Learning and Memory under Stress: A Review Study with Evaluation Techniques

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ABSTRACT

In recent years, stress becomes a global problem faced by human beings at all stages of their life. It represents a serious problem and affects their lifestyle. Academic life is a fertile environment for stress forming due to the different stressing factors faced by students during all stages and to the various cognitive functions applied to acquire the new knowledge. In this review, stress impacts and effects on learning and memory are highlighted. Learning and memory are wital in students' achievement and improvement as they are part of the cognitive functions of the brain. Academic stress influences these two main skills, and it may impair the three stages of learning and memory: encoding, consolidation and retrieval. Thus, in this work, the proposed literature reviews the effects of academic stress on learning and memory cognitive functions based on six models including functional near-infrared spectroscopy (fNIRS), electroencephalogram (EEG), magnetic resonance imaging (MRI), electrocardiogram (ECG), behavioral analysis and multiple models. Finally, the challenges are highlighted, and further studies are proposed.

INTRODUCTION

Learning and memory performances are affected by stress which is caused due to psychophysiological responses. The effects of stress on learning and working memory are not homogenous [1]. Stress is reported as a cause of impaired memory performance ([2], [3], [4]). On the other hand, some other researchers suggested that no effects of stress on learning and working memory and it could have a positive influence on them ([5], [6], [7]). Stress affects the human nervous system, and this led to changes in the structures of the brain's parts [8]. The atrophy of the brain mass and weight could be also affected by stress [9]. The brain structural changes cause different responses to stress and working memory [8]. The duration and level of stress also determine the amount and intensity of the structural changes of the brain [8]. Academic environment is also affected by stress and this influence academic achievement of students and their abilities to learn and memorize the new acquired knowledge. Students in all stages of learning, not only adult students, are affected by the sequences of stress even at primary stage of school [10]. Academic stress may cause depression behavioral problems and anxiety among students [11], [12]. Future expectation, failure phobia, recognizing problems and memory retrieval were results of stress [13].

The academic stress has a noticeable effect on cognitive functions, which refer to various mental capabilities including thinking, learning, remembering, attention, reasoning, decision making and problem solving. Attention is affected by stress because it distracts the awareness during the stage of catching new knowledge [14]. Stress restricts the memory during the task of encoding the information and recalling it [15]. Focusing is also affected by stress because it may scatter students' Keywords: Cognitive Functions; Stress; Learning; Memory; MRI; EEG, fNIRS

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thoughts. Decision making, problems solving and judgments as parts of the cognitive function are influenced by stress in many different ways.

Learning and memory are affected by stress positively or negatively. The influence depends on the learning context, stressors or the learning task itself. Stress may occur in any stage of learning acquisition "encoding", consolidation and retrieval. In [16], researchers suggested if the stress starts at the encoding stage it will either impair or enhance the acquisition. Source of stress, stressors intensity, stressors duration and stressors timing are factors determining the level of the influence of stress in memory and learning [17]. Lately, the curfew and the lock down announced by governments and health organizations because of the pandemic of Covid-19 charged students with new stressors. These stressors may lead to anxious student, sleeping problems and low achievement. Furthermore, academic performance and learning abilities are affected. Thus, it is worth to study them in ordered to provide and give effective solutions [18]. The main contribution of the proposed study is to review the effects of academic stress on learning and memory cognitive functions based on six models including functional near-infrared spectroscopy (fNIRS), electroencephalogram (EEG), magnetic resonance imaging (MRI), electrocardiogram (ECG), behavioral analysis and multiple models. Finally, the challenges and possible future trends are highlighted.

METHODOLOGY AND MEASUREMENTS

The pandemic of COVID-19 has affected all people and changed everything in their life's. The way people live and interact, how they work and communicate and how they move, and travel are examples of COVID effects. As every aspects of the world have been affected, learning is the most affected aspect because of the lock down announced by the governments and the shift to the distance learning or what it is called e-Learning. Hence, the stress has been supported and being rich. In this review, the effects of stress have been placed on highlight based on the modalities used to measure and analyze stress. The review methodology was to collect articles studying the effects of stress on learning and memory retrieval using Google scholar. The researchers of those articles were using a variety of methodology and measures to study the effects of stress. Twenty articles used the behavioral analysis model such as surveys, questionnaires, interviews, and stress scales. Whereas the literature reviewed seven paper studying stress influences on learning and memory using Electroencephalogram (EEG). MRI (magnetic resonance imaging) is also a model used to determine the level of stress with four papers. Another four articles were selected to study the effects of stress with testing the level of cortisol hormones in the body and salivary cortisol. Finally, seven researchers used more the one model from the modality mentioned above.

LITERATURE REVIEW

This paper reviews different work literature related to the impact of academic stress on the memory and learning cognitive skills. For each work, the year of publication, the modality used, the methodology applied and the significant results of the work. Noticeably, it is clear that stress has an impact on learning and retrieval of probabilistic knowledge and sequence learning but it is not the case with procedural learning. Stress level also varies according to the subject being learnt and the environment of learning. Gender, exam phobia, requirements, mental health, change of lifestyle, quality of sleep, the field of studying weather theoretical or clinical, language barriers and more are factors that influence the level of stress.

MAGNETIC RESONANCE IMAGING (MRI)

Magnetic resonance imaging (MRI) is a method using powerful magnetics radio waves and computer to take images of the parts of the body and how healthy they are. When it is used to scan the brain, MRI provides detailed pictures of the brain and produces a map of blood vessels that indicates the level of stress. It is used to study the changes of activity of the brain after and before the participants face stressor. The data are analyzed by studying and analyzing the images from the machine using behavioral and physiological changes of the brain. Table. 1 summarizes the literature of the effects of stress on learning and memory based on MRI.

Table 1: The Literature of the Effects of Stress on Learning and Memory Based on M	1RI
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Paper	Year	Modality	Methodology	Results
[19]	2020	MRI	Behavioral and physiological analysis	Cortisol has an effect on modifying memory tasks while retrieval. Stress obliges multi memory tasks to use normal memory that may reduce working memory.
[20]	2020	MRI	Statistical analysis, behavioral and physiological data analysis	Stress could affect the memory tasks such as retrieval that is to mean it support habitual tasks by cortisol level.
[21]	2019	MRI	Data analysis	The ability to memorize is affected by acute stress. Stress has impact on recalling memories from the past
[22]	2017	Functional MRI	Data Analysis (image analysis)	Academic stress may affect the brain activities that may lead to change in the amount in food intake.

ELECTROENCEPHALOGRAPHY (EEG)

Electroencephalography (EEG) is an electrophysiological method used for monitoring the electrical activity of the brain. It is noninvasive placed on the scalp to detect the electrodes. It measures the voltage functions produced by the neurons of the brain. It is used to record the brain spontaneous electrical activities within a period of time [23]. Here, the papers used EEG to gather data and information about participants before and after they introduced to stressors. Then, the data were analyzed to gather and notice the changes. Table 2 summarizes the literature of the effects of stress on learning and memory based on EEG.

Table 2: The Literature of the Effects of Stress on Learning and Memory Based on EEG

Paper	Year	Modality	Methodology	Results
[24]	2020	EEG	Behavioral performances analysis, event-related potentials (ERPs), correlation analysis revealed	Enhanced working memory for high responders. There is a positive relationship between cortisol level and working memory.
[25]	2019	EEG	LME analyses socially evaluated cold pressor test -SECPT	Stress and cortisol reduce learning and memory feedback.
[26]	2020	EEG	Naive Bayes, support vector, KNN (k-Nearest Neighbors), and random forest	Stress level is higher during first time task in the audienced situation while it is less in the second time despite of the existence of audience

[27]	2018	EEG	Statistical analysis and behavioral analyses	The elderly inability to retrieve memory and maintain new knowledge is results from the stress faced during life. Thus, stress has a long-term effect on the health of cognitive functions.
[28]	2016	EEG	Statistical analysis (ANOVA Perceived Stress Scale (PSS)	Long term stress influences task of initializing the working memory and has an impact on attention.
[29]	2020	EEG	EEG prestress analysis algorithm	The theta main power is enhanced by pre learning stress. Thus, the long-term memory retrieval could be improved by pre learning stress.
[30]	2017	EEG	EEG pre-stress analysis algorithm	Theta is supposed to be the index of long- term memory.

CORTISOL LEVEL

Cortisol is a steroid hormone that is produces as a response of the stressed body [31]. Short memories are created by cortisol and adrenaline work, it is known as a flash bulb memories mechanism for storage, it could also

function as a mean in memorizing at future. Furthermore, hippocampus cells could be damaged by long term exposure to cortisol [32]. Table 3 summarizes the literature of the effects of stress on learning and memory based on cortisol level.

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Paper	Year	Modality	Methodology	Results
[33]	2020	salivary cortisol level,	Statistical analysis questionnaire-based rating	Stress has an influence on learning and retrieval of probabilistic knowledge and null on sequence learning. Stress may support procedural learning but confuse explicit process.
[34]	2019	salivary cortisol level	Analysis of salivary cortisol socially evaluated cold pressor test -SECPT	Stress support memory if the stressors occur in the same context of the engaged memory.
[35]	2018	salivary cortisol level	socially evaluated cold-pressor test Statistical analyses	The effect of stress on memory retrieval depends on the learning material, increases in stimuli material and decreases in ecological materials
[36]	2018	cortisol, heart rate	mood questionnaire data analysis	Social learning isn't affected by acute stress. Social learning doesn't cause stress, stress arises from human behaviors.

BEHAVIORAL ANALYSIS

Behavior analysis is the study and experimental investigating of the factors or variables that affects human or non-human behaviors [37], [38]. Here, we find researchers used a number of techniques to study stress and learning including cross sectional, statistical, algorithms and task data analysis. The data were collected by surveys, questionnaires or interviews conducted by the researchers. Table 4 summarizes the literature of the effects of stress on learning and memory based on behavioral Analysis.

Table 4: the literature of the effects of stress on learning and memory based on behavioral Analysis.

Paper	Year	Modality	Methodology	Results
[39]	2020	online survey	Statistical Package	Students experienced high level of stress
			for the Social	during Pandemic of Covid -19
			Sciences (SPSS)	The stress and anxiety increase as the
				mandatory staying at home continues.
[40]	2019	Perceived Stress Scale	Machine Learning	Stress could be detected by PSS before the
		(PSS)	Algorithms	exam. Thus, learner can be supported to
				reduce stress.
[41]	2018	Patient Health	Task data analysis	Stress may worsen depression if it
		Questionnaire-9 PHQ-9		accompanies decision making.
		State-Trait		
		Anxiety Inventory STAI		
		Snaith Hamilton		
		Pleasure Scale SHAPS		

[42]	2018	Nursing Work Functioning Questionnaire (NWFQ), and the Demand- Control-Support questionnaire (DCS).	Data Analysis	High job requirements increase learning and knowledge and less job impairment. Social support reduces stress.
[43]	2018	survey	Statistical Analysis	Stress arises from the feeling of insecurity and it will be less in save situations
[44]	2018	survey	Data analysis	Motivation overcomes academic stressors. Academic stress could be a catalyst in learning.
[45]	2017	web-survey questionnaire.	Self-directed learning readiness (SDLR) scale Scale of academic stress (SAS)	Academic stress affects negatively in Self- directed learning readiness. Self-directed learning readiness could be evaluated from academic stress and motivation
[46]	2018	interview-based study	Content Analysis Method approach	Learning environment has a vital role in the level of stress e.g., communication, learning tasks, context, and clinical scenario
[47]	2018	Survey California Psychological Inventory	Data analysis	Learning environment has a vital role in the level of stress, student indecency reduces stress.
[48]	2018	questionnaire	The scale for assessing academic stress (SAAS) Statistical analysis	Change of lifestyle increases level of stress. Competitive environment also increases the level of stress.
[49]	2018	survey	The first was The Perception of Academic Stress Scale (PAS) The Self-Regulatory Inventory Mindful Attention Awareness Scale (MAAS),	Stress affects negatively self-regulation. Stress restricts some learning skills such as critical thinking and problem solving. Mindfulness is also influenced by stress.
[50]	2018	questionnaire	Academic Stress Scale Data analysis	Stress level varies according to the subject being studied and gender.
[51]	2017	survey	Perceived Stress Scale (PSS) Data analysis	Stress level varies according to the subject being studied. Stress level reduces with experience during studying journey. Caffeine is being used to treat stress as a drug.
[52]	2017	survey	Positive Mental Health Scale With Educational Stress Scale for Adolescents	Private schools' students experience high level of stress while governmental schools are less, the same result for mental health. Stress also has an impact the mental health of students.
[53]	2017	questionnaire	Data analysis	Female students experience stress more than male students. Educational level also affects the level of stress.
[54]	2016	Cross- sectional survey	Data Analysis- Levene statistic	Academic stress and cell phone addiction doesn't affect their studying. If academic stress rises cell phone addiction rises and vice versa. These findings are stronger with male than female
[55]	2016	questionnaire	(ANOVA) ANalysis Of VAriance	Stress has no effects on students' sleep time but effect the sleeping quality. Students with low academic achievement may suffer with sleep problems which may worsen academic stress.
[56]	2016	The PSS-14 and the	Statistical Package	Stress level varies according to the subject

		Stress Survey	for the Social Sciences (SPSS)	being studied and the exams are the strongest stressor. Number of children for married students increases stress. Full time track students experience more stress.
[57]	2016	Goldberg's General Health Questionnaire (GHQ-28)	Beck Depression Inventory(BDI)	Male students are more stressful and depressed than female. Language obstacle may worsen the stress with students. New enrolled students are facing stress more than seniors.
[58]	2016	Ways of Coping Inventory (WCI) Nursing Education Stress Scale (NESS).	(SPSS) Statistical Package for the Social Sciences	Studying for the exam is the strongest stressor for theoretical subjects. Clinical practice stressor order as: instructor criticism, facing dying patient and fear of making errors.

COMPOUND ANALYSIS

Table 5 shows the effect of stress on learning and memory based on multiple modalities. The researchers

used models mentioned above to study the effect of stress on memory and learning and how the used modalities vary in their accuracy and results.

Table 5: the literature of the effect	s of stress on lear	rning and memor	v based on	multiple models.
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Paper	Year	Modality	Methodology	Results
[59]	2020	Electroencephalogram (EEG), cortisol level	State-Trait Anxiety Inventory (STAI)	There is a vital correlation between the dorsolateral prefrontal cortex
		Questionnaire		(dlPFC) and stress manipulating.
		Transcranial direct		Social stress has an impact on the
		current		working memory.
		stimulation (tDCS)		
[60]	2019	Electroencephalogram	Statistical Analyses	Brain activities are lower in stressed
		(EEG) Functional near-		situations.
		infrared spectroscopy		FMRI is more accurate than EEG
		(fNIRS)		
[61]	2020	Magnetic Resonance	Statistical Analyses	Obsessive-compulsive
		Imaging(MRI)	Image Acquisition	disorder patients suffer from acute
		behavioral analysis		stress which affects their memory
				performance.
[62]	2018	salivary cortisol	Data analysis	Stress can support the instruction of
		Vital signs		learning and this depends on the
		Questionnaire.		physiological stress response.
				Whereas anxiety reduces the
				learning performance.
[63]	2020	MAST	Self-Report	Stress doesn't have negative impact
		galvanic skin response	Questionnaire,	in all hippocampal-based learning
		(GSR) measures.	analysis of variance	types." declarative based memory"
			(ANOVA)	
[64]	2017	salivary cortisol	Data analysis	Post learning stress with high
		Questionnaire		adrenaline led to impair
				consolidation as well as stimulus-
				response.
[65]	2017	salivary cortisol	Data analysis	Habit learning is impaired by
		Heart rate	General linear models	psychological stress rather than
			(GLM)	reinforced.

FUNCTIONAL NEAR-INFRARED SPECTROSCOPY (FNIRS)

Functional near-infrared spectroscopy (fNIRS) is used to notice the simultaneous changes in the prosperities of the cortex of human brain from different places of the scalp. It displays the results by picturing or mapping the needed area [66], [67], [68]. Recently, this technology has been used to detect the effects of stress on cognitive functions. Searching Google Scholar, fNIRS was not found as a single modality to study the effects of stress on learning and memory. The literature will include this modality while reviewing compound modality section.

DISCUSSION

In this review, it is clear that stress has an impact on the working memory, and as a result it influences the learning process. Cortisol is the responsible hormone for controlling stress. From nerves system point of view, stress and the increase of cortisol hormone were accompanied by a high level of activity in the dorsal striatum while memorizing task [19]. But stress doesn't function negatively in all learning situation, it depends on the learning context or the learning task itself. Stress that is found within the context of a person well-known field or his own experience will increase the attention and enhance the working memory during the process of memory retrieval. but this will not happen with irrelevant experience [69]. Stress level also varies according to the subject being learnt and the Gender, exam phobia, environment of learning. requirements, mental health, change of lifestyle, quality of sleep, the field of studying weather theoretical or clinical, language barriers and more are factors that influence the level of stress. In contrast some researchers' findings reported that stress does not have impacts in some learning processes and memory performance. Thus, stress can be manipulating in a way to support learning and memory retrieval. Stress has an impact on learning and retrieval of probabilistic knowledge and sequence learning but it is not the case with procedural learning [33]. Importantly, social learning has no relationship with stress level; it is caused from the behaviors of learners themselves [36]. Undoubtedly, stress could be beneficial to learning and memory if the causes of stress occur in the same context of the task being practiced [34]. Remarkably, there are many factors that reduce stress or enhance working memory: social supports, feeling of security, motivation, along with experience, caffeine intake, and control over phone addiction, mental health and academic achievement.

CHALLENGES AND FUTURE TRENDS

Studying stress and its effects on the learning and memory performance is a wide subject. Undoubtedly, stress has three types: acute stress, episodic acute stress, and chronic stress and each one has its symptoms and characteristics. Stress also falls in many branches such as academic stress, social stress, environmental stress cultural stress and more. Thus, stress could be studied from different point of view. This section summarizes some of the challenges and future works that could be investigated:

• The mental health and the changes lifestyle and their relationship with the academic stress and academic achievement [70].

• Gender differences and their correlation in the level of stress among students.

• Does second language affect the level of stress as a media of instruction [71].

• The psychological aspect of stress among students and the family support.

• It is recommended to develop a methodology to study stress effects on learning and memory performance [17].

• The role of instructors and teacher of manipulating stress and reducing stress [72]

• Social factors may be further study stress and memory such media addiction [54]

• Parents' role in manipulating stress and determining the level of stress [73]

• Advanced technologies such as Internet of Things (IoT), wearable computing, big data, cloud and fog computing have to be investigated more to enhance evaluation capabilities [74-77]

CONCLUSION

Lately, the curfew and the lock down announced by governments and health organizations because of the pandemic of Covid-19 charged students with new stressors. However, the authors aimed to address the following question "how does the stress affect students' achievement to give chance for those who are interested in solving students' difficulties to provide solutions?". In this paper, six evaluation techniques about the effects of stress on memory and learning cognitive functions (such as, fNIRS, EEG, MRI, ECG, behavioral analysis and multiple models) are reviewed. Moreover, results of each study which is reviewed in the literature are discussed and highlighted. Finally, the challenges and possible future directions are highlighted.

REFERENCES

- Shields GS, Sazma MA, Yonelinas AP. The effects of acute stress on core executive functions: A metaanalysis and comparison with cortisol. Neurosci Biobehav Rev. 2016 Sep;68:651-668.
- Gärtner, M., Rohde-Liebenau, L., Grimm, S., Bajbouj, M., 2014. Working memory-related frontal theta activity is decreased under acute stress. Psychoneuroendocrinology 43 (5), pp.105-113
- 3. Qin, S., Hermans, E.J., van Marle, H.J., Luo, J., Fernandez, G., 2009. Acute psychological stress reduces working memory-related activity in the dorsolateral prefrontal cortex. Biol. Psychiatry 66 (1), pp. 25–32.
- Schoofs, D., Preuss, D., Wolf, O.T., 2008. Psychosocial stress induces working memory impairments in an n-back paradigm. Psychoneuroendocrinology 33 (5), pp. 643–653.
- M. Cornelisse, S., van Stegeren, A.H., Joels, M., 2011. Implications of psychosocial stress on memory formation in a typical male versus female student sample. Psychoneuroendocrinology 36 (4), pp. 569– 578
- Stauble, M.R., Thompson, L.A., Morgan, G., 2013. Increases in cortisol are positively associated with gains in encoding and maintenance working memory performance in young men. Stress-the International Journal on the Biology of Stress 16 (4), pp. 402–410.
- Schoofs, D., Preuss, D., Wolf, O.T., 2008. Psychosocial stress induces working memory impairments in an n-back paradigm. Psychoneuroendocrinology 33 (5), pp. 643–653.
- Lupien, S., McEwen, B., Gunnar, M. et al. Effects of stress throughout the lifespan on the brain, behaviour and cognition. Nat Rev Neurosci 10, 434– 445 (2009).
- Sarahian N, Sahraei H, Zardooz H, Alibeik H, Sadeghi B. Effect of memantine administration within the nucleus accumbens on changes in weight and volume of the brain and adrenal gland during chronic stress in female mice. Modares J Med Sci: Pathobiology. 2014;17:71–82.
- Pozos-Radillo, Blanca Elizabeth, María de Lourdes Preciado-Serrano, Martín Acosta-Fernández, María de los Ángeles Aguilera-Velasco, and Diemen Darwin Delgado-García. "Academic stress as a predictor of chronic stress in university students." Psicología educativa 20, no. 1 (2014): 47-52.
- 11. Deb, S., Strodl, E., & Sun, J. Academic stress, parental pressure, anxiety and mental health among Indian high school students. International Journal of Psychology and Behavioral Sciences, 5(1): 26-34 (2015).
- Verma, S. Sharma, D., & Larson, R. W. School stress in India: Effects on time and daily emotions. International Journal of Behavioral Development. 26(6): 500-508 (2002).
- Busari, A. O. Evaluating the Relationship between Gender, Age, Depression and Academic Performance among Adolescents. Scholarly Journal of Education, 1(1): 6-12 (2012).

- 14. Sänger, Jessica, Laura Bechtold, Daniela Schoofs, Meinolf Blaszkewicz, and Edmund Wascher. "The influence of acute stress on attention mechanisms and its electrophysiological correlates." Frontiers in behavioral neuroscience 8 (2014): 353.
- Kuhlmann, S.; Piel, M.; Wolf, O.T. (2005). "Impaired Memory Retrieval after Psychosocial Stress in Healthy Young Men". Journal of Neuroscience. 25 (11): 2977 2982
- 16. Sandi, Carmen, and M. Teresa Pinelo-Nava. "Stress and memory: behavioral effects and neurobiological mechanisms." Neural plasticity 2007 (2007).
- 17. Porcelli, Anthony J., and Mauricio R. Delgado. "Stress and decision making: effects on valuation, learning, and risk-taking." Current opinion in behavioral sciences 14 (2017): 33-39.
- S. P. Becker, M. A. Jarrett, A. M. Luebbe, A. A. Garner, G. L. Burns, and M. J. Kofler, "Sleep in a large, multiuniversity sample of college students: sleep problem prevalence, sex differences, and mental health correlates," Sleep health, vol. 4, no. 2, pp. 174-181, 2018
- 19. Zerbes, Gundula, Franziska M. Kausche, and Lars Schwabe. "Stress-induced cortisol modulates the control of memory retrieval towards the dorsal striatum." European Journal of Neuroscience (2020).
- Zerbes, G., Kausche, F. M., & Schwabe, L. (2020). Stress-induced cortisol modulates the control of memory retrieval towards the dorsal striatum. European Journal of Neuroscience.
- Gagnon, S. A., Waskom, M. L., Brown, T. I., & Wagner, A. D. (2019). Stress impairs episodic retrieval by disrupting hippocampal and cortical mechanisms of remembering. Cerebral Cortex, 29(7), 2947-2964.
- Neseliler, S., Tannenbaum, B., Zacchia, M., Larcher, K., Coulter, K., Lamarche, M., ... & Dagher, A. (2017). Academic stress and personality interact to increase the neural response to high-calorie food cues. Appetite, 116, 306-314.
- 23. Niedermeyer E.; da Silva F.L. (2004). Electroencephalography: Basic Principles, Clinical Applications, and Related Fields. Lippincott Williams & Wilkins. ISBN 978-0-7817-5126-1.
- 24. Lin, Li, Ada WS Leung, Jianhui Wu, and Liang Zhang. "Individual differences under acute stress: Higher cortisol responders performs better on N-back task in young men." International Journal of Psychophysiology 150 (2020): 20-28.
- 25. Paul, Marcus, Christian Bellebaum, Marta Ghio, Boris Suchan, and Oliver T. Wolf. "Stress effects on learning and feedback-related neural activity depend on feedback delay." Psychophysiology 57, no. 2 (2020): e13471.
- Antonijevic, M., Zivkovic, M., Arsic, S., & Jevremovic, A. (2020). Using AI-Based Classification Techniques to Process EEG Data Collected during the Visual Short-Term Memory Assessment. Journal of Sensors, 2020.
- Marshall, A. C., Cooper, N., Rosu, L., & Kennett, S. (2018). Stress-related deficits of older adults' spatial working memory: an EEG investigation of occipital alpha and frontal-midline theta activities. Neurobiology of aging, 69, 239-248.
- Yuan, Y., Leung, A. W., Duan, H., Zhang, L., Zhang, K., Wu, J., & Qin, S. (2016). The effects of long-term stress on neural dynamics of working memory

processing: An investigation using ERP. Scientific reports, 6(1), 1-10.

- O. M. AlShorman and A. M. Alshorman, "Frontal lobe and long-term memory retrieval analysis during prelearning stress using EEG signals," Bulletin of Electrical Engineering and Informatics, vol. 9, no. 1, 2020.
- O. AlShorman, T. Ali, and M. Irfan, "EEG Analysis for Pre-learning Stress in the Brain," in Asian Simulation Conference, 2017, pp. 447-455: Springer
- 31. Van der Valk ES, Savas M, Van Rossum EFC. Stress and obesity: Are there more susceptible individuals?. Curr Obes Rep. 2018;7(2):193-203. doi:10.1007/s13679-018-0306-y
- McAuley MT, Kenny RA, Kirkwood TB, Wilkinson DJ, Jones JJ, Miller VM (March 2009). "A mathematical model of aging-related and cortisol induced hippocampal dysfunction". BMC Neuroscience. 10: 26. doi:10.1186/1471-2202-10-26
- 33. Toth-Faber, Eszter, Karolina Janacsek, Agnes Szollosi, Szabolcs Keri, and Dezso Nemeth. "Procedural learning under stress: boosted statistical learning but unaffected sequence learning." bioRxiv (2020).
- 34. Sazma, Matthew A., Andrew M. McCullough, Grant S. Shields, and Andrew P. Yonelinas. "Using acute stress to improve episodic memory: the critical role of contextual binding." Neurobiology of Learning and Memory 158 (2019): 1-8.
- 35. Stock, Lisa-Marie, and Christian J. Merz. "Memory retrieval of everyday information under stress." Neurobiology of Learning and Memory 152 (2018): 32-38.
- 36. Cingl, Lubomír. "Social learning under acute stress." PloS one 13, no. 8 (2018): e0202335.
- 37. Sulzer-Azaroff, B., & Mayer, G. R. (1991). Behavior analysis for lasting change. Holt, Rinehart & Winston.
- 38. Pierce, W. D., & Cheney, C. D. (2013). Behavior analysis and learning. Psychology Press.
- Husky, Mathilde M., Viviane Kovess-Masfety, and Joel D. Swendsen. "Stress and anxiety among university students in France during Covid-19 mandatory confinement." Comprehensive Psychiatry 102 (2020): 152191.
- 40. Ahuja, Ravinder, and Alisha Banga. "Mental Stress Detection in University Students using Machine Learning Algorithms." Procedia Computer Science 152 (2019): 349-353.
- 41. Heller, Aaron S., CE Chiemeka Ezie, A. Ross Otto, and Kiara R. Timpano. "Model-based learning and individual differences in depression: The moderating role of stress." Behaviour research and therapy 111 (2018): 19-26.
- 42. Magnavita, Nicola, and Carlo Chiorri. "Academic stress and active learning of nursing students: A cross-sectional study." Nurse Education Today 68 (2018): 128-133.
- 43. Poalses, Jacolize, and Adéle Bezuidenhout. "Mental health in higher education: A comparative stress risk assessment at an open distance learning university in South Africa." International Review of Research in Open and Distributed Learning 19, no. 2 (2018).
- 44. You, Ji Won. "Testing the three-way interaction effect of academic stress, academic self-efficacy, and task value on persistence in learning among Korean college students." Higher Education 76, no. 5 (2018): 921-935.
- 45. Heo, JeongChul, and Sumi Han. "Effects of motivation, academic stress and age in predicting self-directed

learning readiness (SDLR): Focused on online college students." Education and Information Technologies 23, no. 1 (2018): 61-71.

- 46. Johnson, Natasha R., Andrea Pelletier, Xiaodong Chen, and Beryl L. Manning-Geist. "Learning in a high-stress clinical environment: stressors associated with medical students' clerkship training on labor and delivery." Teaching and Learning in Medicine 31, no. 4 (2019): 385-392.
- 47. Wardley, C. Sonia, E. Brooks Applegate, A. Deyab Almaleki, and James A. Van Rhee. "Is Student Stress Related to Personality or Learning Environment in a Physician Assistant Program?." The Journal of Physician Assistant Education 30, no. 1 (2019): 9-19.
- 48. Alsulami, Saleh, Zaid Al Omar, Mohammed S. Binnwejim, Fahad Alhamdan, Amr Aldrees, Abdulkarim Al-bawardi, Meshary Alsohim, and Mohammed Alhabeeb. "Perception of academic stress among Health Science Preparatory Program students in two Saudi universities." Advances in medical education and practice 9 (2018): 159.
- Ramli, Nur Hamizah, Masoumeh Alavi, Seyed Abolghasem Mehrinezhad, and Atefeh Ahmadi. "Academic stress and self-regulation among university students in Malaysia: Mediator role of mindfulness." Behavioral Sciences 8, no. 1 (2018): 12.
- 50. Reddy, K. Jayasankara, Karishma Rajan Menon, and Anjana Thattil. "Academic stress and its sources among University students." Biomedical and Pharmacology Journal 11, no. 1 (2018): 531-537.
- 51. Al Rasheed, Fatima, Atta Abbas Naqvi, Rizwan Ahmad, and Niyaz Ahmad. "Academic stress and prevalence of stress-related self-medication among undergraduate female students of health and nonhealth cluster colleges of a public sector university in Dammam, Saudi Arabia." Journal of pharmacy & bioallied sciences 9, no. 4 (2017): 251.
- 52. Subramani, C., and S. Kadhiravan. "Academic stress and mental health among high school students." Indian Journal of Applied Research 7, no. 5 (2017): 404-406.
- 53. Shadi, Maliheh, Nooshin Peyman, Ali Taghipour, and Hadi Tehrani. "Predictors of the academic stress and its determinants among students based on the theory of planned behavior." Journal of Fundamentals of Mental Health 20, no. 1 (2017): 87-98.
- 54. Thomas, Darrin. "Cellphone addiction and academic stress among university students in Thailand." In International Forum, vol. 19, no. 2, pp. 80-96. 2016.
- 55. Alsaggaf, Mohammed A., Siraj O. Wali, Roah A. Merdad, and Leena A. Merdad. "Sleep quantity, quality, and insomnia symptoms of medical students during clinical years: relationship with stress and academic performance." Saudi medical journal 37, no. 2 (2016): 173.
- 56. Brown, Kimarie, Pauline Anderson-Johnson, and Andrea Norman McPherson. "Academic-related stress among graduate students in nursing in a Jamaican school of nursing." Nurse education in practice 20 (2016): 117-124.
- 57. Hossain, Molla Muntasir, and Md Abdul Wahab. "Academic stress, anxiety and depression among the students of Armed Forces Medical College, Dhaka Cantonment." Journal of Armed Forces Medical College, Bangladesh 12, no. 1 (2016): 79-82.

- 58. Bahadır-Yılmaz, Emel. "Academic and clinical stress, stress resources and ways of coping among Turkish first-year nursing students in their first clinical practice." Kontakt 18, no. 3 (2016): e145-e151.
- Ankri, Yael LE, Yoram Braw, Galia Luboshits, and Oded Meiron. "The effects of stress and transcranial direct current stimulation (tDCS) on working memory: A randomized controlled trial." Cognitive, Affective, & Behavioral Neuroscience 20, no. 1 (2020): 103-114.
- 60. Al-Shargie, F. (2019). Assessment of Mental Stress Using EEG and fNIRS Features.
- 61. Li, Qianqian, Jun Yan, Jinmin Liao, Xiao Zhang, Lijun Liu, Xiaoyu Fu, Hao Yang Tan, Dai Zhang, and Hao Yan. "Distinct Effects of Social Stress on Working Memory in Obsessive-Compulsive Disorder." Neuroscience Bulletin (2020): 1-13.
- 62. Vogel, Susanne, and Lars Schwabe. "Tell me what to do: Stress facilitates stimulus-response learning by instruction." Neurobiology of learning and memory 151 (2018): 43-52.
- 63. Ballan, Ranin, and Yafit Gabay. "Does Acute Stress Impact Declarative and Procedural Learning?." Frontiers in psychology 11 (2020): 342.
- Goldfarb, E. V., Mendelevich, Y., & Phelps, E. A. (2017). Acute stress time-dependently modulates multiple memory systems. Journal of Cognitive Neuroscience, 29(11), 1877-1894.
- Fournier, M., d'Arripe-Longueville, F., & Radel, R. (2017). Effects of psychosocial stress on the goaldirected and habit memory systems during learning and later execution. Psychoneuroendocrinology, 77, 275-283.
- 66. Ferrari, M., & Quaresima, V. (2012). A brief review on the history of human functional near-infrared spectroscopy (fNIRS) development and fields of application. Neuroimage, 63(2), 921-935.
- 67. Coyle, S. M., Ward, T. E., & Markham, C. M. (2007). Brain-computer interface using a simplified functional near-infrared spectroscopy system. Journal of neural engineering, 4(3), 219.
- 68. Sitaram, R., Zhang, H., Guan, C., Thulasidas, M., Hoshi, Y., Ishikawa, A., & Birbaumer, N. (2007). Temporal classification of multichannel near-infrared spectroscopy signals of motor imagery for developing a brain-computer interface. NeuroImage, 34(4), 1416-1427.
- 69. Joëls, Marian, Zhenwei Pu, Olof Wiegert, Melly S. Oitzl, and Harm J. Krugers. "Learning under stress: how does it work?." Trends in cognitive sciences 10, no. 4 (2006): 152-158.
- 70. Dalky, Heyam F., and Assel Gharaibeh. "Depression, anxiety, and stress among college students in Jordan and their need for mental health services." In Nursing forum, vol. 54, no. 2, pp. 205-212. 2019.
- 71. Celik, Bünyamin Celik. "Relationship between Foreign Language Learning and Exam Stress with Gender: A Study on Tshik International University Preparatory School Students, Iraq." International Journal of Social Sciences & Educational Studies 5, no. 3 (2019): 311-322.
- 72. Theoharides, Theoharis C., and Maria Kavalioti. "Effect of stress on learning and motivationrelevance to autism spectrum disorder." (2019): 2058738419856760.
- 73. P. Arun, R. Garg, and B. S. Chavan, "Stress and suicidal ideation among adolescents having

academic difficulty," Industrial psychiatry journal, vol. 26, p. 64, 2017.

- 74. O. AlShorman, B. AlShorman, M. Alkhassaweneh, and F. Alkahtani, "A Review of Internet of Medical Things (IoMT)-Based Remote Health Monitoring through Wearable Sensors: A Case Study for Diabetic Patients," Indonesian Journal of Electrical Engineering and Computer Science, vol. 20, no. 1, pp. 414-422, 2020.
- 75. O. AlShorman, B. AlShorman, and F. Alkahtani, "A review of wearable sensors based monitoring with daily physical activity to manage type 2 diabetes," International Journal of Electrical & Computer Engineering (2088-8708), vol. 11, no. 1.
- 76. O. AlShorman, B. Alshorman, and M. Masadeh, "A Review of Physical Human Activity Recognition Chain Using Sensors," Indonesian Journal of Electrical Engineering and Informatics (IJEEI), vol. 8, no. 3, 2020.
- 77. M. Al-khassaweneh and O. AlShorman, "Frei-Chen bases based lossy digital image compression technique," Applied Computing and Informatics, 2020.