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Evaluation of Academic Stress Employing Network and Time Series Analysis on EEG Data

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Abstract: Stress management during examinations is an issue perpetually concerning students at all levels of education. This research endeavor focuses not merely on the plethora of factors associated with stress during examinations but rather focuses primarily on specific emotions developed during written and oral exams, introducing an original method, based on electroencephalograph (EEG) data. In an attempt to address the role of emotions in stress management, we organized an experiment on a sample of 30 postgraduate students, administering the Trier research protocol. The validated Emotiv Epoc+ device was used, while acquired the data were processed using a combined methodology of network and time series analysis applied in three (3) steps. Initially a descriptive analysis was performed based on the extracted frequencies, while in the second phase a network analysis was conducted to understand the extend of coordination between measured emotions (stress, engagement, interest, relaxation, excitement, and focus), using the tools of centrality. Finally, time series analysis was employed to indicate the level of auto- and cross-correlation between stress and other emotions. Our findings show that (eu)stress plays an imperative role in examination success, as long as it normally fluctuates within middle-range values (on a scale 0–100), and is being restrained by other feelings, such as interest, excitement, and focus

Keywords: stress; stress control; constructive stress; destructive stress; EEG data process methodology

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1. Introduction

The term stress refers to non-specific responses of the body [1], which may stem from an external source triggering the body's reaction; any noxious stimulus, time pressure, a loss, working conditions, or a natural phenomenon may be considered as such a source. Even though, according to Lu et al. [2], "stress is essential for building biological shields to guarantee normal life processes", the negative concepts of unpredictability, crisis, loss of control, and uncertainty are inextricably linked to those of stress [3]. In such circumstances, the organism enlists various methods that involve either vigilance organism processes by increasing the available energy resources or activating the immune response mechanism in order to be able to successfully respond to a crisis situation that directly threatens its viability [4].

It is a fact that stress is divided into three different reactions in terms of an organ-ism's response, namely physiological, behavioral, and psychological reactions. Each category of reactions is separate, and the literature distinguishes the way in which these can be measured; also, these reactions are divided into involuntary and voluntary, depending

on whether the individual can determine the reaction and, thus, control it or not. For this reason, different methods have been developed to determine and measure these reactions (biosignals) [5–9]. For example, facial reactions, speech patterns, electrodermal conductivity (EDA), skin temperature (SKT), brain activity (EEG), cardiac activity (ECG), and blood pressure (BVP) are measured [10]. In particular, the use of electroencephalography (EEG) in recent years has given a particular boost to the measurement of emotions and how they relate to and influence, along with stress, the body's response.

In terms of duration, stress may be chronic or momentary [11], depending on the length of time that it affects the body (referring to chronic situations that affect the body's homeostasis for long periods of time, such as poor working conditions, a loss, or financial difficulties), while according to Poganik et al. [12], transient stress usually refers to short-term stimuli—such as an examination—following which the body recovers after a short time.

Another differentiation according to Greco et al. [13] is that of creative and destructive stress. According to the latter research, creative stress contributes to creativity and success of purpose by intensifying the required alertness of successfully completing a mental task, generating positive feelings of well-being, interest, attachment, optimism, etc. In contrast, destructive stress inhibits the success of an endeavor, generating a range of negative emotions and psychosomatic symptoms, such as fear, shame, and inhibition, or even physical pain, antisocial behaviors, and depression as a result of chronic stress. These symptoms were also highlighted by Kiecolt-Glaser et al. (2002) [14] and Sternberg et al. (1992) [15], indicating the effect of distress in behavior and also the overall state of health. In line with the aforementioned information, Popovic & Lavie [16] distinguish three types of stress: sustress, eustress, and distress. According to the authors, sustress represents inadequate stress, described as a state where homeostasis is not challenged due to the absence or inadequacy of stressors, reducing the buffering capacity of homeostasis. Eustress, or good stress, is a state where homeostasis is mildly challenged by moderate levels of stressors, enhancing the buffering capacity of homeostasis, and also preparing the individual to handle and survive future challenges, while distress occurs when homeostasis is strongly challenged by high levels of stressors, leading to pathological conditions. In both cases, and taking into account that stress significantly affects human behavior, a plethora of researchers have worked on several methods aiming to acknowledge the stress network of variables, mainly focusing on (1) qualitative and quantitative research methods based on observation, in-depth interviews (etc.), and the employment of Likert scale-based structured questionnaires, and (2) experiments mainly based on biological data and brain activity frequencies.

Academic stress, according to Spiljak et al. [17] is a prevalent issue among students, with a severe impact on their psychological well-being, affecting various aspects of their academic life and performance, mainly deriving [18] from various sources, including exams, grades, and competition with peers. O 'Connor et al. [19] states that exams are considered one of the most acute stressors for students, while younger students tend to experience higher stress levels compared to older students, primarily due to concerns about grades, exams, and the fear of failing the academic year. In many cases, students—and particularly postgraduate students (who were the sample of the experiment performed by the research team)—feel distressed due to the demanding nature of their studies, reporting increased anxiety, depression, and a tendency to drop off their studies, since the combination of everyday work, family, and rigorous academic obligations functions as a significant stressor. The examination period in such a highly demanding environment is the escalated zenith of stress, and coping with this stress is an issue that needs to be thoroughly tackled. Towards this effort, various methods have been used to assess academic stress, ranging from self-

report questionnaires to physiological measures [20,21]. The Scale for Assessing Academic Stress (SAAS) and the Perceived Stress Scale-10 (PSS-10) are commonly used tools that measure students' perceived stress levels providing researchers' subjective data on how students cope with academic demands. Considering the extensive influence of stress on academic performance and psychological well-being, researchers have argued that psychometric Likert-based scales produce data of conscious thought and are not quite spontaneous [22] but are instead subjected to various forms of bias. For that reason, a new methodological approach was employed to try to acknowledge the association and correlation between emotions and stress. This approach differs from other methodological approaches, since network and time series analysis were used on the EEG data, allowing us to observe the emotion matrix and the extent of the auto- and cross-correlation of emotions, providing a more nuanced understanding of how to transform academic stress into eustress.

2. Materials and Methods

The research methodology of the present study attempts to determine the role of academic stress during written and oral exams in postgraduate students, and more significantly to identify the impact of stress in association with the role of other emotions, such as focus, engagement, interest, relaxation, and excitement, as means to convert it from distress to eustress. Thus, instead of using simple descriptive statistics in this paper, we decided to implement a combined methodology of network and time series analysis to provide a comprehensive understanding of the interplay between stress and other emotions. More specifically, network analysis allows us to observe and visualize the coordination between emotions and focus by using centrality measures to identify key emotions that influence stress levels, while time series analysis complements this by examining the temporal dynamics of these emotions, capturing both autocorrelation and cross-correlation. The integration of these two methods offers a more nuanced perspective than traditional psychometric scales, which often fail to capture the spontaneous and interconnected nature of emotional responses. Towards this objective, an experiment took place at the research lab of knowledge management at the International Hellenic University on a sample of 30 postgraduate students. The employed protocol was based on the Trier modified protocol, which is widely used by the scientific community as a stress induction protocol [23–26]. The proposed research methodology used in the experimental procedure is discussed below.

2.1. Participants

A total of thirty (30) healthy participants, namely postgraduate students of the International Hellenic University, took part in this study, with age range from 28 to 50 (with an average age of 32.5 years). The Research Ethics Committee of the International Hellenic University approved this experimental protocol, and each participant signed the consent form in order to participate in the procedure, which would be the final examination procedure for each participant; the final grade each participant came solely from the experimental procedure. It is worth noting that participation in the experimental procedure was voluntary. Each participant was informed prior to the procedure (8 h) not to consume tobacco or caffeine, and individuals with drug or alcohol addiction issues, people with metal implants in their bodies, and those regularly taking medication, were excluded. In addition, they were advised to refrain from any other physical exercise for at least 24 h prior to the procedure and to have slept for at least eight (8) hours prior to the procedure.

2.2. Experimental Protocol

Each participant in the experimental procedure was subjected to an experimental protocol which included four stages, in front of a three-member committee. In the first stage,

which was the calm and relaxation stage, each participant was informed to be in a state of calm and relaxation for five minutes (5 min). During this stage, we constantly validated the contact quality and EEG quality, to make sure that the device worked properly and that the measurements were reliable. In the second stage, each participant was subjected to a written examination on the course being taught for a period of fifteen minutes (15 min). In the third stage, each participant was subjected to an oral examination for a period of fifteen minutes (15 min) by the three-member panel. In the fourth and final phase, each participant remained in a state of rest for five minutes (5 min), doing absolutely nothing. Apart from the fact that the three-member panel, as stipulated by the Trier experimental protocol, caused a priori reinforcement of the feeling of stress, the examination process was, in itself, a process that causes increased stress in students. Furthermore, the oral examination itself in front of a panel of three was, in itself, sufficient to cause a great deal of stress in the candidates. By essentially modifying Trier's original protocol and adapting it to the examination process, more emphasis was placed on the induction of stress, in an already stressful situation that students are obliged to go through several times during their student life. More precisely, the written test consisted of twenty (20) multiple choice questions with four (4) alternative answers each, which had to be completed within the time given. The oral examination was based mostly on the cases participants seemed to have difficulties answering, and in other cases students were asked to justify their answers in detail.

Figure 1 below shows the stages of the experimental process and their duration. As can be observed, the experimental protocol consisted of four stages:

(A) Phase 1 (RX—relaxation): In this stage, the participants calmed down and prepared for the experimental procedure. In this stage, the baseline measurements were taken from the equipment used.

(B) Phase 2 (WE—written examination): In this stage, participants had to complete the written examination as best as they could in the time given, which was limited for the requested tasks.

(C) Phase 3 (OE—oral examination): In this stage, the participants were subjected to an oral examination by the three-member committee, which asked questions continuously for the entire time available, in order to put as much pressure on each participant as possible.

(D) Phase 4 (RX—relaxation): In this stage, the participants relaxed and calmed down after they had finished the experimental procedure. It was the last stage of the experimental protocol.

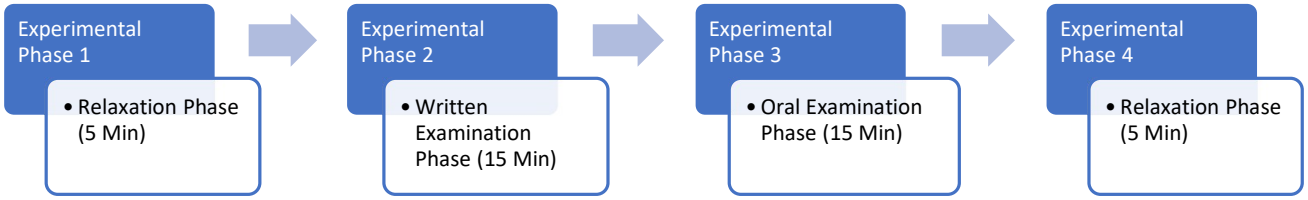

Figure 1. The four phases of the experimental procedure.

2.3. Psychometrics Tests

Prior to the start of the experimental procedure and after the final phase, participants completed STAI questionnaires, as indicated by Balsamo et al. [27], to determine their stress levels before and after the procedure.

2.4. Equipment

The main device used in this study was the EMOTIV portable electroencephalograph (EMOTIV, San Francisco, CA, USA), the Epoc+ model. In recent years this device has been used in research related to cognitive neuroscience. The 14 + 2 electrodes on this electroencephalograph are positioned in the following regions [28]:

- F3, F4, AF3, AF4, F7, and F8 for frontal lobe activity;
- T7, T8, FC5, and FC6 for temporal lobes activity;
- P7 and P8 for lobus parietalis activity;
- O1 and O2 for depicting activity in the lobus occipitalis.

This device has a sampling rate between 128 Hz and 256 Hz, a bandwidth of 0.2–45 Hz, and digital notch filters at 50 Hz and 60 Hz, and it connects wirelessly to a computer, on which the EmotivPRO v.3.8.0.532, Emotiv BCI v.4.3.0.290, and Emotiv BrainVIZ v.4.3.0.146 software are installed, so that the machine can be installed correctly and the data it receives can be captured [28].

The main reasons for choosing this EEG were the number of sensors available, its identification of emotions, which has been validated in the literature, and the ease of use of the accompanying software, as well as its commercial penetration and relatively low purchase cost [29–35]. With this portable electroencephalograph device, measurements were obtained regarding the following six emotions: (a) stress, which is the main factor of the research; (b) engagement; (c) interest; (d) excitement; (e) focus/attention; and (f) relaxation. The device measurements have been validated multiple times in the literature (e.g., [29–35]) and measured on a scale 0–100 by the EmotivPRO v.3.8.0.532 software. It should be noted that these emotions are determined by the software, which essentially translates the frequency measurements obtained from the electrodes placed on the head of each participant, assigning them to measurements of these six emotions.

According to Emotiv (EMOTIV, San Francisco, CA, USA), the company that manufactures the portable EEG, the definitions of the six factors under study are as follows [28,36]:

- Stress: characterized as a measure of a person's comfort with the situation they confront. High stress can be caused by an inability to execute tough work, feelings of being overwhelmed, and dread of negative repercussions if the activity is not completed successfully. In general, a low to moderate degree of stress can boost productivity, but a greater level tends to be detrimental and can have long-term consequences for health and well-being.
- Engagement: defined as wakefulness and intentionally focusing attention on task-related inputs. It assesses the amount of absorption at any particular time and is a combination of attention and focus that differs from boredom. Engagement is characterized by higher physiological arousal, more Beta waves, and fewer Alpha waves. The greater the attention, focus, and workload, the higher the value of this element as indicated by EEG software (EmotivPRO v.3.8.0.532).
- Excitement: characterized as a favorable physiological stimulation. It is characterized by sympathetic nervous system activation, which causes a variety of physiological reactions, such as pupil dilation, ocular dilatation, sweat gland stimulation, increased heart rate and muscular tension, blood diversion, and digestive function inhibition. In general, when physiological stimulation increases, so does the value of the component reflected by the EEG software. Excitement detection is designed to offer capture values that indicate short-term fluctuations in excitement across time periods as short as a few seconds, according to Emotiv.
- Focus: a metric for maintaining attention on a certain job over time. Both the intensity and frequency of attentional shift between tasks are measured by focus. Frequently

moving between activities and even challenging ones might result in low factor values, which indicate inattention and a lack of focus.

- Interest: the degree of attraction or repulsion to the environment, activity, or stimuli at hand. While mid-range values show neither aversion nor a desire to complete the activity, low interest levels show a significant distaste to the task, and high interest scores show a great desire for the action.
- Relaxation: defined as an indicator of a person's ability to recover from high levels of concentration.

In addition to the Emotiv Epoc device, participants were asked to wear the Empatica E4 wristband (Empatica, Boston, MA, USA) [37]. With this wristband, electrodermal conductance (EDA) measurements are taken through two electrodes (fs = 4 Hz) and heart rate (HR). This device is one of the few on the market that was developed based on studies in the fields of psychophysiology and affective computing. In addition, it is simple to use, and one can follow the experimental process in real time even from a smartphone connected to the device. Participants wore this device on whichever wrist they used less during the process, in order to keep it as still as possible [38,39].

3. Analysis of the Acquired Data

The following procedure was followed for the analysis of the data.

Bearing in mind that our data consist of frequencies of brain activity under specific conditions, an analysis was performed, as described below in Figure 2.

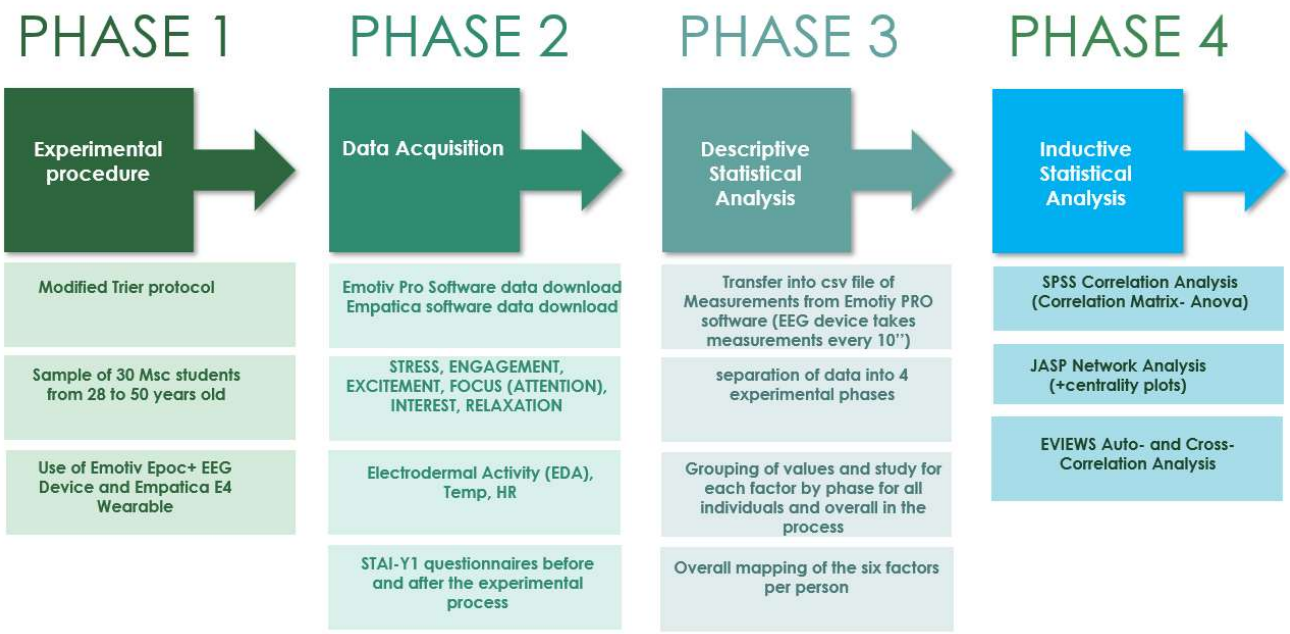

Figure 2. Phases of the experiment and data analysis.

First, a descriptive statistical analysis was performed with data obtained from frequency recordings every 10 s from the EEG software, EmotivPRO. This first part of the data analysis (descriptive analysis) involves separating the collected data by phase for each of the four phases of the experimental procedure. More specifically, Phase 1 involved the relaxation of the sample participants for a period of 5 min, while Phase 2 involved the written examination procedure, where each participant had to answer in writing the questions given for a period of 15 min. In Phase 3, the oral examination was conducted, which had a duration of 15 min. Finally in Phase 4, a 5 min relaxation procedure was followed.

Values were grouped by factor (stress, engagement, relaxation, focus, interest, and excitement) and by phase for all subjects. Finally, in the descriptive statistical analysis, overall and individual graphs were created to test absolute values by subject, phase, and factor.

In the second part of the analysis of the experimental data, an inferential statistical analysis was performed, employing the statistical package SPSS v.21.0. The network analysis and centralities were analyzed using JASP v.0.17.1.0, while the time series analyses (auto- and cross-correlation performance) were conducted using the Eviews v.10 software.

- Spearman and Pearson correlation analyses by phase were performed for each participant using SPSS v.21.0 software. These analyses result in a square matrix of values (a correlation matrix) by phase-based on Pearson analysis to assess the linear relationships between the continuous variables, where the factor of stress is significantly correlated with the factors of focus, excitement, interest, engagement, and relaxation. The statistically significant correlation of the emotions led to the conclusion that there is a significant level of association between them.
- Using the JASP software v.18.1.0, a network analysis was then attempted, where for each phase of each participant's experimental process, the correlations of the six factors are mapped as parts of a single network, and the higher the correlation between two factors (either positive or negative), the stronger the link that is mapped. Also, through the analysis of the networks by phase, this software provides a visualization of the centrality of each factor by phase, and through this mapping, it is possible to further analyze whether each factor can influence the overall correlation network in each phase. In a network analysis, it is important to clearly define the concept of centrality. With this term, an attempt is made to identify the importance and impact that a node (an emotion in this case) has in a network [40–43]. According to the concept of centrality, each node has a value which depends on its position in the network. For this reason, different concepts categories of centrality have been developed [41,44]. (1) Degree centrality refers to the degree of importance of a node in a network. This can be defined according to its connections with as many nodes as possible. (2) Closeness centrality refers to the importance of a node in a network and is approached from the perspective of the proximity of a node to the others. (3) Betweenness centrality refers to the shortest paths that pass through a particular network node. That is, the shorter the paths that pass through a node in order to share information between them, the higher the centrality value for that node.

Time Series Analysis

In the last part of the inferential analysis, EVIEWS10 software was used to answer the question of how the six factors influence and correlate with each other (auto- and partial correlations and cross-correlations). The data collected from the EMOTIV PRO software are time series data and, as such, can be further studied. More specifically, it is quite important to capture the autocorrelation of the stress factor, as well as the cross-correlations of the stress factor with the other factors by pairs. Thus, time series analysis, during which time series are moved over t-x time intervals, is of great interest to understand the influence of stress and other emotions on the final outcome and how an autonomic brain network functions under specific stress conditions. This analysis also provides important results in relation to the role of stress in the process, as well as which factors are correlated with it and in which phases of the process, in order to study the functioning of emotions at the process level and how they affect the individual in quite stressful situations. The study of these two parameters (autocorrelation and cross-correlation) concerns the process as a whole and, also, each one of the four phases of the experiment.

4. Results

The results were obtained from the data analysis, which included (a) the descriptive statistical analysis of the six emotions, where values and variances were observed, and (b) inferential statistical analysis, more specifically (1) network analysis, and (2) centrality analysis, and (3) time series analysis.

During the descriptive statistical analysis of the data, the graphs of the six emotions were generated for each individual, as well as overall graphs of the factors for all the participants. The findings of the descriptive statistical analysis for each emotion are as follows:

Stress: The stress factor is the main emotional factor studied in the experimental procedure used in this study. The main conclusion drawn from studying the graphs for each individual is as follows:

- In the majority of the participants, it was observed that during the third phase of the oral test, the levels of stress were higher than those of the second phase, which concerned the written test (84.6% of participants). This practically means that the participants experienced greater difficulty during the oral examination, and that it was a more stressful situation for them than the written procedure.
- When high value fluctuations were observed during the process, this resulted in a lower performance by the individual during the examination process, as reflected by his/her score. Conversely, when the stress value fluctuations were at low levels, a better performance by the individual was observed.
- When stress was identified at levels higher than the other factors, the person's performance was at a low level. Conversely, when stress values were in the low–medium range, their performance was better.

Engagement: In the majority of the participants, as reflected in the graphs of the six factors under study, it was observed that at the beginning of the process. the feeling of engagement reached very high values. As the phases passed, its value decreased only slightly, to 96.1%. In the fourth and final phase, the commitment factor demonstrated the lowest value. This can be explained by the fact that this process was something new for the participants and their desire to respond successfully was quite high, so their commitment to the process was at an increased level. As the phases progressed, their familiarity with the process became greater, and the rates of this feeling decreased.

Excitement: In the majority of the participants, as reflected in the graphs of the six factors, it was observed that the feeling of Excitement had a particularly high average value during the oral procedure compared to during the written examination. This means that the oral examination increased the rates of this emotion, which provides more intense arousal to the individual by increasing the secretion of noradrenaline in the body [45]. As a result, sometimes a person was much more affected by the domination of high levels of both stress and excitement (being both primary emotions) and had a reduced performance compared to the previous phase, when the levels of both emotions were not dominant.

Focus: In the majority of the participants, as reflected in the graphs of the six factors, it was observed that the feeling of concentration presented a particularly increased average value during the written procedure compared to during the oral examination, with a rate of 53.8%. This means that the written examination increased the rates of this emotion and that the individuals showed a higher rate of concentration while undergoing a written procedure.

Interest: In the majority of the participants, as reflected in the graphs of the six factors under study, it was observed that the feeling of interest showed a particularly increased average value during the oral procedure compared to during the written examination, with a value of 88.4%. This means that participants showed more interest during the oral test

than during the written test, probably due to the interaction created through the process of questioning.

Relaxation: A characteristic feature of the relaxation factor was the fact that almost all participants had very low average values compared to the other factors, especially in the first two phases of the process. It is a fact that the majority of participants showed higher levels of relaxation in the third phase of the experimental procedure than in the previous two phases, which possibly testifies to the comfort in the procedure that the interaction of the examiners with the participants confers. Also, participants may have experienced greater comfort regarding the oral examination, as they could correct any errors they might have made in their answers.

During the inferential analysis, the correlation tests were performed at each stage of the experimental procedure via *t*-tests, which were used to determine the statistical significance of differences between the emotions. The Pearson correlation showed significant correlations of the factors, allowing us to proceed to factor analysis using the JASP v.18.1.0 software. The network structure, estimated from the graphical correlation algorithm, showed that nodes belonging to each construct were generally strongly associated and close to each other. More specifically, for each phase, an overall table of graphs of the resulting network of the six factors is provided in the following Figure 3.

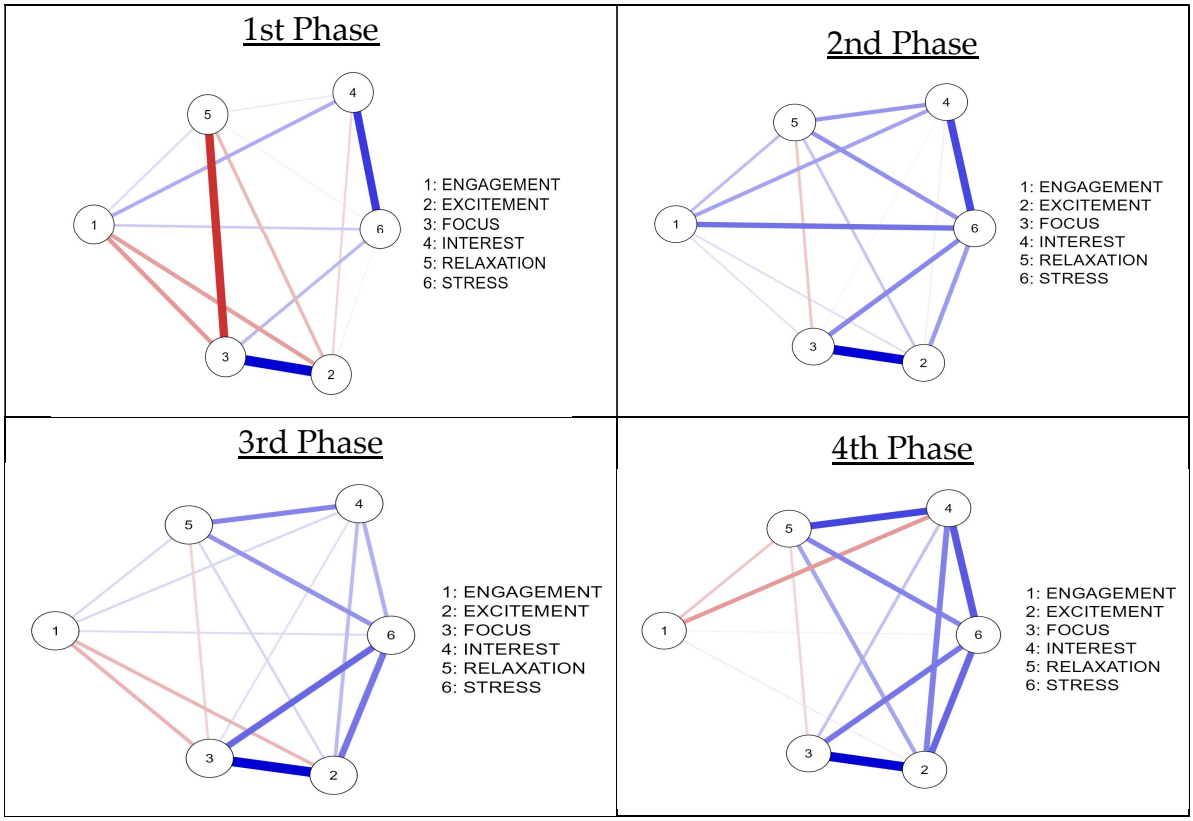

Figure 3. Emotion network for the four phases of the experimental procedure. Blue lines present positive correlations, while red lines present negative correlations. The thicker the line, the strongest the correlation.

It is noted that during the first phase of the experimental procedure, there are some negative correlations, mainly with the focus factor, while the stress factor is strongly correlated with the interest factor. In the second phase, the correlation of stress with interest remains strong, while the correlation between excitement and focus also strengthens. In the third phase, the correlations of stress with excitement and focus are strengthened, and

the correlation between excitement and focus strengthens. During the last phase, where subjects were asked to relax with their eyes closed, all emotions apart from engagement, have a strong relationship. Stress also has a strong correlation with excitement, interest, and focus indicating that, in this phase of relaxation, stress remains a key element in the network.

In the second stage of the inferential analysis, the measurement of centralities was performed using the JASP software in order to highlight the most central emotions associated with stress. The variables measured were betweenness, closeness, strength, and expected influence centralities, as shown in Figure 4. It should be stated that betweenness represents the number of times a node is the intermediary in connecting two other nodes [46]. Closeness defines the proximity of the node with respect to other nodes in the network in terms of the number of direct and indirect connections (the average distance from the node to all other nodes in the network) [47]. Strength identifies the weight of a node's influence on others in the network [48,49]. Expected influence is the sum of all edges extending from a given node (maintaining the sign) while considering the presence of negative associations [50,51].

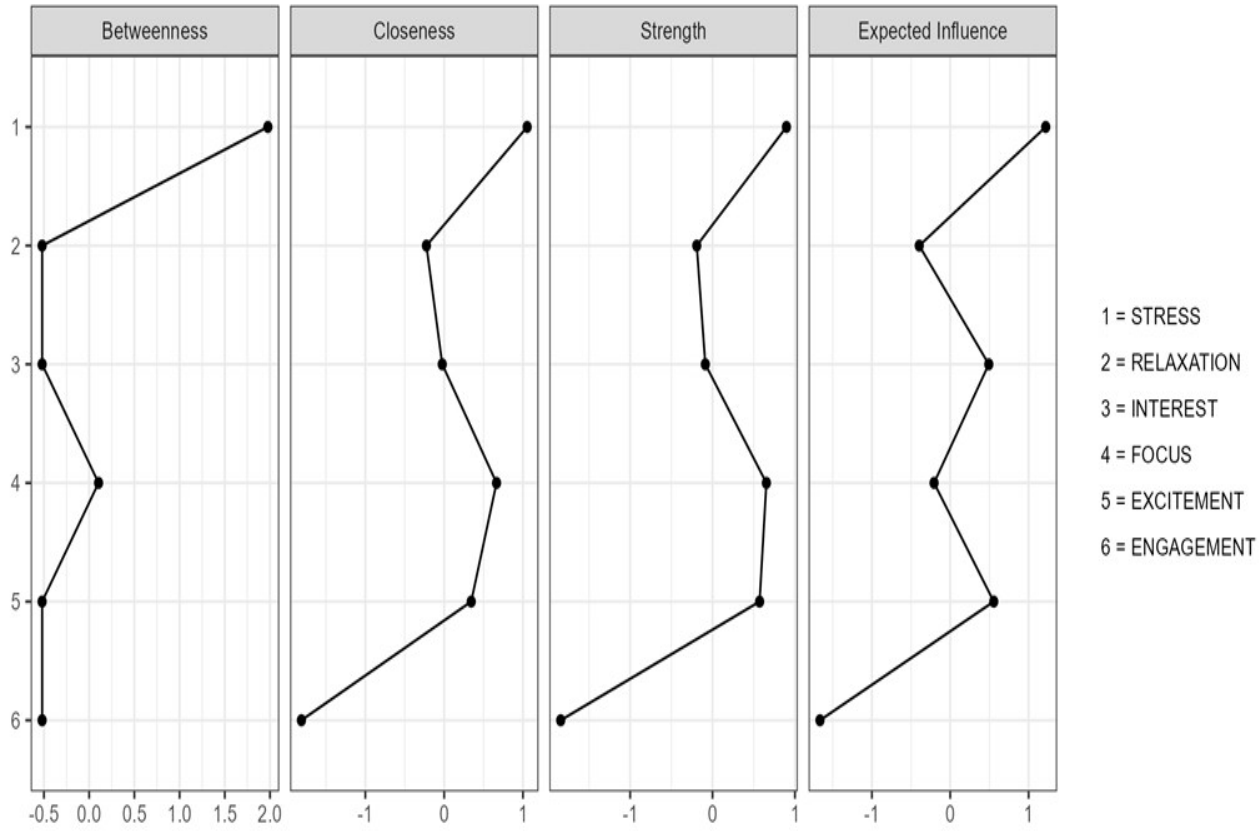

Figure 4. Representation of the centralities of emotions during the experimental process for all participants.

As shown in Figure 4 and Table 1, the role of stress shows a high centrality in the network, meaning that, during its absence, the network seems to be less tight. More specifically in the betweenness index, stress seems to have the highest degree of centrality, while in the other types of centralities in the process, this emotion seems to show very high values compared to the other emotions, which highlights its primary role in the network. Also, the emotion of excitement also seems to have a central role in the process, as does focus.

Table 1. Means of the centralities of the six emotions for all participants in the experimental process.

Centrality Measures per Variable (Average Values)				
	Network			
Variable	**Betweenness**	**Closeness**	**Strength**	**Expected Influence**
Engagement	−0.52	−1.811	−1.843	−1.663
Excitement	−0.52	0.343	0.571	0.555
Focus	0.104	0.664	0.654	−0.207
Interest	−0.52	−0.024	−0.088	0.492
Relaxation	−0.52	−0.225	−0.191	−0.396
Stress	1.977	1.053	0.897	1.219

Overall, and using average values for all participants in the process, stress has a betweenness index value of 1.977, a closeness index value of 1.053, a strength index value of 0.897, and an expected influence index value of 1.219, highlighting its status as a dominant emotion. Similarly, focus has a betweenness index value of 0.104, a closeness index value of 0.664, a strength index value of 0.654, and an expected influence index value of −0.207. Commitment has a betweenness index value of −0.520, a closeness index value of −1.811, a strength index value of −1.843, and an expected influence index value of −1.663. Enthusiasm shows betweenness index value of −0.520, a closeness index value of 0.343, a strength index value of 0.571, and an expected influence index of 0.555. Interest shows a betweenness index value of −0.520, a closeness index value of −0.024, a strength index value of −0.088, and an expected influence index value of 0.492. Finally, relaxation shows a betweenness index value of −0.520, a closeness index of −0.225, a strength index value of −0.191, and an expected influence index value of −0.396.

As can be seen from the analysis, the dominant role in the formed networks is played by the emotion of stress, for which the average values of the centrality are the highest compared to the other emotions. As a node of the formed emotion networks, this emotion has the most central role. This finding indicates the role of stress over the other emotions in the process. In addition to stress, however, two other emotions, namely excitement and focus, play an important role in the formed network, which had high values in each centrality variable.

In the third part of the inferential analysis, time series analysis was carried out through the EVIEWS10 software to capture the stress autocorrelation and partial correlation and also to acknowledge the cross-correlation of the stress factor with the other five sentiments. The overall findings are as follows. The degree of autocorrelation of the stress factor is limited to one lag of the overall process, suggesting that for the stress factor, there is autocorrelation among the first lags of the process, leading to the inference that stress promotes itself. A key finding that will help in understanding the role of stress in the process. The cross-correlation analysis also revealed a strong cross-correlation between stress and the other five emotions. The main observation of the stress correlograms essentially confirms the Pearson correlation tables, highlighting the positive or negative correlations between stress and the other factors. Combined with the fact that stress is the most important node overall in the experimental procedure for the participants, it can be supposed that stress is the central node of the emotional network, playing an imperative role in emotional coordination and student overall performance in the examination process. More specifically, as we can see from the graph below, the autocorrelation of stress seems to be a quite central and important finding. In the following Figure 5, the graphs of the stress autocorrelations

and cross-correlations with the other five factors are presented for one person, selected at random.

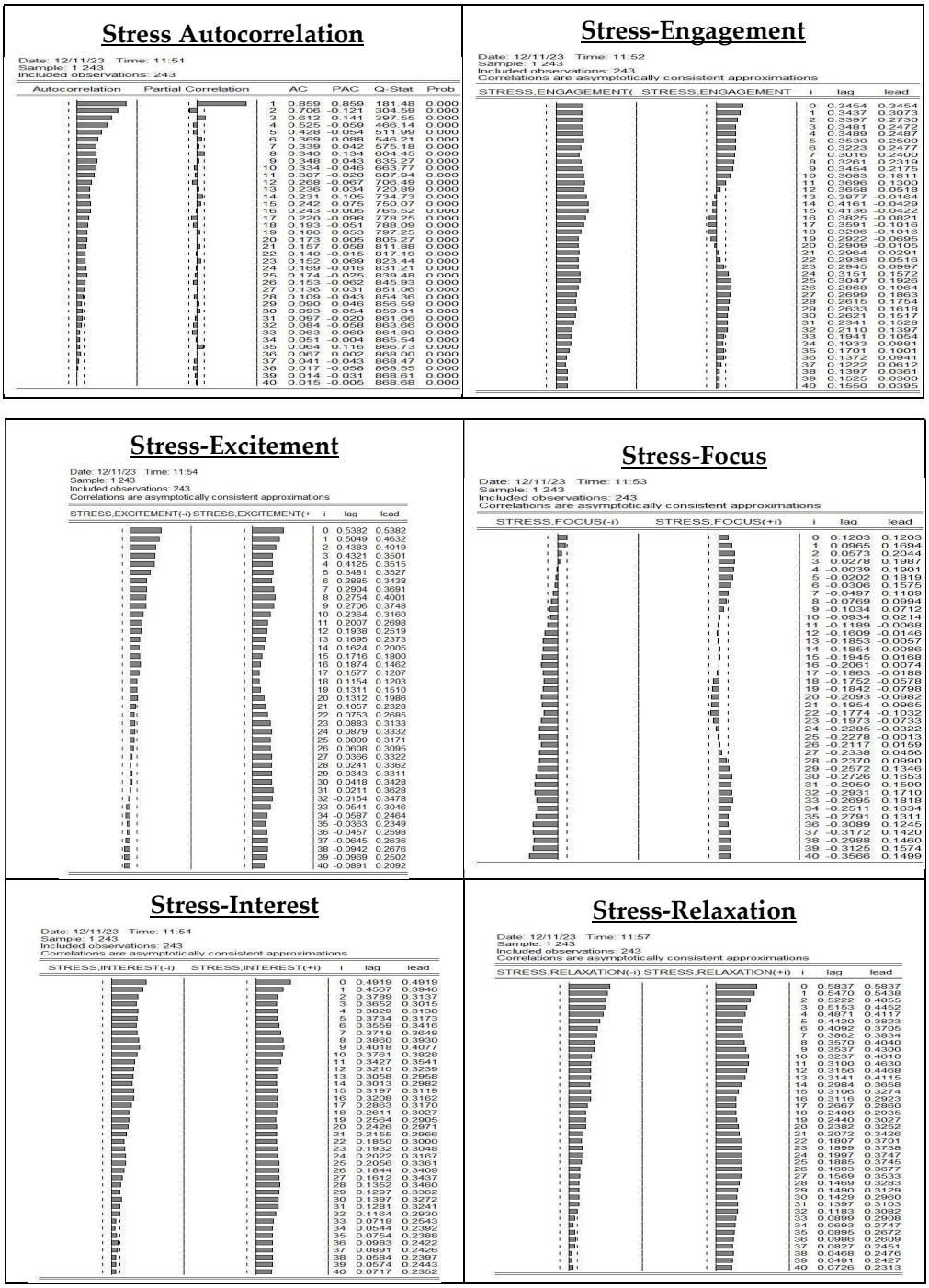

Figure 5. Stress autocorrelation and cross-correlation graphs for one person. AC: autocorrelation, PAC: partial Autocorrelation, Q-Stat: Ljung-box Q-statistic.

5. Discussion

According to the above analysis, it is observed that academic stress plays an imperative role during exams, meaning that lack of stress and high levels of stress could lead to failure. On the contrary, middling values of stress in association with other emotions, such as interest, excitement, and focus, could turn distress to eustress, leading to high performance outcomes. Being more specific, the main finding of our experiment and analysis is that stress during exams must be contained in the mid-values and influenced by other (dominant)

emotions, such as interest and focus. Stress should follow a non-intense curve with few fluctuations, since it (stress) demonstrates a high autocorrelation, meaning that high stress produces even higher stress. These findings could lead to the inference that other emotions, such interest and excitement, should be stimulated during the teaching process, in order to suppress stress during exams. Excited students with high interest and focus during exams tend to cope more efficiently with stress while achieving higher grades.

Without any doubt, managing academic stress is of the utmost importance for substantially affecting the attainment of academic objectives; therefore, we need to observe how stress interacts with other emotions. In alignment with this argument, Brooks [52] postulated that excitement could mediate the intense effects of stress, providing the stimulus to discuss the role of stress in relation to other emotions.

The contribution of the paper works in a twofold direction. It primarily introduces an innovative method to process data from EEG apparatus, based on averaged values of an every-ten-seconds timeline, extracted from EmotivPRO software, and employing (i) network analysis to observe the emotional matrix of stress, excitement, interest, focus, engagement, and relaxation. We also use the indicators of centrality to acknowledge how to cope with academic stress, stimulating other critical-to-success emotions. (ii) Time series analysis has been used to observe and acknowledge the extent of the autocorrelation and inter-correlation of emotions. Moreover, this paper contributes to the academic stress management academic field, underlining the association of stress with itself and other emotions, to transform academic destructive stress into academic eustress. It could be said that stress exhibits a high degree of autocorrelation, meaning that once stress levels increase, they tend to perpetuate themselves unless stress is dominated by other emotions, such as interest, excitement, engagement, relaxation, and focus. By stimulating these emotions, it is possible to transform distress into eustress, and, thus, to enhance academic performance and well-being. Also, this approach underscores the importance of a balanced emotional state during exams, where moderate stress levels, influenced by other positive emotions, can lead to better outcomes.

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