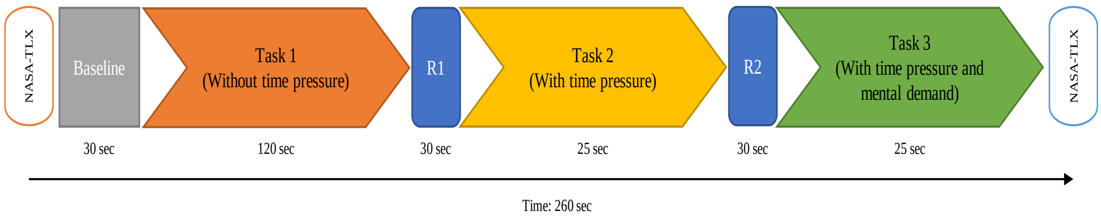

Figure 5. Experiment layout

RESULTS AND DISCUSSION

In this study, hemodynamic activity trends in the left orbitofrontal cortex (L-OFC) and left dorsolateral prefrontal cortex (L-DPFC) were investigated under two task situations using fNIRS. The findings in Table 1 demonstrated a relationship between task difficulty and PFC activation, showing that the addition of time constraints to the second task (Condition II) increased PFC response. The reported rise in PFC activity in Condition II demonstrates that individuals considered the activity more difficult under time constraints and concentrated on maximising their rewards by finishing the activity fast and receiving greater rewards. This might have led individuals to have a propensity to ignore the task's potential hazards. The conclusions show that the current results are consistent with previously conducted field studies. Overall, our findings imply that, in conditions of heightened task difficulty, especially those occurring during time pressure, PFC activation can act as an accurate substitute for decision-making efforts.

Table 2. Subject performance

Subjects	Condition I	Condition II	Condition III
1	(44.20$) 10/10 balloons	(12.80$) 6/10 balloons	(15.40$) 9/10 balloons (2-Back 60% correct)
2	(34.60$) 10/10 balloon	(14.20$) 7/10 balloon	(4.9$) 3/10 balloons

			(2-Back 90% correct)

In Condition III, individuals undertook a task that involved working under restricted time and finished a 2-back exam designed specifically to assess working memory. Working memory is a form of short-term memory that primarily relies on the PFC for synthesizing and managing recently gathered information. Working memory load increases result in increased mental stimulation throughout the PFC. Figure 2 illustrates how, in contrast to Condition I, Condition III significantly raised the amount of oxy-Hb level in the DLPFC section of the cerebral cortex. The amount of working memory utilized for processing the data that has been acquired is shown by a significant rise in neural activity observed in the PFC area.

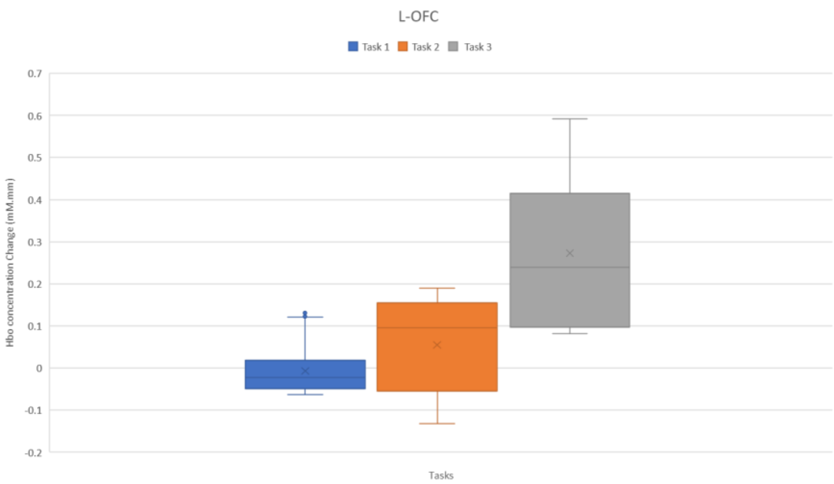

Figure 6. Statistical Analysis and Activation Difference Among Three Tasks

CONCLUSION

In the present research, fNIRS signals were utilized to measure participants' mental states under stressful circumstances. The complicated interplay between cognitive load and mental stress has been made clear by the study's findings. According to this study, task performance is significantly impacted by time constraints and mental stress, resulting in a high level of cognitive load. These findings have significant ramifications for comprehending the fundamental mechanics of the mental state amid stressful circumstances. These findings have significant consequences for learning the fundamental mechanics of mental demand in high-stress situations.

REFERENCES

Balconi, M. and Vanutelli, M.E. (2016) 'Emotions and BIS/BAS components affect brain activity (ERPs and fNIRS) in observing intra-species and inter-species interactions', *Brain Imaging and Behavior*, 10(3), pp. 750–760. Available at: https://doi.org/10.1007/S11682-015-9443-Z/METRICS.

Cho, H. *et al.* (2016) 'Herbal Extracts That Reduce Ocular Oxidative Stress May Enhance Attentive Performance in Humans', *Computational intelligence and neuroscience*, 2016. Available at: https://doi.org/10.1155/2016/4292145.

Hakimi, N. and Setarehdan, S.K. (2018) 'Stress assessment by means of heart rate derived from functional near-infrared spectroscopy', *https://doi.org/10.1117/1.JBO.23.11.115001*, 23(11), p. 115001. Available at: https://doi.org/10.1117/1.JBO.23.11.115001.

Lazarus, R. and Folkman, S. (1984) *Stress, Appraisal, and coping*, *Stress, appraisal and coping*. Springer publishing company. Available at:

 Copyrights© 2023 ISBN 978-954-712-925-2 (Print); e-ISBN 978-954-712-926-9

https://books.google.com/books/about/Stress_Appraisal_and_Coping.html?hl=bg&id=i-ySQQuUpr8C (Accessed: 28 May 2023).

Minguillon, J., Lopez-Gordo, M.A. and Pelayo, F. (2016) 'Stress assessment by prefrontal relative gamma', *Frontiers in Computational Neuroscience*, 10(SEP), p. 101. Available at: https://doi.org/10.3389/FNCOM.2016.00101/BIBTEX.

Mirbagheri, M. *et al.* (2020) 'Simulation and in vivo investigation of light-emitting diode, near infrared Gaussian beam profiles', *Journal of Near Infrared Spectroscopy*, 28(1), pp. 37–50. Available at: https://doi.org/10.1177/0967033519884209/ASSET/IMAGES/LARGE/10.1177_0967033519884209-FIG6.JPEG.

Moghimi, S. *et al.* (2012) 'Automatic detection of a prefrontal cortical response to emotionally rated music using multi-channel near-infrared spectroscopy', *Journal of Neural Engineering*, 9(2), p. 026022. Available at: https://doi.org/10.1088/1741-2560/9/2/026022.

Pruessner, J.C. *et al.* (2008) 'Deactivation of the Limbic System During Acute Psychosocial Stress: Evidence from Positron Emission Tomography and Functional Magnetic Resonance Imaging Studies', *Biological Psychiatry*, 63(2), pp. 234–240. Available at: https://doi.org/10.1016/j.biopsych.2007.04.041.

Pruett, S.B. (2003) 'Stress and the immune system', *Pathophysiology*, 9(3), pp. 133–153. Available at: https://doi.org/10.1016/S0928-4680(03)00003-8.

Roy, R.N. *et al.* (2016) 'Efficient mental workload estimation using task-independent EEG features', *Journal of Neural Engineering*, 13(2), p. 026019. Available at: https://doi.org/10.1088/1741-2560/13/2/026019.

Sabeti, M. *et al.* (2016) 'A multi-resolution approach to localize neural sources of P300 event-related brain potential', *Computer Methods and Programs in Biomedicine*, 133, pp. 155–168. Available at: https://doi.org/10.1016/J.CMPB.2016.05.013.

Seo, S.-H. *et al.* (2010) 'Stress and EEG', *Convergence and Hybrid Information Technologies* [Preprint]. Available at: https://doi.org/10.5772/9651.

Stress (2011) *American Psychological Association*. Available at: http://www.apa.org/helpcenter/stress-kinds.aspx (Accessed: 28 May 2023).

Tiwari, A. and Falk, T.H. (2019) 'Fusion of Motif-and Spectrum-Related Features for Improved EEG-Based Emotion Recognition', *Computational Intelligence and Neuroscience* [Preprint]. Available at: https://doi.org/10.1155/2019/3076324.

Tucker, J.S. *et al.* (2008) 'A temporal investigation of the direct, interactive, and reverse relations between demand and control and affective strain', *http://dx.doi.org/10.1080/02678370802190383*, 22(2), pp. 81–95. Available at: https://doi.org/10.1080/02678370802190383.

Vander Weele, C.M. *et al.* (2013) 'Restoration of hippocampal growth hormone reverses stress-induced hippocampal impairment', *Frontiers in Behavioral Neuroscience*, 7(MAY), p. 66. Available at: https://doi.org/10.3389/FNBEH.2013.00066/BIBTEX.

Wei, W. *et al.* (2018) 'Emotion Recognition Based on Weighted Fusion Strategy of Multichannel Physiological Signals', *Computational Intelligence and Neuroscience*, 2018. Available at: https://doi.org/10.1155/2018/5296523.