Consequence of Stress on Cognitive Performance: An EEG and HRV Study

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***Abstract*—Frontal cortical activity can be used as an indicator of mental stress. Using the frontal alpha activity in the electroencephalogram (EEG) as a basis, the Frontal Brain Asymmetry, Resting Brain Asymmetry, Frontal Asymmetry Index and Alpha Band Power along with Heart Rate Variability have been used as features in the present work to analyse the level of stress in subjects. Eleven healthy subjects participated in the experiments with 3 tests each based on 4 trials, with each trial posing an added cognitive challenge. Trials consisted of the Hopkins Verbal Learning Test, Trial Making Test, and Corsi Block Tapping Test. They were tested on factors based on verbal understanding, memory, attention, focus and overall cognitive performance. Using a rule-based classification model and combining the results from the features, 3 categories (low, medium and high) of stresses were identified. Partial consistency through the various extracted features indicate that subjects vary in their ability to manage stress. Overall, 2 subjects were indicative of a low stressed state, 6 subjects showed medium stress levels and 3 subjects were categorized under the high stress state.**

***Index Terms*—Electroencephalogram, Heart Rate Variability, Stress Analysis, Cognitive Load, Frontal Lobe.**

I. Introduction

Stress can be considered as physical or emotional response to a situation, feeling or an event that interferes with the sense of general well-being [1]–[4]. It can be broadly categorized into 2 classes; negative stress or 'distress' and positive stress or 'eustress' [2] [3]. According to Walter, the stress reaction causes a myriad of reactions like pain, hunger, fear and rage [4]. A prolonged, repetitive pattern of stress could cause the 'wear and tear' of the organism [2]–[4].

According to the American Institute of Stress (AIS), about 75% of the population suffer from psychological or physical forms of stress [5]. Although short-term stress is shown to be beneficial, a chronic condition of stress causes physical problems in the form of hypertension, coronary artery disease, back pain, gastroesophageal reflux disease, and irritable bowel syndrome just to name a few [6]–[8].

With an increase in cognitive load and decrease in cognitive resources, it becomes difficult to fluently switch from one task to another [9]. This inability to manage multiple or larger cognitive loads can lead to a stressed state. Further, stress has also been associated with a greater risk of error-related brain functioning [10]. Heart Rate Variability (HRV) is a physiological measure that is said to increase in relaxed states and decrease during stressed states [11]. It is shown that there is a relationship between HRV and prefrontal cortex activity in electroencephalogram (EEG) [12]. HRV is shown to be an indicator for time related pressures or emotional strain on a person, and not particularly for mental workload [12]. Hence by finding a relationship between HRV and EEG, it is possible to quantify and approximate the mental processing capacity of an individual.

EEG plays an important role in the research concerning psychological functions and mental disorders [13] [14]. Powerful signal processing tools help to improve the diagnosis, and aids to provide more insights into the underlying behaviour of the brain [15]. Linear techniques of EEG processing are based on the computation of the power spectral density of the individual frequency bands [16] [17]. More emphasis is placed on the α ($8-12$Hz) and β ($13-35$Hz) bands, as they represent the calm and awake states of the brain, respectively. The frequency bands and its relation to stress is provided in Table I.

TABLE I
EEG FREQUENCY BANDS AND THEIR RELATION TO STRESS

EEG	Frequency (Hz)	Relation to stress
δ	< 4	Increased power during difficult conditions
α	$8-12$	Power suppressed during stress
β	$13-35$	Power varies according to task difficulty

Studies made on subjects who suffered damage to their anterior cortex show the asymmetric involvement of the left and right prefrontal cortical regions [18]. Recent studies have suggested that the asymmetric activations in humans are specific to the frontal cortex. The frontal cortical asymmetry is assessed based on the varied α activities over the 2 hemispheres. Asymmetry over the 2 hemispheres is determined by the capacity of one hemisphere inhibiting the other [19].

Previous studies have suggested that the excitation or inhibition of EEG rhythms in the frontal cortical areas indicate a sign of stress. Evidence also suggests that the α power is inversely related to the regional brain activity [20] [21]. Increased α activity indicates a relaxed state, while a decrease might suggest a person is in a more stressed state and this in-

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verse relationship would indicate an increased engagement of mental activity. From initial neuropsychological experiments, researchers observed that both hemispheres were engaged in different emotional and mental processes [22]. In this context, it was noted that the activation of the left frontal hemisphere co-related to motivational behaviour or experience of positive emotions, whereas activation of right frontal hemisphere related to withdrawal behaviour and associated to the experience of negative emotions [23] [25].

Studies indicate that the α activity is a good indicator of cortical deactivation across both hemisphere, as it is very sensitive to minor manipulations in stimuli. Also, people with left sided frontal activation were shown to have higher threshold experiencing stress, whereas individuals with right sided frontal activation had a lower threshold to experience mental stress [21] [24]–[26]. Studying resting brain asymmetry (RBA) reported that the right-sided resting EEG asymmetry is noticed initially in subjects suffering from depression, anxiety and separation [24] [27]–[29]. HRV is affected by both the parasympathetic and sympathetic nervous systems, predominantly being affected by the vagal tone of the sympathetic nervous system [8] [33]. Hence, to avoid the numerable issues relating to stress, an automated detection system is necessary, but it is still an unsolved challenge [34] [35].

II. Materials and Methods

A. Test selection and procedure

The experiment lasted about 40min and consisted of 3 tests: Hopkin Verbal Learning Test (HPVLT), Trial Making Test (TMT), and a Corsi- Block Tapping Test (CBTT). It consisted of a total of 4 trials, including an initial trial that was captured at rest state. The tests were decided based on a mixture of cognitive abilities, mainly related to auditory processing, verbal understanding, memory, attention, motor-coordination and focus. The subjects were given prior instructions regarding the test. Experiments involved a total of 11 volunteers (P1 to P11) aged between 21 and 29 years. All the volunteers were healthy and had no previous history of being diagnosed with any clinical condition relating to stress or depression.

1) HPVLT: This test is performed to assess the short-term verbal memory and attention, where the subjects must recall as many words as they can after the list of words is read out to them. Each page consisted of a 12-item word list and was composed of three semantic categories.

2) TMT: It consists of 2 parts (letters ranging from A to I and numbers from 1-15), where the subject is instructed to connect a set of dots as quickly as possible without raising their hand. This test is used to assess the subjects' mental flexibility, speed of processing and executive functioning.

3) CBTT: This psychological test assesses visuospatial short-term working memory. Square blocks would appear on the computer screen one after another, and once all the blocks have appeared, the subject must select the blocks in the same order of appearance. For wrong order selection, the blocks would remain on the screen and for the right selection, the blocks would disappear. This test is used to assess the subjects memory, attention span and focus.

To pose a challenge to the subjects and induce an elevated state of mental stress, multiple tests were carried out in the succeeding trials, as mentioned in Table II.

TABLE II
Indication of increase in mental load for each trial

Trial #	Test type	Mental load
1	Rest	Baseline
2	2 pages of HPVLT	Verbal+listening
3	2 pages of HPVLT + TMT	Trial 2 + Motor co-ordination + Focus
4	CBTT + Trial 3	Trial 3 + memory

B. Experimental setup: Electrode selection and HRV wristband

For EEG experiments, the g.tec system consisting of an electrode-cap, g.USBamp and the g.tec gamma box were used. In accordance with the 10-20 electrode placement system, 13 active electrodes (excluding one ground and one reference electrode) were selected (Fig. 1) to capture the readings from the EEG system, with the electrodes primarily located in frontal regions and temporal regions. The electrodes selected co-relate to the brain functions assessed during the individual tests, as shown in Table III. A wristband connected to the Sumondo application uses HRV as inputs and outputs 4 levels of stress indices (SI). The algorithm in the Sumondo App works on the high frequency (HF) method.

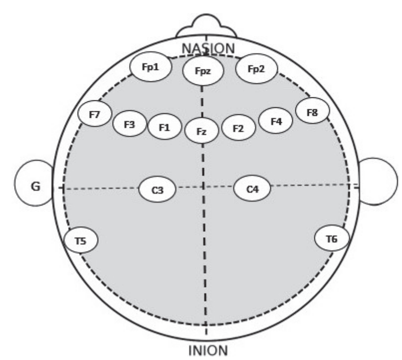


Fig. 1. Illustration of the electrode montage for the experiments

TABLE III
Brain functions around the respective electrode positions

Electrode Locations	Functions
F7	Near centres for rational activities
F8	Close to centres for emotional impulses for emotional regulation and social inhibition
C3/C4	Sensory Motor Integration
T5	Verbal understanding and Memory
T6	Emotional Understanding and Motivation

C. EEG pre-processing

Raw EEG data for each subject, over 4 trials were collected. The noise and ocular artefacts were eliminated by a built-in Butterworth band-pass ($2-32$Hz) filter. The power spectral density for individual frequency bands (δ, α, and β) were computed using Welch's method. Further, the relative power for each frequency band is calculated by taking the ratio of the power of the individual frequency bands over the total power of the entire signal.

III. Feature Extraction: Rule Based Model

Since the subjects did not undergo pre-assessment tests to be categorized into labels prior to the tests, a rule-based classification system was used to identify if an individual is stressed or not. The individual band powers were primarily used as a basis for calculating the features, which were used to classify the stress levels.

1) Alpha Band Power (ABP): It is calculated using the α relative power of the pair of the pre-frontal electrodes (Eq.(1)).

$$ABP = \frac{p^{\alpha}_{Fp_2} - p^{\alpha}_{Fp_1}}{p^{\alpha}_{Fp_2} + p^{\alpha}_{Fp_1}}, \tag{1}$$

where, $p^{\alpha}_{Fp_1}$ and $p^{\alpha}_{Fp_2}$ are the EEG power in the α band from Fp1 and Fp2 electrode positions, respectively.

2) HRV Stress Index (SI): A single numerical value (0-20) calculated by the Sumondo App using the HRV as input.

3) Fz Alpha Relative Power: It is used as an index to monitor and analyse the α activity of electrode Fz to provide an overview of both hemispheres of the brain.

4) Resting Frontal Alpha Asymmetry (RFA): Measured from the difference in α activity at rest state between electrode pairs F3-F4 and F7-F8 to provide an overview of the persons' mental state prior to the commencement of the tests [36].

5) Temporal Alpha Activity (T5 and T6): The hypothalamic - pituitary - adrenal (HPA) axis is found under the temporal region of the brain, and by studying the α activity of electrodes T5 and T6, we can approximate the cortisol secretion of the HPA under a stressed state [8].

6) Frontal Asymmetry Index (FAI): Due to their sensitivity in changes, electrode pair F7-F8 is considered for calculating the FAI (Eq.(2)).

$$FAI = \ln(p^{\alpha}_{F8}) - \ln(p^{\alpha}_{F7}), \tag{2}$$

where, p^{α}_{F8} and p^{α}_{F7} is the relative power in the α band of the EEG signal from electrodes F8 and F7, respectively [37] .

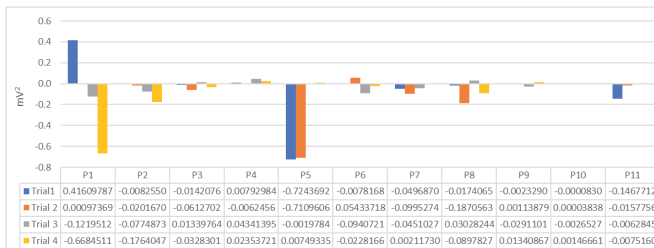
7) Frontal Brain Asymmetry (FBA): It is similar to FAI, but considers the relative β band power values too (Eq.(3)). Ideally, the ratio between relative β and α power gives an overview of the persons mental activity (since α is prominent in a more relaxed state and β in a more active state).

$$FBA = \left(\frac{p^{\beta}_{F4}}{p^{\alpha}_{F4}}\right) / \left(\frac{p^{\beta}_{F3}}{p^{\alpha}_{F3}}\right), \tag{3}$$

where, p^{α}_{F4} and p^{β}_{F4} are the powers in the α and β bands of the signal from electrode location F4. p^{α}_{F3} and p^{β}_{F3} are the corresponding powers for the electrode location F3 [23] [29].

IV. Results

1) ABP: The ABP (Fig.2) is inversely related to the stress. Except subjects P5 and P7, most subjects show a decrease in ABP from rest state or in between trials. Though trial 4 is considered to be the most challenging, few subjects show a higher decline in their ABP in other trials (subjects P1 and P2 indicate the least values in trial 4; subjects P3, P4, P5, P7, P8, and P11 indicate least values in trial 2 and subjects P6, P9, and P10 indicate least values in trial 3, respectively). An increase in ABP after a decline indicates lack of stress or more mental coherence. The variation of ABP over the trials can indicate two things: (i) Subjects are affected by different aspects of cognitive load (memory, attention, motor-coordination at different instances), and (ii) Subjects can better handle stress and get used to the cognitive load. The least overall ABP was noted by subject P5 at rest state.



	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Trial1	0.41609787	-0.0082550	-0.0142076	0.00792984	-0.7243692	-0.0078168	-0.0496870	-0.0174065	-0.0023290	-0.0000830	-0.1467712
Trial 2	0.00097369	-0.0201670	-0.0612702	-0.0062456	-0.7109606	0.05433718	-0.0995274	-0.1870563	0.00113879	0.00003838	-0.0157756
Trial 3	-0.1219512	-0.0774873	0.01339764	0.04341395	-0.0019784	-0.0940721	-0.0451027	0.03028244	-0.0291101	-0.0026527	-0.0062845
Trial 4	-0.6684511	-0.1764047	-0.0328301	0.02353721	0.00749335	-0.0228166	0.00211730	-0.0897827	0.01340867	0.00146661	-0.0075160

Fig. 2. ABP indicated for the frontal pair of electrodes

2) HRV−SI: An increasing SI (Fig.3) reflects a state of stress, and is noticed in all subjects except P7. According to the SI and based on their ability to manage a cognitive load, we can classify subjects into two categories: (i) Subjects who indicate a steady increase in their SI values corresponding to the difficulty of the task (subjects P1, P2, P3, P9, P10 and P11), and (ii) Subjects P4, P5, P7 and P8 indicate an initial decrease in SI from rest state, and then show a gradual increment of the SI values between trials. Subject P11 indicates the largest variance and highest value of SI in reference to the rest state. Although there is an initial increase in SI for subject P6, a drop in SI value after trial 3 indicates that the individual gets accustomed to managing a greater cognitive load. According to the subjects' basal heart rate, they can be categorized into: (i) Subjects having a higher than normal basal heart indicated major changes in the SI values (subjects P2 & P11), and (ii) Subjects with lower basal heart rate started with a higher SI and did not reflect major variations through the 4 trials (subjects P4, P5, P7 and P8).

3) Fz ARP: Mental activity and α power are inversely related, and decrease in ARP indicates higher mental activity [20] [26] [31] [32], as noted in Table IV. All subjects except P7 indicate a drop in ARP. Subjects P1, P2, P5, P6, and P9 show a larger change in the ARP, whereas subjects P4 & P8 show a minor change in their ARPs. Subjects P1 and P10 show the least ARP in trial 3. Unlike the intended gradual decline of the ARP over the 4 trials, subjects P6, P7 and P11 have a spike in their ARPs in trial 3. Subjects P5, P6 and

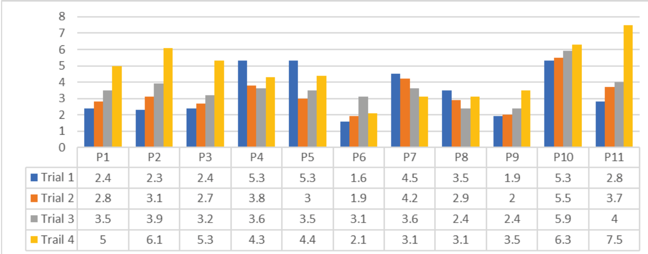


Fig. 3. SI values using HRV and Sumondo App

P11 show a temporary increase of the ARP in trial 3 before decreasing in the following trial. These variations could arise from imbalanced hemispheric mental processing. The highest ARPs are shown by subject P11 in trial 3 and subject P6 in rest state, respectively.

TABLE IV
FZ ALPHA RELATIVE POWER

Fz	Trial 1	Trial 2	Trial 3	Trial 4
P1	1.71×10^{-3}	1.05×10^{-1}	9.80×10^{-7}	6.54×10^{-5}
P2	5.21×10^{-2}	3.34×10^{-2}	1.71×10^{-2}	3.11×10^{-3}
P3	5.36×10^{-4}	5.61×10^{-4}	5.57×10^{-4}	5.33×10^{-4}
P4	5.15×10^{-5}	5.51×10^{-5}	5.65×10^{-5}	5.34×10^{-5}
P5	8.86×10^{-5}	8.71×10^{-5}	3.33×10^{-2}	9.95×10^{-7}
P6	3.26×10^{-1}	2.37×10^{-5}	1.42×10^{-3}	1.92×10^{-7}
P7	2.67×10^{-4}	6.97×10^{-4}	1.65×10^{-3}	1.09×10^{-3}
P8	4.70×10^{-5}	5.24×10^{-5}	4.99×10^{-5}	4.48×10^{-5}
P9	9.35×10^{-2}	8.50×10^{-2}	5.00×10^{-2}	2.78×10^{-2}
P10	7.08×10^{-2}	7.48×10^{-2}	6.74×10^{-2}	8.70×10^{-2}
P11	6.83×10^{-2}	5.79×10^{-2}	9.22×10^{-2}	5.04×10^{-2}

4) RFA: The RFA for electrode pairs F3-F4 and F7-F8 are shown in Fig.4. A negative value on either or both electrode pairs (subject P5,P6 and P8) is a clear sign of asymmetry, and a greater negative value indicates a larger asymmetry between the frontal hemisphere. Positive values (subject P4) or values close to 0 (subjects P2, P9 and P11) indicate lesser likelihood of being stressed. Since greater right-sided activation relates to a lower threshold experiencing stress, subjects P5, P6 and P8 are considered more probable to be stressed.

Fig. 4. RFA for electrode pairs F3-F4 and F7-F8

5) Temporal Alpha Activity: Subjects P1, P2, P4 and P10 are largely affected during trial 3 whereas subjects P5, P6, P7, P8, P9 and P11 are affected during trial 4, as indicated in Table V. Subjects P1, P5 and P6 show greatest variance in α activity over the 4 trials, whereas subject P7 has the least variance. Highest and lowest α activity is noted by subjects P6 at rest state and P5 in trial 4, respectively. Although it is inexact to extract information about cortisol secretion just from temporal cortical activity, such variations in the subjects temporal α activity may indicate imbalances in the level of cortisol secretion along the HPA axis.

TABLE V
TEMPORAL ALPHA POWER FOR ELECTRODES T5 & T6 OVER THE 4 TRIALS

Temporal	Trial 1	Trial 2	Trial 3	Trial 4
P1	6.25×10^{-3}	1.03×10^{-1}	1.39×10^{-6}	1.17×10^{-4}
P2	5.15×10^{-2}	3.23×10^{-2}	1.49×10^{-2}	2.14×10^{-3}
P3	4.98×10^{-5}	6.87×10^{-5}	5.80×10^{-5}	5.31×10^{-5}
P4	5.28×10^{-5}	5.77×10^{-5}	7.94×10^{-5}	1.08×10^{-4}
P5	4.62×10^{-4}	5.45×10^{-4}	3.14×10^{-2}	5.34×10^{-7}
P6	4.54×10^{-1}	1.32×10^{-5}	9.69×10^{-4}	1.85×10^{-5}
P7	5.23×10^{-5}	5.58×10^{-5}	6.31×10^{-5}	5.63×10^{-5}
P8	4.96×10^{-5}	9.33×10^{-5}	7.79×10^{-5}	6.20×10^{-5}
P9	9.40×10^{-2}	8.54×10^{-2}	4.12×10^{-2}	3.11×10^{-2}
P10	7.07×10^{-2}	7.53×10^{-2}	6.67×10^{-2}	8.81×10^{-2}
P11	6.82×10^{-2}	5.79×10^{-2}	9.05×10^{-2}	4.99×10^{-2}

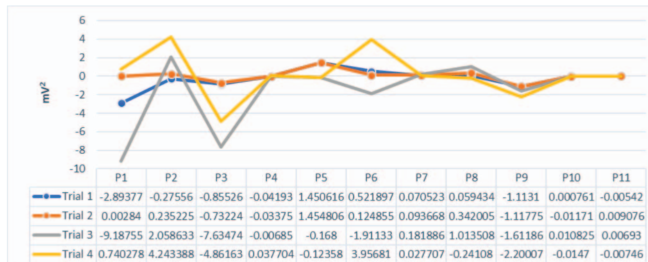


Fig. 5. FAI over the 4 trials

6) FAI: It is calculated using the difference of the α activity in the frontal region, and decreased FAI is noted to be a sign of increased mental stress (Fig.5). All subjects show a gradual decline in their α activity from rest state. Subjects P1, P2, P3, P4, P5 and P6 indicate a greater decline in their α activity in trial 3 whereas, subjects P7, P8, and P10 show an increase in the α activity in trial 3 before a decrease in trial 4. Subjects P1 & P3 show extremely high negative values (-9.1 and -7.6) in trial 3 compared to other subjects, indicating they are most affected whereas, P2 and P6 are least affected under this category. Considering the subjects' age, it is noted that the average age between subjects P1 & P3 is 25 (most affected), whereas that of subjects P2 & P6 is 21 (least affected). This might relate to how stress affects people differently as they age.

7) FBA: Decreased α activity and increased β activity is a sign of increased mental stress and this can affect the FBA. Subjects P2, P7 and P9 show little variance of the FBA, whereas subjects P6 & P11 show clear indication of an increase in FBA over the 4 trials, suggesting they are most affected,while subjects P4 & P8 are least affected, as shown in Fig.6. Subjects P6 & P11 are both noted to be female subjects, whereas subjects P4 & P8 are male subjects. This can be an assumption that females are susceptible to stress

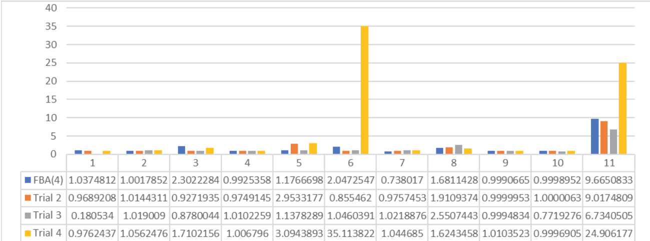


Fig. 6. FBA as indicated in the 4 trials

based on emotional imbalances in the frontal substrate linking both hemispheres [27].

V. Discussion

Combining the 7 features, we seek to understand how subjects have been affected differently, and this is summarized in Tables VI, VII, and VIII. Table VI gives an overview of the trial number that primarily affects the feature values of each subject over the 4 trials. The highlighted '3-4' indicate that the subjects had little variation of the feature values between trials 3 and 4. Table VII identifies a pattern through individual feature values for subjects affected at both extremes. Subject P5 occurs 3 times in the *most affected* list, whereas subjects P4 & P7 occur 3 or more times in the *least affected* list. Subject P4 shows a clear indication of being less stressed and better at managing a cognitive load, while subject P5 is worst affected.

TABLE VI
Comparing trial numbers which significantly affect the individual features for all 11 subjects

Most affected Trial	FBA	Fz α	FAI	HRV	Temporal	ABP
P1	4	3	3	4	3	4
P2	4	4	3	4	3	4
P3	4	**3-4**	3	4	**3-4**	2
P4	3	3	3	4	3	2
P5	4	4	4	4	4	2
P6	4	4	3	3	4	3
P7	**3-4**	4	4	3	4	2
P8	3	**3-4**	4	4	4	2
P9	**3-4**	4	4	4	4	3
P10	4	3	4	4	3	3
P11	4	4	4	4	4	2

TABLE VII
'Most Affected' and 'Least Affected' features and subjects

Category or Feature	Most affected	Least affected
ABP	P1 & P2	P4 & P7
Fz ARP	P5 & P6	P4 & P7
HRV−SI	P2 & P11	P7 & P6
RFA	P5 & P8	P4 & P11
Temporal alpha activity	P5 & P8	P10 & P11
FAI	P1 & P3	P2 & P6
FBA	P6 & P11	P4 & P8

Even though trial 4 poses the most challenging mental tasks, most subjects are affected greatly on trial 3. This could be due to the larger difference in cognitive load between trials 2 and 3, as compared to trials 3 and 4. Table VIII reflects how individual subjects varied in their cognitive performance. The column 'Ability to manage Cognitive load' is based on differences in the individual feature values between 2 trials, and the repeated occurrence of the trial numbers in Table VI. A higher occurrence of trial 3 in Table VI indicates they can manage cognitive load better (subjects P3 & P4), whereas a higher occurrence of trial 4 indicates they are worse at managing a cognitive load (subjects P5 & P11). Having little variance in feature values between trials is an sign of stable cortical α activity, and this also indicates the ability to manage stress better. As noted in Table VIII, subjects indicative of a higher value in trial 4 have a lesser ability to manage stress, whereas an increased value in trial 3 following a decrease in trial 4 indicates a better ability to manage stress. The column 'Easily prone to stress' is derived from positive or negative RFA values, since it provides an overview of an individual's threshold to experiencing stress.

TABLE VIII
Comparison between subjects based on their Stress Level, Ability to Manage Cognitive Load and susceptibility to stress

Subjects	Stress	Ability to manage Cognitive load	Easily prone to stress
P1	Medium	Good	Yes
P2	Medium	Good	No
P3	Medium	Very good	Yes
P4	Low	Very good	No
P5	High	Not good	Yes
P6	Medium	Not good	Yes
P7	Medium	Very good	Yes
P8	Medium	Not good	Yes
P9	Medium	Good	No
P10	Medium	Not good	Yes
P11	High	Not good	Yes

Tabulating the parameters into Table VIII, we note that subjects P3, P4 and P7 are good at managing stress, whereas subjects P5 & P11 are not. Combining Tables VI and VII, we draw the following comparisons: (i) Under ABP it is found that subjects P1 & P2 are affected most in trial 4, whereas subjects P4 & P7 are least affected in trial 2, (ii) Similarly, for the SI, subjects P2 & P11 are most affected in trial 4, and subjects P6 & P7 are least affected in trial 3, and (iii) For the FBA, subjects P6 & P11 are most affected in trial 4, whereas subjects P4 & P8 are least affected in trial 3. Based on the FAI,RFA and Tables II, VI and VII, subjects P1,P3, P5 and P8 are more susceptible to issues relating to social behaviour.

VI. Conclusions

Our study showed that stress is induced primarily due to focus, motor-coordination and memory related tasks. Few subjects are better equipped to handle a higher mental threshold, and even surpass the threshold with training. This was reflected with higher levels of stress in trial 3, even though trial 4 posed a heavier cognitive load. The exact reasoning for this is unclear, but a clear pattern is seen in subjects over the multiple feature values. HRV is shown to be an agreeable marker to detect mental stress, and the findings in our studies suggest an important relationship between cognitive performance, HRV and prefrontal cortical functions. Interpreting the results from Tables VI and VII, a higher percentage of subjects were found to be in the medium stress level, with only 2 subjects showing low stress and 3 subjects indicative of high stress(Table VIII).

Labels acquired from a pre-assesment test, combined with a multi-modal system of EEG, HRV and bio-markers (such as cortisol levels, saliva, urine etc.) could be a more effective process for stress classification. Future studies are required to deduce the differences in cortical functions while involving a wider range of situations and populations.

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