



# Classification of Neuroticism using Psychophysiological Signals During Speaking Task based on Two Different Baseline Measurements

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DOI: <https://doi.org/10.30880/ijie.2019.11.03.013>

Received 22 February 2019; Accepted 4 July 2019; Available online 3 September 2019

**Abstract:** Biosignals from psychophysiological changes can be measured as electroencephalography (EEG), heart rate, skin conductance, and respiration rate, to name a few. They have been used in many research areas including human personality. Neuroticism, one of the five major traits underlie personality, reflects stable tendency towards experiencing negative emotions. An understanding of how neuroticism influences responses to psychological distress may shed a light upon individual differences in emotion self-regulation. To study the causal relationship between neuroticism and psychophysiological signals, a selection of appropriate baseline signals as a reference signal is essential to compare to current experimental signals of interest. Thus, we present classification of neuroticism using psychophysiological signals obtained during a speaking task based on two different baseline measurements (eyes closed and eyes open). Eight healthy male participants consisting of four neurotic and four emotionally stable subjects were recruited based on Eysenck Personality Inventory (EPI) and Big Five Inventory (BFI) scoring system. Four features including mean EEG beta power, heart rate, skin conductance, and respiration rate were used for the classification using a Support Vector Machine (SVM). The results showed higher classification accuracy achieved with eyes open as the baseline (62.5%) as compared to eyes closed as the baseline (37.5%), during speaking task. This indicate the importance of selecting appropriate baseline in analysis involving EEG and physiological signals.

**Keywords:** Neuroticism, Electroencephalography (EEG), Heart rate, Skin conductance, Respiration rate, SVM, Classification.

## 1. Introduction

Neuroticism or also known as emotional stability has been interpreted as the capability of a person to remain stable and balanced to the surrounding world [1, 2]. People with high neuroticism or known as neurotic persons have low emotional stability where they feel stress easily, have low self-esteem, and tend to have negative emotions such as fear, worry, insecurity and bitterness towards the surrounding world [3]. They are also more susceptible to anxiety and depression than others [4, 5]. On the other hand, people with low neuroticism have high emotional stability where they

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have high self-esteem and tend to experience positive emotions such as happy, gratitude, and serenity. Furthermore, it has been discovered that neuroticism has a negative correlation with mindfulness (i.e., paying attention to the present moment without judgement), where a person with high level of neuroticism has low level of mindfulness, and vice versa [6].

There were studies that investigated the relationship between the Big Five personality traits and health including mental health [7, 8]. For instance, in a study on Han Chinese women, neuroticism was found to be a risk factor for major depressive disorder (MDD) which was found to be consistent with the finding based on populations in the West [9]. They mentioned that the level of neuroticism was strongly correlated with the lifetime prevalence of MDD and a greater level of neuroticism increased the probability of comorbid disorders in those with MDD. In addition, it was also found that neuroticism increased the risk of schizophrenia and contributed to the risk of psychotic symptoms [10, 11]. Other than mental illnesses, there were studies that found neuroticism to have a positive association with several illnesses such as cancer [12, 13] and mortality [14]. However, the correlation between neuroticism and health status is remain unclear [15], in which there were studies mentioned neuroticism to be not associated with the risk of death [16, 17] and cancer [18]. Since neurotic people have a tendency to have negative emotions such as misery, apprehension, and mood swings, they could easily slip into unhealthy lifestyles [19]. These unhealthy lifestyles can lead to the health issues, such as depression in neurotic people.

In addition to health, personality traits were also discovered to influence physiological signals such as brain electrical activities (electroencephalography or EEG signals), heart-beat rate (electrocardiogram or ECG/EKG signals), skin conductance (electrodermal activity or EDA signals), respiratory rate and content (capnogram), and muscle current (electromyography or EMG signals) [20-22]. As we all know, our body generates physiological signals during the functioning of various physiological systems. These physiological signals consist of information that could be taken from the signals to be used in identifying and monitoring the state of the functioning of these physiological systems. For example, the skin conductance readings could be one of the criteria for demonstrating emotional responses and cognitive activities [23], in which some people tend to be sweating when feeling nervous or under tense conditions (that represents conductivity of our skin) [24].

To the best of our knowledge, there were studies found high correlation between neuroticism and physiological signals [22, 25], but, the relationship between neuroticism and the physiological signals associated with speaking task has not been properly investigated. In this study, the speaking task was chosen as a proxy in our investigation on the changes in psychophysiological signals during social interaction among neurotic and emotionally stable subjects. Initially, we investigated the changes in physiological signals such as the skin conductance, heart rate, and respiration rate, or known as peripheral signals, during speaking tasks, for both neurotic and emotionally stable subjects [26]. This paper extends the study by including analysis on brain signals (i.e. EEG beta power) and performing classification on all the physiological signals obtained (skin conductance, heart rate, and respiration rate), including the brain signals (EEG beta power) in our investigation on the appropriate baseline signal for classification of neuroticism during speaking task. A selection for an appropriate baseline depending on the problem being addressed is of paramount importance since baselines have EEG signals differing in topography as well as power levels [27]. For instance, Barry et al. mentioned that apart from EEG power, eyes closed and eyes open conditions also produce different skin conductance [28]. Because of these differences, a selection of baseline measurement must be considered. The findings from this study can serve as a guideline for further studies in neuroticism.

## 2. Methodology

In this study, investigation based on EEG and physiological/peripheral signals was carried out using data acquired from our preliminary study [26] which was mainly focusing on changes in peripheral signals alone to investigate neuroticism in regard to social interaction. The details of this study including the subjects, experimental tasks, procedures involved, and the data analysis are provided in this section.

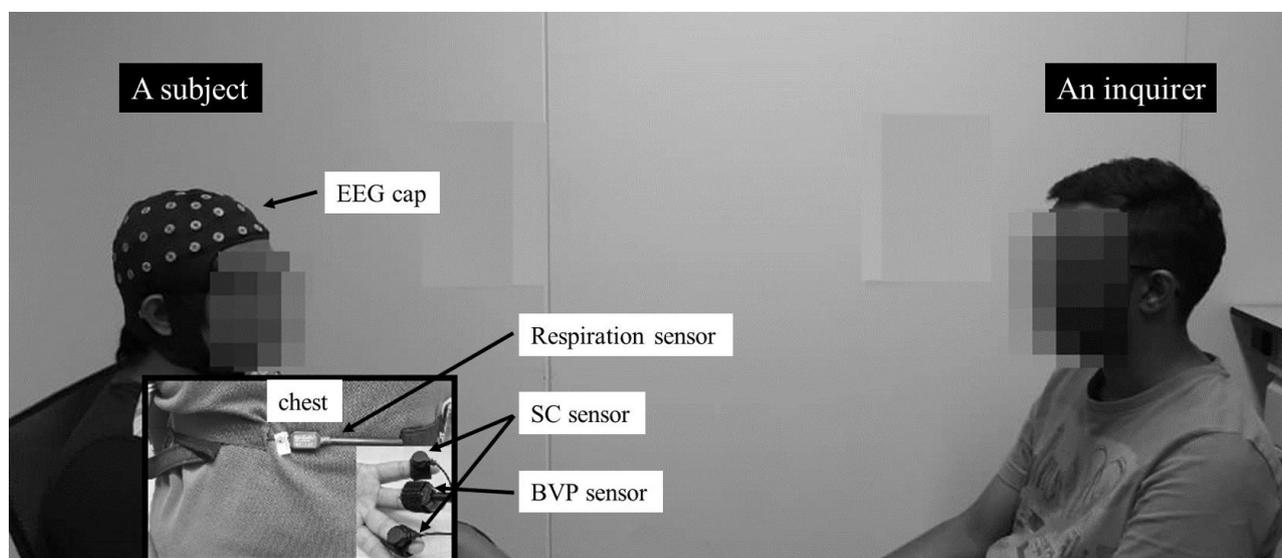
### 2.1 Participants

Twenty-eight right-handed male students of Universiti Teknologi PETRONAS (UTP) with normal or corrected-to-normal vision and normal hearing volunteered to participate in this study. Their ages were between 18 to 21 years old. The neuroticism levels of all volunteers were measured by two personality tests, which are the Big Five Inventory (BFI) and Eysenck's Personality Inventory (EPI). Seventeen volunteers were excluded due to their scores in two personality tests were contradicted or they had intermediate scores (50%) of neuroticism personality. Only eleven volunteers fulfilled the requirement to be included in this study. Seven of these subjects scored low in neuroticism hence considered as emotionally stable subjects and the other 4 scored high in neuroticism hence considered as neurotic subjects (emotionally unstable). In order to conduct an unbiased study, four stable subjects were selected randomly from the seven to be included in the study as we have only four neurotic subjects. The mean age of these eight subjects was  $19.50 \pm 0.76$ . The mean neuroticism score of BFI and EPI for stable subjects were  $1.81 \pm 0.33$  and  $5.5 \pm 1.29$  respectively, while for neurotic subjects,  $3.81 \pm 0.43$  and  $18.25 \pm 1.26$ , respectively.

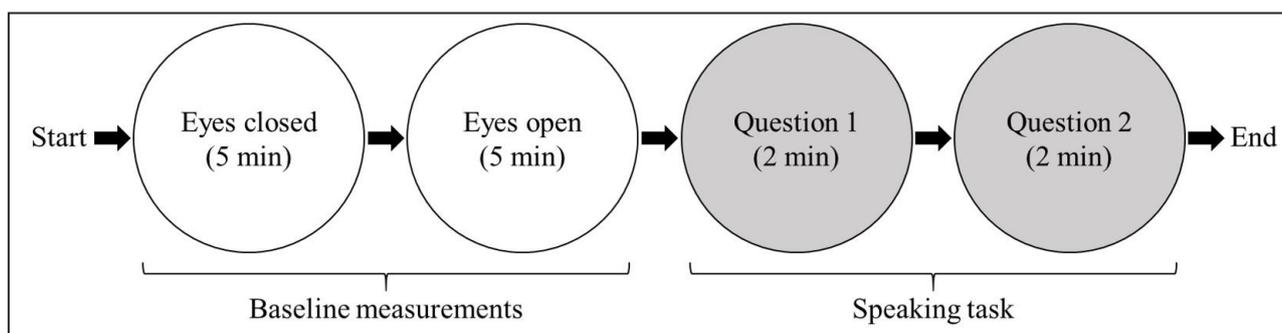
All subjects were ensured to be free from any drugs or medication for at least 7 days before the experiment, not suffering from, or having family histories related to cognitive disorders, and not experiencing chronic mental stress or adverse psychology states. They gave informed consent and were recompensed for their participation. This study was approved by the Ethics Coordination Committee of the Universiti Teknologi PETRONAS, and by the Medical Research Ethics Committee of University of Kuala Lumpur Royal College of Medicine Perak, Malaysia.

## 2.2 Experimental task: A speaking task

As presented in [26], during the speaking task, subjects were seated in front of an inquirer (see Fig. 1). The inquirer was a total stranger to the participants. Speaking task with an unfamiliar person was chosen as it is known to be able to cause stress and or distress and social anxiety. This task can be more challenging for the neurotic subjects. In this task, two general questions which were not related to academic will be asked by the inquirer to the subjects, one question at a time. Subjects were given two minutes to answer each question spontaneously (see Fig.2). Once the time is over, subjects need to stop answering immediately.



**Fig. 1 - The Speaking task scenario in which a participant and an inquirer had to face each other. The participant was wearing an EEG cap on his head, respiration sensor on his chest, skin conductance (SC) sensor, and blood volume pressure (BVP) sensor on his fingers.**



**Fig. 2 - Experimental timeline for this study which consists of two baseline measurements and a speaking task.**

## 2.3 Procedure

In this study, all subjects performed the experiment individually. Initially, the subjects were briefed about the entire experiment. Then, they were seated on a comfortable chair in a partially sound-attenuated room. Following that, the EEG and other physiological measurement devices were set up; EEG caps, skin conductance sensors, respiration sensors, and blood volume pressure (BVP) sensors (see Fig. 1). In this study, BVP sensors were used to monitor and measure the heart rate of the subjects. After experimental set up completed, the subjects underwent the first task which was the baseline measurement session; 5-minute eyes closed and 5-minute eyes open sessions (see Fig. 2). During the eyes closed session, the subjects were asked to close their eyes and were not allowed to sleep, while during the eyes

open session, they were required to look at a point and stay focus. Once the baseline measurement sessions completed, the subjects were required to sit facing the inquirer to perform the speaking task. The subjects were notified at the end of the experiment that all questions asked by the inquirer should be remained private and confidential. This instruction was crucial in order to prevent other potential subjects for the study from getting information about the questions asked as to avoid them from preparing their answers for the speaking task.

## 2.4 Physiological data analysis

### 2.4.1 Electroencephalography (EEG)

For EEG recordings, 32 channels eego™ sports system (ANT Neuro, Netherlands) with Ag/AgCl scalp electrodes arranged based on the International 10-10 System was used in this study. For a reference electrode, CPz electrode was selected. All electrodes impedances were kept below 10 kΩ and the EEG signals were digitized at the 512 Hz sampling rate.

The recorded EEG data were preprocessed using BESA Research 6.0 ([www.besa.de](http://www.besa.de)) for artifacts correction. These EEG data were filtered using IIR band pass filter of 0.53 – 48 Hz. Eye artifacts (movements, and blinks), and muscles movements were corrected using Berg & Scherg method [29] implemented in the BESA software. Then, the cleaned EEG data were exported to MATLAB for power spectral analysis.

For power spectral analysis, Fast Fourier Transform (FFT) with Hanning window was employed to 512 samples with 50% overlap between successive 2-second segments (1024 points) for estimating power of EEG signals. For this study, EEG beta power during the baseline measurements and speaking task at the frontal region (FP1, FPz, FP2, F7, F3, Fz, F4, F8) were measured and extracted for standard frequency of 13 – 30 Hz. The extracted EEG beta power were averaged within all electrodes at the frontal region and then averaged within the subjects. For the speaking task, the extracted EEG beta power were averaged within the questions in the speaking task. Standard errors for EEG beta power were then measured for baseline measurements and the speaking task.

### 2.4.2 Skin conductance, heart rate, and respiration rate

Other than EEG, peripheral signals such as skin conductance, heart rate, and respiration rate were also observed and recorded during the baseline measurements and the speaking task. All these peripheral signals were recorded simultaneously by using FlexComp Infiniti encoder with Biograph Infiniti software by Thought Technology Ltd. (<http://thoughttechnology.com/>). The skin conductance and respiration rate were recorded with a sampling rate of 256 samples/second, while heart rate was recorded with a sampling rate of 2048 samples/seconds. The statistical data of all the subjects were analyzed using custom software written in the BioGraph Infiniti Software. The mean and standard deviation of all peripheral signals for all subjects were extracted and measured (see Table 1). The unit for skin conductance response or commonly known as electrodermal response is microsiemens (μS). As mentioned in Section 2.3, the BVP sensors were used to measure the heart rate of all subjects. The BVP sensor measured the heart rate (beats per minute) by referring to the volume of blood that passes through the tissues in a localized area with each beat (pulse) of the heart. On the other hand, the respiration/respiratory rate is the rate at which breathing occurs. The readings of respiration rate were recorded by counting the number of times the chest rises or falls per minute and the unit for the respiration rate is breaths per minute.

For analysing the data, the mean of all peripheral signals for each participant were measured for a duration of 5 minutes for eyes closed and eyes open respectively, and 2 minutes for each question in the speaking task. The obtained mean of the peripheral signals of stable and neurotic subjects were then averaged within stable and neurotic subjects, respectively, and the standard error of each peripheral signals was calculated. For the speaking task, the mean for all questions were averaged within the questions to represent the task and the standard errors for all peripheral signals were measured.

## 2.5 Classification: Support vector machines

As mentioned, the physiological data of neurotic and stable subjects will be used in the classification of neuroticism based on two different baseline measurements (eyes closed and eyes open) as references. First, all physiological data of neurotic and stable subjects were divided into two categories which are experimental data relative to (a) eyes closed and (b) eyes open as baselines. The physiological data of the experimental task relative to baseline,  $A_{ER}$ , were calculated by using a method in [30] as given in the Eq. (1).

$$A_{ER} = \frac{(A_E - A_R)}{A_R} \quad (1)$$

where  $A_E$  is the physiological data during the experimental task (in this case speaking task data),  $A_R$  is the physiological data during baseline measurement (i.e., reference). Then, the classification of neuroticism using  $A_{ER}$  (i.e. EEG beta power, heart rate, skin conductance, and respiration rate) was performed using a supervised machine learning algorithm namely the support vector machines (SVM) implemented in Classification Learner App in MATLAB as used by [31]. The main approach of SVM is to transform input data into a higher dimensional space by means of a mathematical function or known as kernel function, prior to construction of an optimal separating hyperplane between data classes in the transformed space [32]. There are many types of kernel functions that can be used with SVM such as Linear, Quadratic, Cubic, Fine Gaussian, Medium Gaussian and Coarse Gaussian functions. In this paper, we performed the classification with all the kernel functions described earlier. Furthermore, as we can only consider data from eight subjects (4 neurotics, 4 non-neurotics), we also employed cross-validation to overcome overfitting, whereby the physiological data were divided into 4 subgroups using 4-folds cross-validation. We trained the algorithm on 3 subgroups and took the remaining subgroup/fold as our test data set. This process was repeated 4 times until each fold was used 3 times for training and once for testing. In overcoming the overfitting issue, the cross validation technique helps in selecting the optimal parameters of SVM [33]. The SVM performances were assessed by measuring its accuracy as given in Eq. (2).

$$Accuracy = 100 \times \frac{TP + TN}{TP + FP + TN + FN} \quad (2)$$

where TP, FP, TN, and FN are the true positives, false positives, true negatives, and false negatives, respectively [32, 34]. In our case, we computed 3 trials of SVM classification for each baseline measurement to check for the consistency of its accuracy.

### 3. Results and Discussion

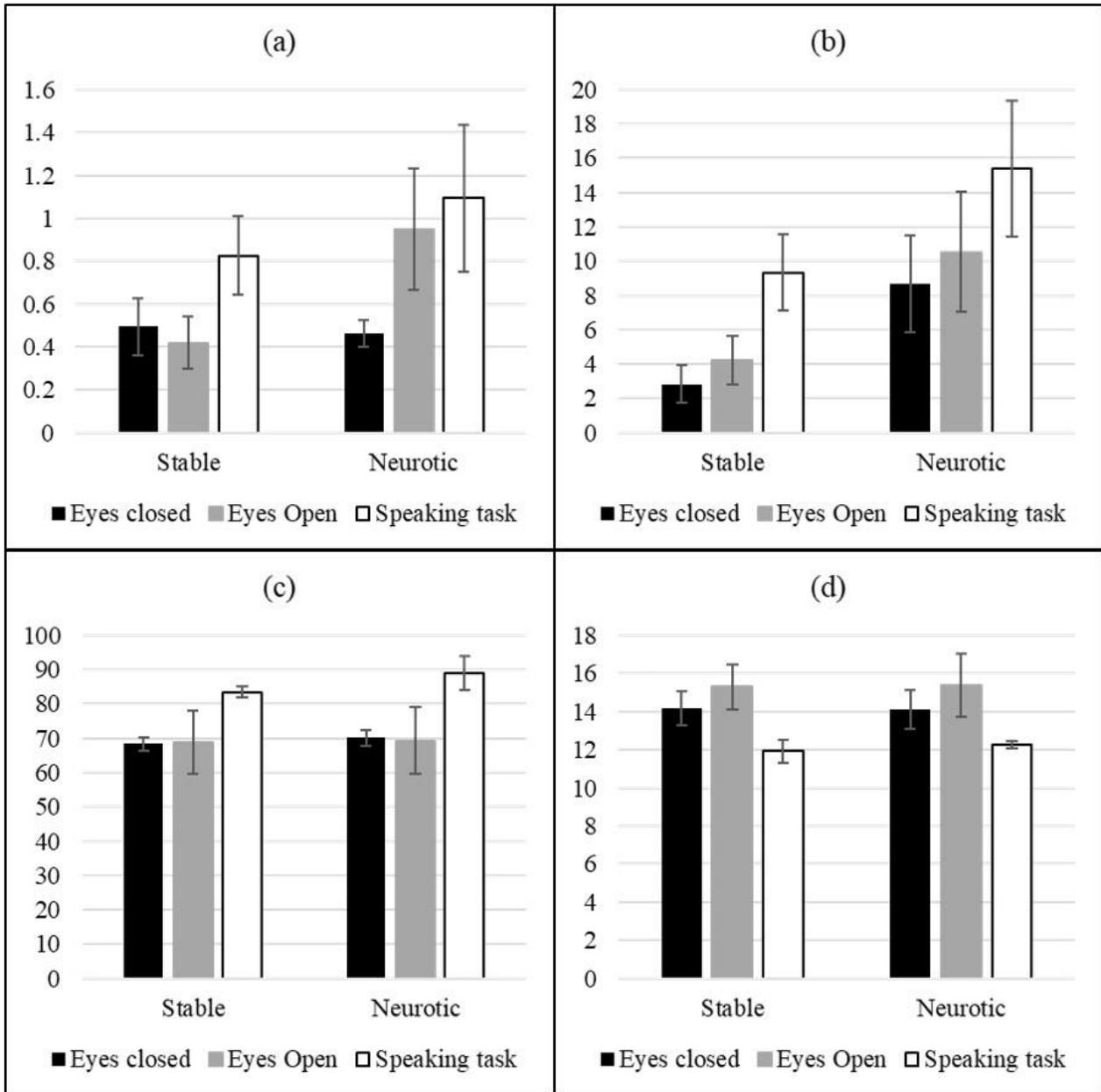
As mentioned, the mean of EEG beta power and the peripheral signals (i.e., heart rate, skin conductance and respiration rate) of neurotic and emotionally stable subjects were extracted from the 5-minute eyes closed, the 5-minute eyes open and the 4 minutes of speaking task (2 minutes/question). These EEG and physiological signals during two baseline measurements (i.e., eyes closed and eyes open) and the speaking task were analyzed and compared between neurotic and stable subjects (see Table 1 and Figure 3). The physiological data of experimental task relative to two different baseline measurements were subsequently measured and used for the classification study (see Figure 4).

**Table 1 - Mean and standard deviation of all physiological signals for stable and neurotic subjects**

		Mean ± Standard Deviation	
		Stable	Neurotic
<b>EEG beta power (<math>\mu V^2</math>)</b>	<b>Eyes closed</b>	0.49 ± 0.26	0.46 ± 0.13
	<b>Eyes open</b>	0.42 ± 0.24	0.95 ± 0.56
	<b>Speaking task</b>	0.83 ± 0.34	1.09 ± 0.68
<b>Skin conductance (<math>\mu S</math>)</b>	<b>Eyes closed</b>	2.83 ± 2.23	8.70 ± 5.64
	<b>Eyes open</b>	4.21 ± 2.88	10.54 ± 6.98
	<b>Speaking task</b>	9.34 ± 4.49	15.39 ± 7.89
<b>Heart rate (beats/min)</b>	<b>Eyes closed</b>	68.35 ± 3.96	70.13 ± 18.48
	<b>Eyes open</b>	68.73 ± 4.59	69.36 ± 19.66
	<b>Speaking task</b>	83.52 ± 2.86	89.08 ± 9.95
<b>Respiration rate (breaths/min)</b>	<b>Eyes closed</b>	14.19 ± 1.79	14.14 ± 2.04
	<b>Eyes open</b>	15.31 ± 2.38	15.36 ± 3.32
	<b>Speaking task</b>	11.92 ± 1.20	12.28 ± 0.39

Table 1 shows the results of all physiological signals for neurotic and stable subjects. As presented in Table 1, mean EEG beta power at the frontal region of all subjects during the speaking task were greater than that of both the baseline measurements. As EEG beta power is reported to represent active thinking especially at the frontal region [35-37], this may be the contributing factor that leads to the higher mean EEG beta power during speaking task. We can consider mean EEG beta power to be more dominant during the speaking task. It is also observed that during the speaking task, the mean EEG beta power of the neurotic subjects was greater than that of the emotionally stable subjects (see Fig.

3(a)). It is presumably due to the nature of neurotic subjects who tend to overthink [38]. Other than that, it could be due to the claim that individuals with high levels of neuroticism tend to be more creative than individuals with low levels [39, 40]. But, since our study involved general questions during the speaking task and did not focus on creativity of the answers or ideas given, the results achieved were probably due to the neurotic subjects' busy mind of overthinking. This assumption was also made based on the mean EEG beta power of the neurotic subjects being greater during eyes open as compared to eyes closed, even though no cognitive task was involved during the eyes open session.



**Fig. 3 - (a) Mean EEG beta power ( $\mu V^2$ ), (b) mean skin conductance ( $\mu S$ ), (c) mean heart rate (beats/min), (d) mean respiration rate (breaths/min) of neurotic and stable subjects obtained during baseline measurements (eyes closed and eyes open) and the speaking task, respectively.**

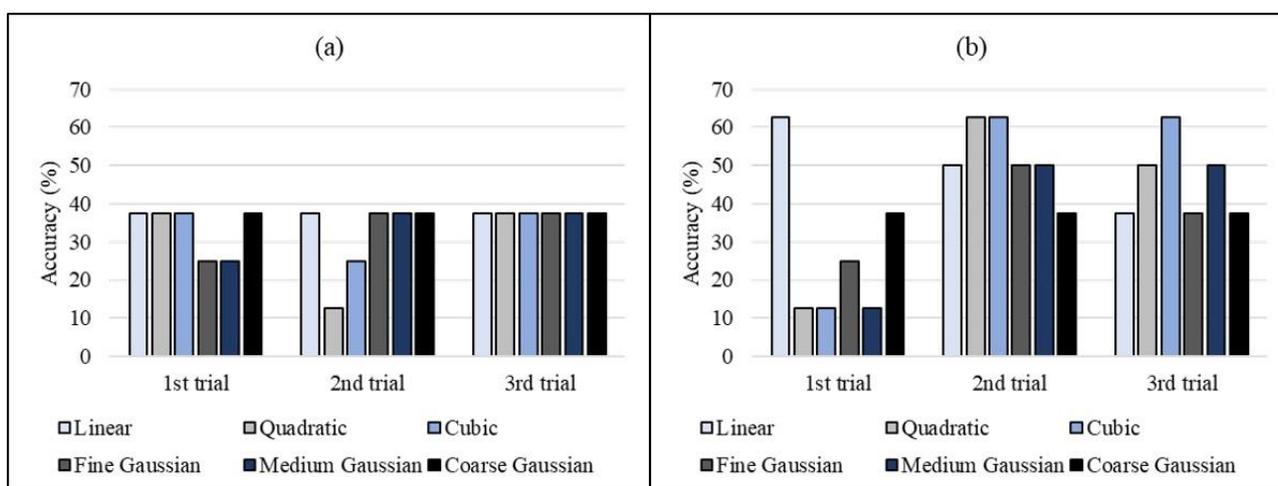
As shown in Table 1, mean skin conductance computed for all subjects during the speaking task were greater than that of the baseline measurements. This may be due to the stress induced by the speaking task based on the fact that mental processes that take place during the speaking task were more intense than that during eyes closed and eyes open [41]. In addition, mean skin conductance of the neurotic subjects was found greater than that of the emotionally stable subjects during the speaking task. The element of having a stranger as the inquirer may induce more stress/distress to the neurotic subjects. Hence the greater mean skin conductance among the neurotic subjects during the speaking task was shown. This result is aligned to the tendency of a neurotic person towards negative emotions in contrast to an

emotionally stable person who is prone to experience positive vibes. It also reveals that individual reactions to stressful situations are important, as the reactions toward the situations have greater impact than the exposure to those stressful situations [42].

It is also observed that the neurotic subjects demonstrated greater mean skin conductance not only during the speaking task but also during the baseline measurements (see Fig.3 (b)) which is still greater than that of the emotionally stable subjects. These findings, particularly during eyes closed, were inconsistent with the findings of a previous study where low skin conductance was observed in neurotic subjects [22]. However, the authors assumed that the results were achieved as such due to the time given to prepare for the game (stimulus) which indirectly enables their emotionally stable subjects to be more mentally ready for the games as well as providing space to their neurotic subjects to minimize pressure from the game [22]. Since our subjects were not given any preparation time prior to the experiment, the results of skin conductance during the baseline measurements showed positive correlation with neuroticism. This indicates neuroticism can affect the skin conductance even when during baseline measurements provided the neurotic subjects are unaware of the setting of the experiment [43].

Similar to the trend in the mean EEG beta power and skin conductance outcomes, the mean heart rate during the speaking task was also greater than that of the baseline measurements for both the neurotic and the emotionally stable subjects (see Fig. 3(c)). Similarly, this was due to the stress induced by the speaking task with a stranger. Moreover, it was also found that the mean heart rate of the neurotic subjects was greater than that of the emotionally stable subjects during the speaking task (see Fig. 3(c)). This can be a result of the neurotic subjects experiencing some negative emotions like anxiety, particularly when they have to interact with strangers.

As illustrated in Fig.3(d), the respiration rates observed for both the emotionally stable and the neurotic subjects during both baseline measurements were within the average respiration rate for a healthy adult at rest ( about 12 to 20 breaths per minute) [44, 45]. We also found that, regardless of personality traits, all subjects showed lower respiration rates during the speaking task as compared to eyes closed and eyes open (see Fig. 3(d)). This finding contradicts our expectation, particularly for the neurotic subjects. We anticipated to see an increase of respiration rate during the speaking task rather than a decrease among neurotic subjects who are known to have tendency to experience anxiety [46]. According to research on verbal articulation, the decrease in respiration rate during a speaking task is likely caused by the human capability to use extended exhalations for speech in order to prevent possible hyperventilation or over-oxygenation from multiple fast breathing cycles [47, 48]. Thus, as shown in Fig. 3(d), the decrease in respiration rate observed in both the stable and neurotic subjects during the speaking tasks are in agreement with the outcome of the verbal articulation studies. The extended exhalation is also reported to be able to assist in improving concentration, and reducing nervousness, anger, and anxiety. The results also showed that during the speaking task, the respiration rates of the neurotic subjects were slightly greater than that of the stable subjects. This is presumably caused by the neurotic subjects being more anxious to speak that has led to shorter extended exhalation than that of the stable subjects.



**Fig. 4 - Classification accuracy percentage of neuroticism during the speaking task based on (a) eyes closed and (b) eyes open of linear, quadratic, cubic, fine gaussian, medium gaussian, and coarse gaussian SVM for 3 trials based on physiological signals.**

As described in Section 2.5, SVM was used for the classification in this study. In this study, SVM was computed with 3 trials for both the baseline measurements, to check for the consistency of its accuracy in classifying between neurotic and emotionally stable person. As represented in Fig. 4(a), with eyes closed as the baseline, at each trial, the highest accuracy percentage of classification achieved was about 37.5%. On the other hand, with eyes open as the baseline, at each trial, the highest accuracy of about 62.5% was achieved for the classification (see Fig. 4(b)). These

results indicate that the baseline plays an important part in the classification using physiological data for neuroticism during speaking task. However, since our sample size is small, to validate the obtained results, we need to increase our sample size. In addition, we should also consider examining more features and other classification techniques for validating these results. Furthermore, we can also implement statistical test with larger sample size to examine the significance of the results between neurotic and stable subjects.

#### 4. Conclusion

In this study, the classification between neurotic and emotionally stable subjects using four different physiological signals based on two different baseline measurements as reference signal was conducted using SVM. Although with only a small sample size, this study shows clearly that baseline measurements play a major role in an investigation involving physiological signals in which the classification accuracy of SVM was higher when eyes open (62.5%) was used as baseline as compared to eyes closed (37.5%). These results also suggest that the eyes open as a baseline measurement should be considered as the best reference signal in studies involving physiological signals, particularly in neuroticism related studies.

#### Acknowledgement

This research was supported by the Malaysian Ministry of Higher Education (MOHE): FRGS Grant FRGS/1/2016/TK04/UTP/03/3 and Higher Institution Centre of Excellence (HICoE) Scheme (Ref No. 015MA0-001). These supports are accepted with gratitude. We also thank Muhamad Hafiz Abd Latif, Rodney Petrus Balandong and Azimah Ajam for their help in collecting physiological data.

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