International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Brain-Computer Interface (BCI) is a Direct Communication Pathway between a Brain and a Device: A Comprehensive Analysis

Md Mostafizur Rahman

Army IT Support Organization.Dhaka, Bangladesh.
Khan.miraz@gmail.com

ABSTRACT

With the progressive advancement in Information and Computer technology, the battlefield scenario is also fetching with more complexity day by day. Therefore, soldiers' overall stress management system has to turn out to be an inescapable part of combat efficiency. During any military operation, a real-time analysis of varied stress factors that troops usually encounter will certainly facilitate the commanders at all levels in their decision-making process. Therefore, the objective of this paper is to develop an early prototype of a stress monitoring system named as Soldiers Stress Monitoring System, in abbreviated form SMS. The proposed system incorporates the brain waves and physiological data of (deployed) soldiers to quantity their stress level and assists the higher commander to take the best decision about troops' deployment (continue/return). The Electroencephalography (EEG) based Brain-Computer Interfacing (BCI) technology was used to acquire the brain signals, while machine learning was adopted to facilitate the decision-making process for the higher commander. A lightweight evaluation study was also carried out where it has been found that the identified stress factors and the decision assistance procedures of the proposed system were effective and efficient for deciding on the military operation by the higher command. Moreover, the study showed that the Bayes Net algorithm demonstrated a better accuracy of 98.4% followed by the JRip algorithm of 97.5% while categorizing the soldiers' stress status.

Keywords: Stress Management, Brain-Computer Interfacing, Decision Making Process,

1.INTRODUCTION

1.1 Soldiers are trained to fight [2]. With the advancement of modern technology, present-day warfare is full of stress trauma, and fatigue and unceasingly molded with numerous complexities and uncertainties. As a consequence, stress, and trauma are commonly fringed with the combat profession. However, the exponential increment of the combat zone in length and breadth, the dreadful capability of mass destruction arsenal, the pervasive use of snipers and flying robots (UAV) in a wider spectrum of battlefield environment have made it almost impossible for a higher commander to appreciate the mental fitness of his under commands (UC) personals. Ensuring mental fitness is a prerequisite to maximizing combat efficiency. However, it is very difficult to predict the level of stress that troops will undergo during active war scenarios and no certain data analysis is available in this regard as well. Therefore, the study of appraising the strain level of troops during various operations or demonstration of a varied scheme of maneuvers can bring up ground-breaking results.

1.2 Brain-computer interface (BCI) or Neural Control Interface (NCI), is a direct communication pathway between a brain and a device that allows the signals to direct some external activity transmitting from the brain. BCIs are mainly devices that conquer and transform neural signals into varied activities intended by the user. Mainly three technological paradigms are commonly used in BCI. They are EEG, MEG, and MRT. MEG and MRT are mostly cast off to develop a noninvasive brain communication interface. On the other hand, EEG has been used for dumpling BCI-based applications. For instance, the BCI tools employing user experience for playing varied games have also been applied simultaneously in robotic arms to assist incapacitated persons who cannot perform daily activities due to extreme medical injuries [3]. Similarly, BCI has been widely used in diverse aspects of combat enhancements.

1.3 The objective of this paper is to determine the stress factors through brain generating waves and physiological signals and thereafter to develop an opposite stress monitoring system within modern combat outfits. This paper will facilitate the commander at different echelons to make appropriate decisions on troops' deployment (continuation/termination) basing on individuals' stress levels during various combat operations or extensive combat exercises at home and abroad.

2.RELATED WORKS

2.1 In this segment of the discussion, an attempt has been made to confer some of the concurrent noteworthy works of BCI on emotions and stress detection systems both in combat and non-combat atmosphere to explore likely research opportunities and validate the development motivation of premeditated systems. In [4], Choi, K.H has carried out an in-depth analysis of human emotions through varied Machine language (ML) algorithms. Similarly, in [5], Murugappan et al. has proposed a dynamic system of identifying various human emotions through discrete wavelet transformation where they have applied three of the brain waves namely Alpha, Beta, and Gamma wavelets and could find five of human emotions (happy, disgust, surprise, fear and neutral) using an audio-visual system. On the other hand, in [6], Vandana, P has steered an in-depth analysis on working people using heart rate along with its unpredictability features to identify instantaneous response for stress prediction. All these above- mentioned research papers have revealed that there is a substantial relation between stress management and physiological data like HRV, Heartrate, etc. However, they have not explored the significance of that relation in a combat operationalenvironment.

2.2 Nevertheless, the Implications of BCI in various combat maneuvers and different types of combat Operations are quite pertinent through previous years. Nowadays, a good no of articles has been published where BCI has been incepted for the advancement of armed forces. In [7], Razzak. A and Islam. K has proposed a communication system to monitor the soldiers deployed in the operation area and facilitate them with real-time guidance from the command base. In [8], Diya, S.Z, and Islam, M.N have proposed developing a sensor-based system for the commander to locate, organize and monitor the troops during a combat operation. Therefore, an endeavor has been made through this paper works to explore BCI and heart rate-based systems to predict the stress status of deployed troops in varied combat operations.

3.Elicitation of Requirements

3.1 In the field of engineering, requirements elicitation is the practice of investigating and determining the necessary attributes of a system from the users' perspective [9]. In this paper, the requirement elicitation aims to explore the scope and situations of the field and to divulge the features that need to be incorporated for developing SMS of Troops operating in the war field. We interviewed 7 active combat combatants between the age group of 25 to 45. All of them were male and served in at least one UN mission with field operational experience. Among them two were combat doctors specialized in Medicine and neurosurgery. The interviews were conducted following the semi-structured questionnaires. In addition, an online survey was conducted among 20 combat personals of different countries following structured close-ended questionnaires via Google Form. During this process, various issues have been identified related to the system requirements. All the germane issues have been contented during the implementation process/stages.

3.2 Moreover, the responses of interviews and online survey were meticulously analyzed through content analysis, and the following signs of the Stress Management System or in abbreviated form "**SMS**" was identified stated below:

3.2.1 Such kind of system will undeniably boost up the confidence level of troops during intensive combat maneuvers oroperations.

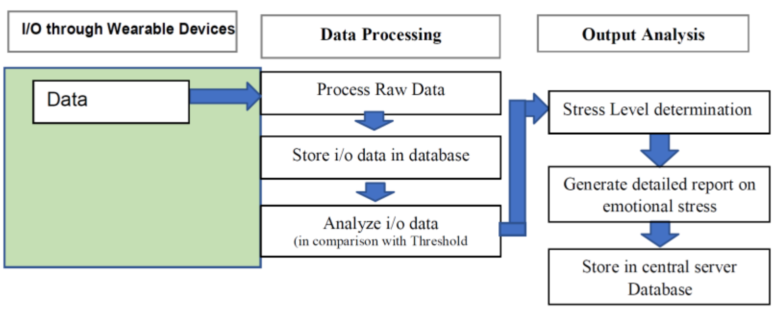
3.2.2 Usually no IT gadgets are being used for troops to monitor their mental health status. Nevertheless, automatic data grabbing devices of brain waves and other physiological signals i.e. heart rate, Heart rate variability (HRV), blood pressure wereappreciated.

3.2.3 Auto processing of data to create an illustrative report regarding the state of stress level of troops will significantly facilitate the decision-making process of commanders at various levels. Prior notice before crossing the threshold was highly recommended for assisting the decision regarding the continuation of deployment [10].

3.2.4 Storage of mental health was to be maintained meticulously [11]. Furthermore, the perception of tracing stress patterns and combat competence of individual soldiers are time-demanding needs in concurrent warfare strategy.

4. METHODOLOGY

4.1 The conceptual framework of our proposed BCI based Stress Monitoring System (SMS) is illustrated in Figure-1below:



(Source: Authors self-construct)

Figure-1: Conceptual framework of our proposed BCI based Stress Monitoring System

5. DATA ACQUISITION

5.1Using Neurosky EEG Devices

In our proposed system Neurosky EEG device is utilized for accumulating the readings of brain waves. It is a wireless EEG headset consisting of one dry electrode to collect EEG signals from the scalp on the frontal lobe (Fp1) of a person [12]. Many data values can be attained by using this device, such as raw EEG data, the magnitude of frequency bands (Theta, Alpha, Beta, and Gamma), signal quality, eye blink, etc [13]. It is capable of detecting two mind states – focused and relaxed as well. This device is used to input data to a TGAM1 (Think Gear ASIC Module) integrated circuit [14]. The device samples data at 512 Hz [15]. The headset uses a wireless Bluetooth connection to send EEG raw data to a recorder platform. We collected the raw EEG data into EDF+ (European Data Format) files using ad hoc LabVIEW (National Instruments Co., Austin, TX, USA) software [16]. Functionality and basic working principles of NED are illustrated below with Figure-2 and 3respectively.

Figure-2: Neurosky EEG Device

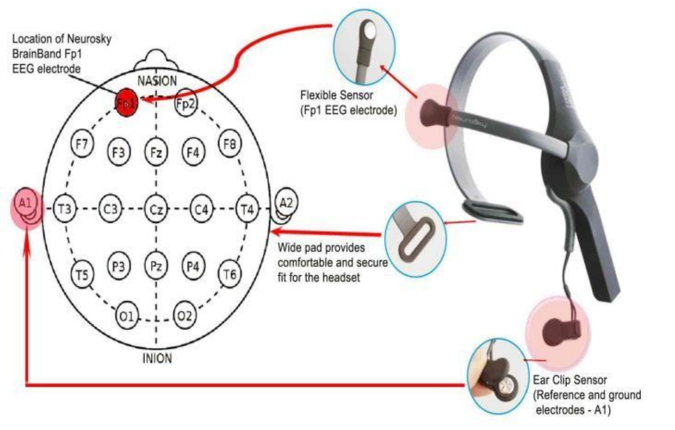


Figure-3: Basic Functionality of Neurosky EEG devices) (Sources: https://biofeedback-neurofeedback-therapy.com)

5.2 USING EMBEDDED SYSTEM (SMARTWATCH)

We use the Fitbitssmartwatch which is a wearable embedded system to track health matrix and variedphysiological parameters like Oxygen saturation (SpO_2), Heart rate (HR), Heart Rate Variability (HRV), Resting Heart Rate(RHR), Blood Pressure(BP), Breathing rate, Skin temperature, Active Zone Minute, etc. Data was collected using android applications named with the brand 'Fitbit health'

5.3 DATA PROCESSING

In the case of Neurosky, data was collected using android applications named "EEG-Id" The inbuilt data processing system through the android application is illustrated in Figure-4below:

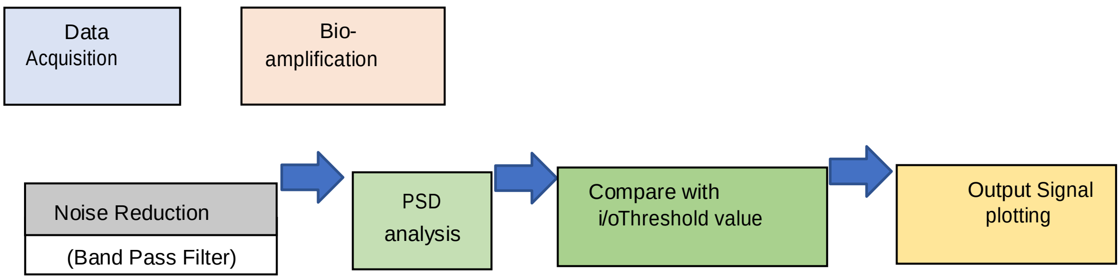


Figure-4: Data Processing flowchart (Neurosky)
(Source: Authors self-construct)

5.4 Data obtained from a wearable embedded system (Fitbits) will be stored in a database. A sample datasheet structure is appended in table-1 below. It is to be noted that for every individual a separate datasheet is maintained as stated in Table-1 below. The threshold value of each physiological parameter will vary for each individual due to variation in sex, age,etc.

Table-1: Datasheet of various physiological parameters)

Time	HR	*Thres hold Value (TV)	HRV	RHR	SpO2	**BP**				Skin Temperature		Activity(energy expenditure-in Kcal)		
												Active		Rest
						Systolic	TV	diastolic	TV		TV		TV	
0600														
0601														
Avg in Hr														

5.4 Using a customized application (windows and android based) of Stress Monitoring System in short "SMS" of raw data (in CSV format) are produced [16], processed, and fed as an input to the main system. The system architecture of the proposed system is illustrated in Figure-5below:

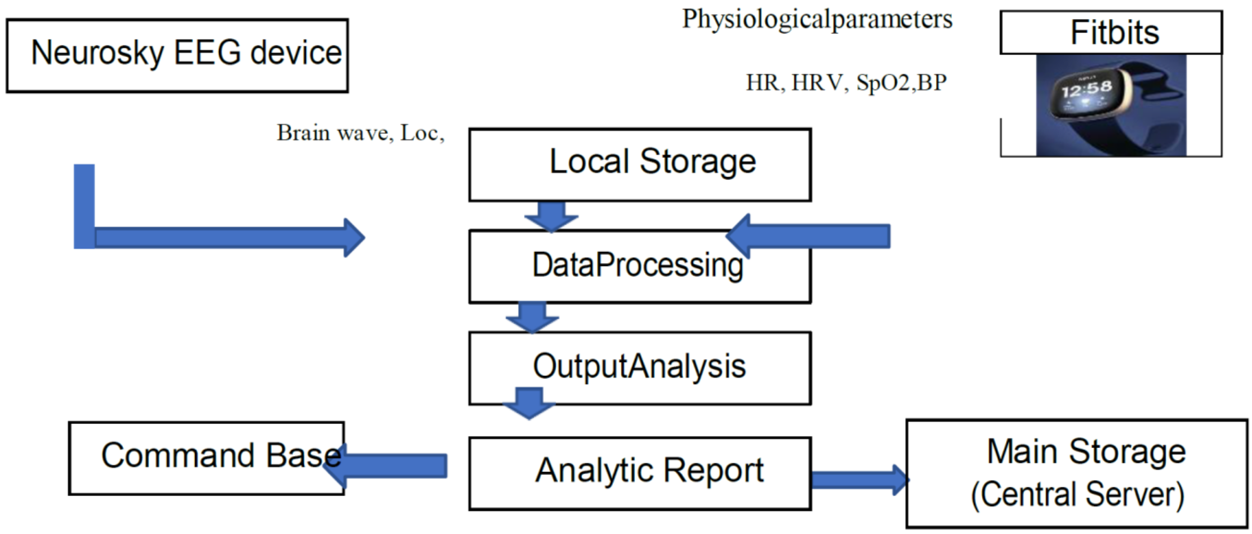


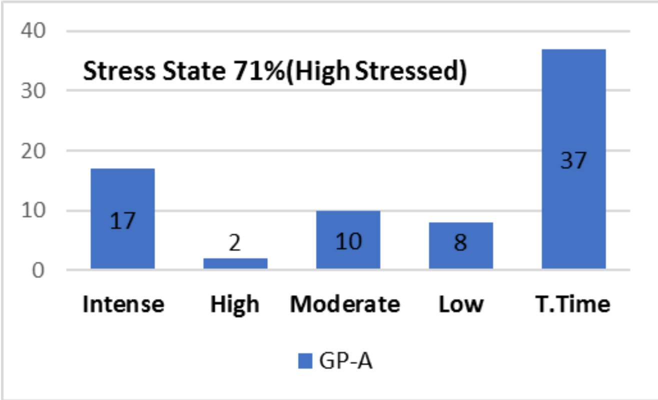
Figure-5: System architecture of the proposed stress monitoring system

6. DATA ANALYSIS

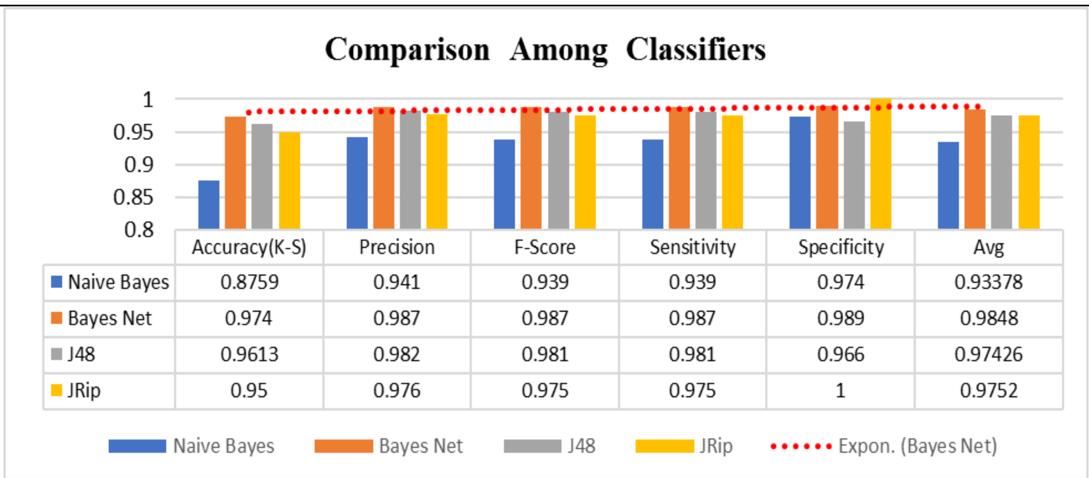
6.1 After noise cancellation and pre-processing a good no of labeled data (total 5250 labeled data with a dimensionof350 rows and 15 columns) has been taken into consideration. For effective output analysis, we have applied some Machine Learning (ML) algorithms, like the data mining system "WEKA[17]. In addition, Naive Bayes, Bayes Net, J48 decision tree and JRip, algorithm have also been used to evaluate the stress status of the participants. Accuracy (Kappa-statistics), F-score, precision, Sensitivity, and specificity are sued as evaluation parameters in this regard. Moreover, to estimate the performance of the above-stated ML algorithm, aPercentage-Split train/test (70/30) is also used as a test prediction model. A comparative analysis has been carried out with some performance parameters and given a data-set in this regard. Details of the analysis are appended in Graph-1below:

RESULT

- In the case of accuracy (Kappa-Statistics) and Precision Bayes Net(98%) and J48(97%) demonstrate a betteroutput.
- In the case of Sensitivity and Specificity Bayes Net(99%) and AdaBoost(98.8%) have shown better results.
- we observed an overall better performance from Bayes Net and JRip as shown in Graph-1below:



Graph-1: Stress State Analysis



	Accuracy(K-S)	Precision	F-Score	Sensitivity	Specificity	Avg
Naive Bayes	0.8759	0.941	0.939	0.939	0.974	0.93378
Bayes Net	0.974	0.987	0.987	0.987	0.989	0.9848
J48	0.9613	0.982	0.981	0.981	0.966	0.97426
JRip	0.95	0.976	0.975	0.975	1	0.9752

Graph-2: Results of stress status for varied classifier models

(Using percentage-split (70/30) techniques)

7. STRUCTURING USER INTERFACE(UI)

7.1 The dataset is uploaded into a google sheet which can be incorporated into any device (android or windows based) utilizing the web-based Graphical User Interface (GUI). The GUI is now linked with a database of a local server. When the system is being used, the server updates its database at a regular time interval (1 min). Therefore, when new data is appended, it is stored in a goggle sheet, and process through a program (developed with anaconda/python programming language). The stress level is ascertained through an exhaustive valuation of the inputs with the training data set (threshold value). using A pre-constructed Bayes- net model is being used in this regard. The output data are stored in the central database of the system. Then the output data is fetched from the central database and various parameters are displayed through the system GUI. (As shown in figure 4a). The GUI of SMS offers real-time wide-ranging visualization of various stress factors in each individual's profile.

7.2 Details of GUI are illustrated in Figure 4b below. In addition, individual soldier's history is being recorded at the back-end server that enables them to have a comprehensive track record on stress patterns. Furthermore, a notification will be automatically generated, when the output of different parameters has reached to preselected benchmark (cumulative threshold value) and represented the individual soldier as "STRESSED". Furthermore, the system has been designed to generate cumulative stress state reports based on troops' formation (i.e., Platoon, Company, Battalion, and brigade) which facilitates the overall decision- making process of top hierarchy command. The proposed UI of the Stress Management System (SMS) is graphically presented with Figure-6below:

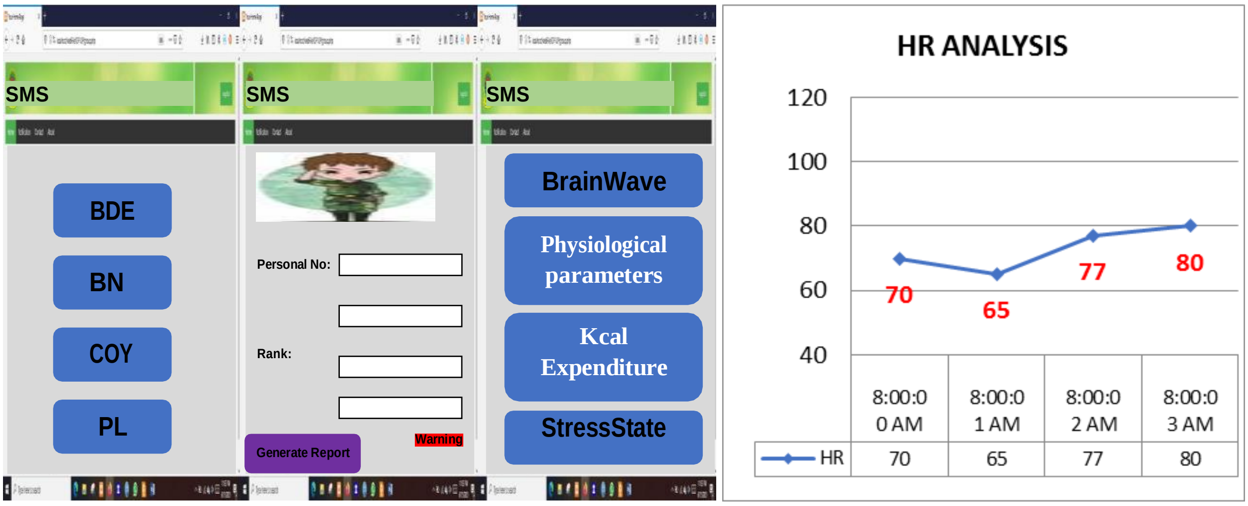


Figure-6: Proposed User Interface(UI) OF SMS
(Source: Authors self-construct)

8. Inclusive Evaluation on Functionality and Usability of SMS

8.1 FieldTest

A field test was conducted to evaluate the overall Functionality and Usability of SMS. Nine combat personnel of different age groups (from 20 to 35 years) were attended as test participants. At the very outset, all participants were thoroughly briefed on the purpose of the study and their role during the study.The field test was organized as "38 minutes maneuver exercise" stated below:

8.1.1 The participants were divided into two groups (group A and Group B) consisting of 4 persons each. The senior-most participants (as per rank) was acted as commanders and instructed to evaluate the stress pattern of subgroups deployed for operations. Both of the groups (A &B) are Instructedto take positions in a pre-designated place Named "Delta-5" and Delta-6respectively.

8.1.2 From "Delta-5". The A-group was instructed to carry out fire and move crossing an artificial obstacle and capture the object "Eico-5". The distance between "Delta-5" and "Eico-5" is 500 meters. Group-B was tasked to provide fire support in favor of GroupA.

8.1.3 Similarly, group B was tasked to carry out fire and move from the present location (delta-6) and capture object "Golf 678". The distance between "Delta-6" and "Golf 6" is 800 meters but having no obstacle inbetween.

8.1.4 From "Eico-5" and "Golf 6" both A & B groups are instructed to fall their earlier position by speed march. Details of the test are illustrated in Table-2below:

Table-2: Event list of 50 minutes' maneuver exercise)

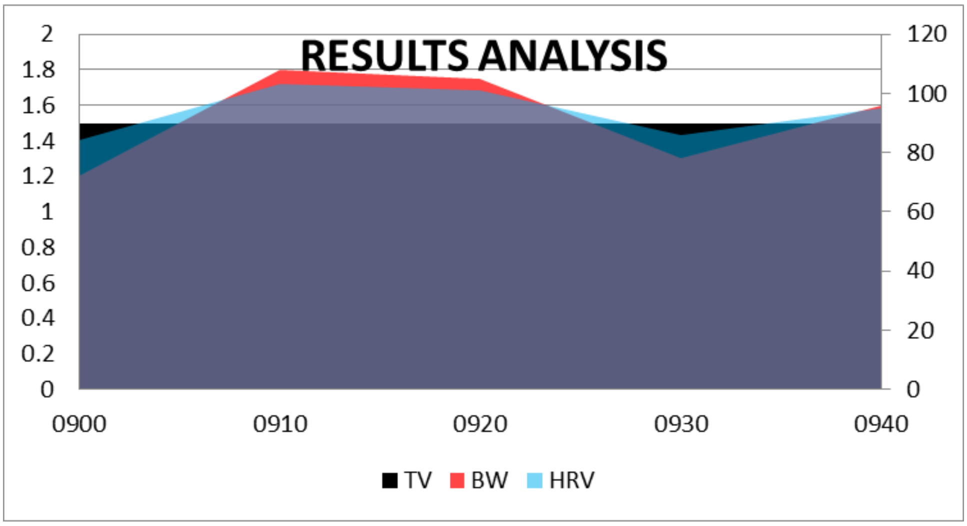
Running Time	Group-A (Group Member A1 – A4)	Activity Level	Group-B (Group Member B1 – B4)	
	Event List			
0900-0902	1. Running from delta-5 to Eico-5 (200m/2mins)	High	Give fire support from a static position	Low
0902-0906	2. Crossing obstacle-1(50m/3 mins)	Intense		
0907-0911	3. Fire and move from Obstacle-1 to Eico-5 (300m/4mins)			
0912-0919	4.Capture Objectives-7 mins			
0920-0929	5. Give fire support (static position)	Low	2. Running fromdelta-6 to Golf-6 (800m/9mins)	intense
0930-0937			3.Capture Objectives -7 Min	
0938-0948	5. Speed march from Eico-5 to Delta-5(500m/7mins)	moderate	5. Speed march from Eico-6 to Golf-6	moderate

(Source: Authors self-construct)

8.2 Commander observed the stress factors of each participant and their stress status (notification while crossing the threshold) through the web-based application for the entire duration of the field study. On completion of the exercise, participants were asked to share their opinion about the usefulness and usability of "SMS" Reports generated were displayed to the commander to assist the decision of deployment for an individual under-command

9. RESULTSANALYSIS

9.1 Among four participants of Group-A 3 (75%) were detected as "overstressed "and one "stressed". In group Bone person (25%) was found over-stressed, one was Stressed (25%) and the rest two were normal (50%). The system almost correctly classified the stress status. Furthermore, the field interview results showed that all participants found the developed **'SMS'** useful interesting, easy to learn, and use. They also appreciated the issues of portability features. However, some of those are recommended for enhancement of power consumption capability of Neurosky EEG device inside the helmet. Details of the analysis are appended in Graph-2 below:



Graph-2: Result Analysis

10.CONCLUSION

10.1 10.1The outcomes of this paper can be deliberated from varied perspectives. Firstly an endeavor has been made through the paper to developed an early prototype of a stress monitoring system (SMS) for troops deployed in various combat operations. The proposed system could monitor the real-time data and visualized the stress status outcome quite reasonably. The proposed system could acquire brain transmitted signals (Alpha and Beta) and varied physiological parameters (SpO2, HR, and HRV) related to the different stress factors, thereafter analyzed the collected data through a classifier. Secondly, based on the different classifying algorithms like Bayes net algorithm the performance of the system was found almost accurate (close 98% in terms of accuracy) finally, the evaluation process has revealed that the proposed system is very useful and efficient to perform its functionality during any combat operation. Finally, all the participants have accredited that the report generated from the system through a comprehensive analysis of stress factors would undeniably assist the higher command in the overall decision-making process during the active battle scenario..

10.2 Our endeavor has some limitations as well. The evaluation study was conducted in an indoor environment. at the same time, the number of participants was not inadequate. Potential future research may be conducted focusing to assess the applicability and effectiveness of the proposed system during the combat training sessions.

REFERENCES

[1] Kris, A and Peterson, M.: Resetting The Force: Reentry And Redeployment, Combat and Operational Behavioral Health,November-2010.pp2

[2] ibid

[3] Gonfalonieri,A.:ABeginner'sGuidetoBrain-ComputerInterfaceandConvolutionalNeuralNetworks ,2018. https://towardsdatascience.com

[4] Choi, K.H., Kim, J, and Park, J.E.: Is heart rate variability (HRV) an adequate tool for evaluating human emotions? - A focus on the use of the International Affective Picture System (IAPS)., Psychiatry Research, Vol. 251,pp. 192?196(2017)

[5] Murugappan, M., Ramachandran, N, and Sazali, Y.: Classification of human emotion from EEG using discrete wavelet transform. Journal of Biomedical Science and Engineering, vol. 03, no. 04, pp. 390? 396 (2010)

[6] Vaid, S., Kaur, C., Singh, P.:EEG analysis for emotion recognition using multiwavelet transform, International Journal of Pharmacy &

Technology, IJPT, Vol. 9 (1), April2017

[7] Razzak, M., and Islam, A., Exploring and Evaluating the Usability Factors for Military Application: A Road Map for HCI in Military Applications.Human Factors and Mechanical Engineering for Defense and Safety, Vol. 4 (1), 2020, Article.4.

[8] Diya, S.Z., and Islam, M.N.: Applying brain-computer interface technology for evaluation of user experience in playing games, International Conference on Electrical, Computer and Communication Engineering (ECCE), Cox's Bazar, Bangladesh, 2019,pp.

[9] Ramos. R and Kurts A.: Requirements Engineering A good practice guide, November-1997.

[10] Akib. Z, Rafat T.K, and Muhammad N.I. : Intelli-Helmet: An Early Prototype of a Stress Monitoring System Suitable for MilitaryOperations

[11] ibid

[12] Biofeedback-Neurofeedback Therapy. Accessed fromhttps://biofeedback-neurofeedback- therapy.com/neurosky.

[13] ibid

[14] Jasper, H.H.:'The ten-twenty electrode system of the international federation'. Electroencephalogram- Neurophysiology. Vol.10, 371–375.1958,

[15] Rebolledo. M, Gaona A.: Assessing NeuroSky's usability to detect attention levels in an assessment exercise. Human-Computer Interaction; Springer: Berlin/Heidelberg, Germany, 2009; pp.149–158.