INFLUENCE OF UNPLEASANT STIMULI ON GSR AND EEG RESPONSES - A COMPARATIVE ANALYSIS

Report submitted to the SASTRA Deemed to be University
as the requirement for the course

BIE300:MINI PROJECT

Submitted by

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DECEMBER 2023

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Bonafide Certificate

This is to certify that the report titled **"Influence Of Unpleasant Stimuli On GSR And EEG Responses - A Comparative Analysis**" submitted as a requirement for the course, **BIE300:MINI PROJECT** for B.Tech Bioengineering programme, is a bona-fide record of the work done by **Ms. Nivetha R. (Reg. No. 123011020), Ms. Aarthi U. (Reg, No. 124011071), Ms. Subalakshmi S.(Reg. No. 124011076)** during the academic year 2023-24, in the School of Chemical and Biotechnology, under my supervision.

Signature of Project Supervisor **:**

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Date **:** 21/12/23

Project *Viva voc*e held on ________________

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<u>Declaration</u>

I declare that the report titled “**Influence Of Unpleasant Stimuli On GSR And EEG Responses - A Comparative Analysis”** submitted by us is an original work done by us under the guidance of **Mr. Celestine Jerald A, Assistant Professor, School of Chemical and Biotechnology, SASTRA Deemed to be University** during the seventh semester of the academic year 2023-24, in the **School of Chemical and Biotechnology.** The work is original and wherever I have used materials from other sources, I have given due credit and cited them in the text of the report. This report has not formed the basis for the award of any degree, diploma, associate-ship, fellowship or other similar title to any candidate of any University.

Signature of the candidate(s) : R. Nivetha U. Aarthi

Name of the candidate(s) : Nivetha R, Aarthi U, Subalakshmi S.

Date :21/12/23

Acknowledgements

We would like to thank our Honourable Chancellor Prof. R. Sethuraman for providing us with an opportunity and the necessary infrastructure for carrying out this project as a part of our curriculum. We would like to thank our Honourable Vice-Chancellor Dr S. Vaidhyasubramaniam and Dr S.Swaminathan, Dean, Planning & Development, for the encouragement and strategic support at every step of our college life. We extend our sincere thanks to Dr R. Chandramouli, Registrar, SASTRA Deemed to be University for providing the opportunity to pursue this project. We extend our heartfelt thanks to Dr K.S. Rajan, Dean, School of Chemical & Biotechnology, Dr K. Uma Maheswari, Dean of Bioengineering, Dr V. Ponnusami, Associate Dean, Department of Chemical Engineering and Dr S. Adline Princy, Associate Dean, Department of Biotechnology for their motivation and support offered in materialising this project. Our guide Mr. A. Celestin Jerald, Assistant Professor-II, School of Chemical & Biotechnology was the driving force behind this whole idea from the start. His deep insight into the field and invaluable suggestions helped us in making progress throughout our project work. We also thank our review panel members Dr. Noel N, Dr .Hemalatha Karnan, Dr. Devipriya N, Dr. Anjan K Dash, Dr. Manikandan, Dr. Hariharan S. We also thank them for their valuable comments and insights which made this project better. We would like to extend our gratitude to all the teaching and non-teaching faculties of the School of Chemical & Biotechnology who have either directly or indirectly helped us in the completion of the project. We gratefully acknowledge all the contributions and encouragement from my family and friends resulting in the successful completion of this project. We thank you all for providing me with an opportunity to showcase my skills through the project

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Nomenclature

GSR-Galvanic skin Response

EEG-Electroencephalogram

ß - Beta Band

Units used:

dB -decibel

μS-microsiemens

Hz – hertz

V-voltage

Abstract

Stress can be defined as the mental and emotional tension that experienced when confronted with demanding situations and unfavourable conditions. The natural response that pushes us to confront difficulties and potential threats in our lives. The objective of this study is to analyse physiological responses due to unpleasant stimuli by conducting an information-based analysis of EEG (electroencephalogram) and GSR (galvanic skin response) signals to investigate the relationship between brain waves and skin conductance in the age group between 20 and 22.GSR measures the electrical conductance of the skin, and EEG measures the electrical activity of brain waves. The study consists of 20 human participants, both males and females. The conditions performed are normal (reference), pleasant video, and unpleasant video for the time duration of 2 minutes. To assess unpleasant stimuli, researchers have observed that changes in emotional and physiological states can lead to shifts in sweat gland activity, affecting the skin's electrical conductance, and changes in brain activity. Sweat gland activity rises in response to unpleasant stimuli because it activates the sympathetic nervous system. These fluctuations in skin conductance can be measured using a GSR (Galvanic Skin Response) sensor. The participants is allowed to watch an unpleasant video based on their interest, and then both EEG and GSR are measured simultaneously. For the EEG study of each participant under every situation, the power spectral density values (dB) were obtained from a range of 0–40 Hz. Then, they were summed up according to their beta bands. The Arduino IDE software is used to retrieve GSR data, and the Labchart software is used to extract EEG beta values. The average of EEG beta values and GSR of all participants was taken, and then it was verified by using a paired T-test to examine statistical differences for each condition. Upon comparing the EEG and GSR values of human participants exposed to unpleasant stimuli it shows that the beta and GSR values increases significantly as compared to control and pleasant stimuli. There is no significant difference between normal(control) and pleasant stimuli. We confirmed that GSR values matches with the EEG values that it shows the same differences.

Individual Contribution

- Nivetha R. - Data recording of GSR for 10 participants, Extraction of GSR for 20 participants, Literature survey on GSR, Statistical analysis of GSR.

- Aarthi U. - Data recording of EEG for 10 participants, Extraction of EEG for 10 participants, Literature survey on EEG, Statistical analysis of Beta values.

- Subalakshmi S. - Data recording of GSR for 10 participants and EEG for 10 participants, Extraction of EEG for 10 participants, Literature survey for aged people.

Specific Learning

- Troubleshooting of GSR and EEG
- Working of GSR and EEG
- Significant differences have been observed by using the Paired-T-test

Technical Limitations & Ethical Challenges faced

- Sensitivity of GSR to external environment

- Accurate results may be obtained via advanced EEG analysis using methods like montage systems and imaging approaches

Keywords: GSR, EEG, Unpleasant stimuli, skin conductance, Beta values

CHAPTER 1

INTRODUCTION

People deal with a lot of difficult or unpleasant situations in their daily lives, and stress is our body's reaction to those circumstances. It includes both physiological and psychological responses. The initial mechanism triggered during those situations is the “flight or fight" response. Stress chemicals like cortisol and adrenaline are released, triggering a response that sets the body for action. To regulate the stress response, our body increases the heart rate, respiration rate becomes faster, and blood flow is redirected to essential organs. If this stress is prolonged, it will lead to serious consequences for both physical and mental health. It may lead to anxiety, depression, cardiac problems and so on. To avoid those problems, stress must be detected earlier. EEG (electroencephalogram) and GSR (galvanic skin response) are used for detecting stress by analysing brain activity and the physiological response of the body to unpleasant conditions [1]. The electrical signals generated by synchronised neural activity are detected by EEG electrodes placed on the scalp. Stress may alter the activity of neuron patterns, which may affect EEG measurements. Electrical brain wave signals generated by the EEG are classified into some frequency bands, such as alpha, beta, gamma, delta, and theta. Some frequency fluctuations, particularly in the beta and gamma bands, are associated with stress and are indicative of elevated cognitive arousal. During resting settings, EEG assesses brain network activation linked to stress and anxiety, especially in the beta band (22–30 Hz). GSR electrodes are placed on the left fingers [2]. The autonomic nervous system will stimulate sweat gland activity during stressful or emotional-arousing situations. The electrical conductance of the skin is a sign of a stress-related physiological response. The electrical conductance of skin can be measured using GSR. In this project, we are correlating the relationship between brain waves and skin conductance in various conditions.

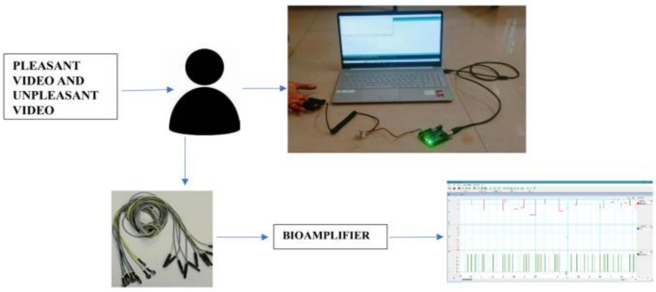

Figure 1.1 Block diagram

1.1 Sweat as Thermoregulator

Stressful conditions produce physiological changes in the body because of the body's "fight or flight" reaction [3]. The sympathetic nervous system is activated to prepare the body to react to perceived threats, which includes rises in heart rate and the production of adrenaline. But it also disrupts homeostasis. To maintain homeostasis, stimulate the sweat glands, which play an important role in thermoregulation. In Figure 1.1, Sweat glands, especially eccrine glands in are present across the body and respond to neural signals that are triggered by stress. The sympathetic nerve activity will be increasing due to stressors, and it will stimulate sweat glands, which leads to the production and secretion of sweat [4]. This sweat then evaporates from the skin surface, helping to dissipate heat and regulate body temperature. As the body temperature raises, blood vessels close to the skin's surface widen, causes an increased flow of blood through them. This helps in the transfer of heat from the body's core to the skin, facilitating heat loss through radiation and convection.

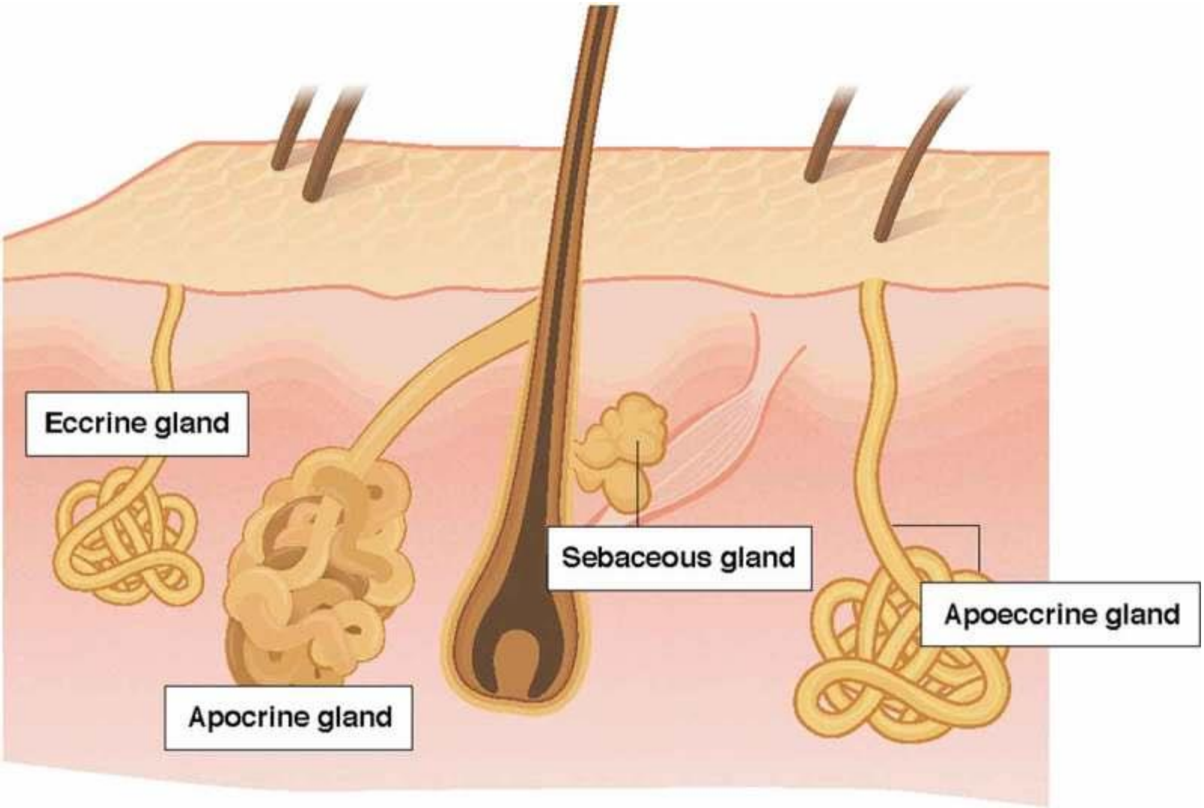

Figure 1.2 Structure of sweat glands (Baker, 2019)

1.2 Activation of amygdala and hippocampus

The complex workings of stress physiology involve a dynamic interaction between the brain and different bodily systems. In Figure 1.3, at the centre of this operation is the amygdala, a structure shaped like an almond located within the limbic system. Serving as an early warning system for stress, the amygdala swiftly processes stress signals, triggering the body's stress response and causing a sequence of physiological alterations. Simultaneously, the hippocampus works in conjunction with the amygdala to manage stress responses, fostering a well-balanced and adaptive reaction. Simultaneously, the sympathetic nervous system, a component of the autonomic nervous system, becomes active, resulting in observable physiological alterations like an increased heart rate and elevated blood pressure. This prepares the body for an immediate response to the perceived threat. Additionally, the prefrontal cortex, particularly the medial prefrontal cortex, assumes a critical role in stress regulation, influencing decision-making, emotional regulation, and cognitive control. However, chronic stress may negatively impact the prefrontal cortex, potentially leading to challenges in decision-making and emotional management over time[5]

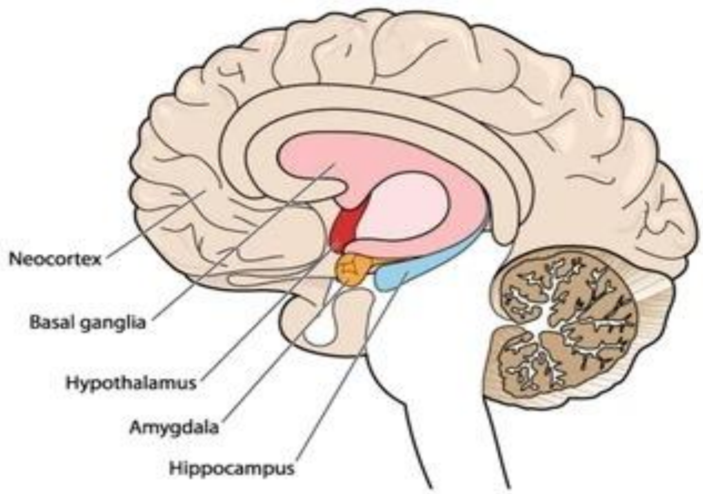

Figure 1.3 Structure of Brain

CHAPTER 2

OBJECTIVE

- To analyse physiological responses due to unpleasant stimuli and by conducting an information-based analysis of EEG (electroencephalogram) and GSR (galvanic skin response) signals.
- To investigate the relationship between brain waves and skin conductance in various conditions.
- The conditions used are
    - Normal(reference)
    - Pleasant video
    - Unpleasant video
- To formulate a null hypothesis for each experimental conditions to carry out a paired t-test
- To determine whether the results obtained from GSR values correspond with the EEG data

CHAPTER 3

EXPERIMENTAL WORK

3.1 List of Hardware / Software

- Grove Galvanic Skin Response Sensor (GSR).
- Arduino UNO
- Arduino UNO software- IDE
- Lab chart Reader

3.2 List of Equipment

Electroencephalogram (EEG)

3.1.1 Galvanic skin response sensor:

Galvanic skin response (GSR) measures skin conductance. Skin conductance is not under conscious control. Sympathetic activity is responsible for autonomous modulation of human behaviour, cognitive and emotional states. The conductance increases due the sweat gland activity. GSR sensor uses principle of ohm's law skin conductance is inversely proportional to the skin resistance. To measure skin conductance, electrodes are placed on the skin, and the electrical properties are measured. Skin conductance rises and skin resistance falls because of increased sweat gland activity. Data is acquired in units of micro-Siemens (μS). The technical specifications of GSR sensors are as follows:

Operating voltage: 5V

Input: skin resistance, not conductivity

Output: micro siemens, analog reading

Finger contact material: Nickel

Electrode used: silver chloride

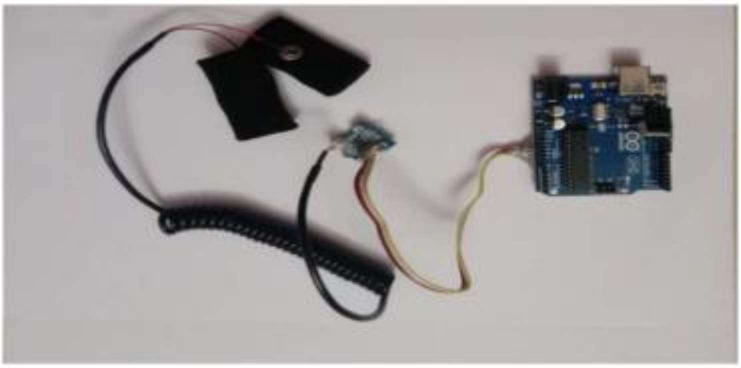

Figure 3.1.1 GSR sensor

3.1.2 Arduino UNO

Arduino is a single-board microcontroller enhances application more accessible to interactive objects and their surroundings. The features of UNO are ATmega328P microcontroller, 6 analog input pins (from A0 to A5), and 14 digital I/O pins, USB.Arduino Uno is combined with galvanic skin response (GSR) sensors, can be used for a variety of applications that involve monitoring and analysing physiological responses

3.1.3 Arduino IDE

The Arduino IDE ("Integrated Development Environment") is software that is used to develop the code and upload the code to the Arduino boards. The software can be used with any Arduino board. There are 4942 libraries registered in the Arduino Library Manager. Among them, 5 library functions are used in our code

Serial. begin (115200):It sets the data rate in bits per second (baud) for serial data transmission

Pin mode ():It is used to configure a specific pin to behave as either input or output

Digital write ():it helps to write a high or low value to a digital pin.

Delay ():It allows pausing the execution of the program for a specified period

3.1.4 LabCharts

LabChart 5 software used for obtaining data for physiological signals, such as ECG, EEG, EMG, and other biomedical signals. This software is used as a signal processing tools to filter, smooth, and process acquired data. The software provides tools for display of graphs, charts, and other visual representations of the data.

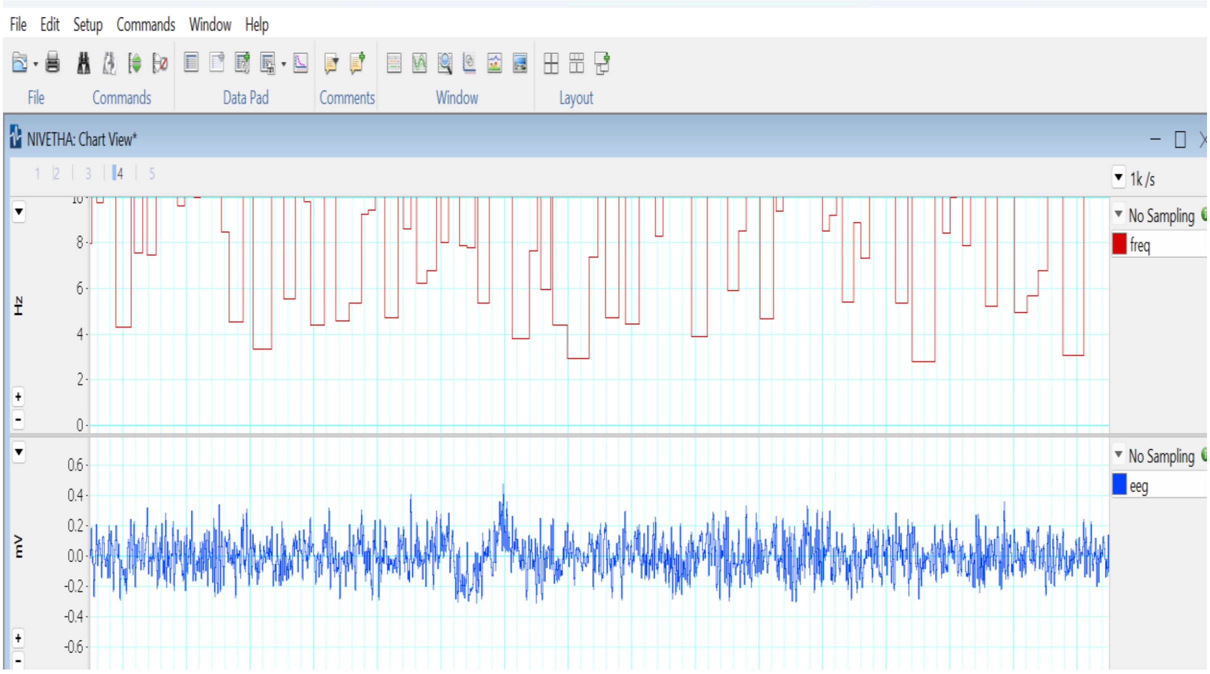

Figure 3.1.4 LabChart Reader

3.2.1 EEG:

Electroencephalography (EEG) is a non-invasive technique that measures the electrical signals of the brain. It involves placing electrodes on the scalps, records the electrical activity of neurons, and to monitor brain activity during various tasks. EEG measures different types of brain waves, including α, β, γ, δ and θ waves.

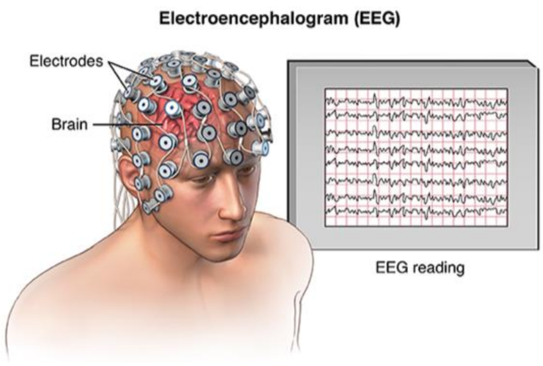

Figure 3.2.1 EEG setup (Shen 2020)

3.3 Methodology

3.3.1 Procedure

In this experiment, we investigated three conditions for checking the physiological response. The conditions performed are

- Normal(reference)
- Pleasant video
- Unpleasant video

The participants were instructed to view the videos in accordance with their areas of interest, which should not have affected how they saw things. We know that age factors affect the data, and hence 20 human participants, i.e., 7 male and 8 female participants, were taken under the age group of 20-22. Each individual's performance on a specific task was recorded for time duration of 120 seconds. The placement of Electrodes based on the international 10-20 system. Electrodes are placed on the frontal lobe (forehead) and reference electrodes are placed on the neck because to reduce muscle artifacts that can obstruct with the EEG signals. The signals of both GSR and EEG were recorded same time by inducing pleasant and unpleasant stimuli to the human participants under room temperature. The EEG waveforms are delta (0.5 to 4Hz), theta (4 to 7Hz), alpha (8 to 12 Hz), beta (13 to 30 Hz cycles per second). The pleasant and unpleasant stimuli in EEG are examined by beta waveforms. Examining changes in beta waves when watching video can assist understand how the brain receives and interprets emotional data. Beta waveform evokes emotional response’s data was recorded in terms of conductance. In this Experiment we investigate 3 conditions for checking the physiological response:

1. Normal

2. Pleasant Video

3. Unpleasant Video

3.3.2 Flow of process:

In this experiment, we investigated three conditions

↓

Human participants 20 (20-21) age group

↓

Time duration 120 seconds

↓

Participants performed by giving videos

↓

Recorded data EEG and GSR simultaneously

↓

Feature extraction in GSR records skin conductance in microsiemens

↓

EEG records frequency waveforms

↓

Feature extraction in EEG

↓

The averages of both EEG and GSR were calculated

↓

A statistical analysis of Paired T test was performed

↓

Analyzed the correlation between the brain waves and skin activities

3.3.3 EEG Data Acquisition

Labchart 5 software was used to collect the EEG data. The extension used to save these files is.adicht. After that, it was assessed using a Lab Chart Reader. For each condition, a total of 120 seconds was recorded.

3.3.4 EEG analysis

In EEG signals, time domain factor was calculated using Labchart software. In this analysis, a digital filter was used, i.e., a bandpass filter at a low cutoff frequency of 0.5 Hz and a high cutoff frequency of 40 Hz. For each condition, 120 seconds were selected and seen in spectrum view, and hence the frequency spectrum analysis was performed. The frequency values of delta, theta, alpha and beta were individually recorded using a labchart reader. For this study, only the beta values are taken into consideration. The average values for each of the 20 individuals are then shown on graphs.

$$F=\beta \text{——-----------------(1)}$$

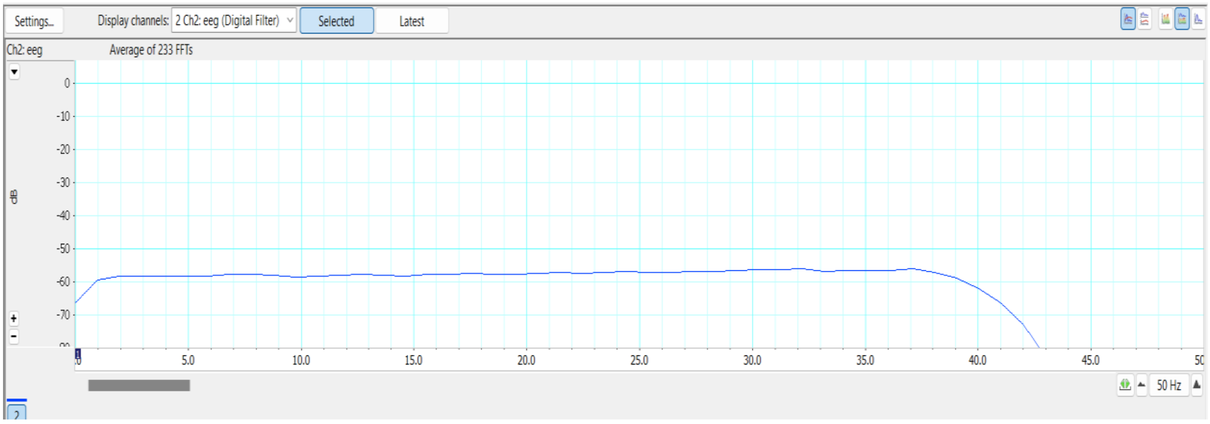

Figure 3.3.4 EEG acquisition

3.3.5 GSR Data Acquisition

GSR data was acquired using Arduino software for 120 seconds. The Cool Term software is used to convert a text file. Then, it is further analysed.

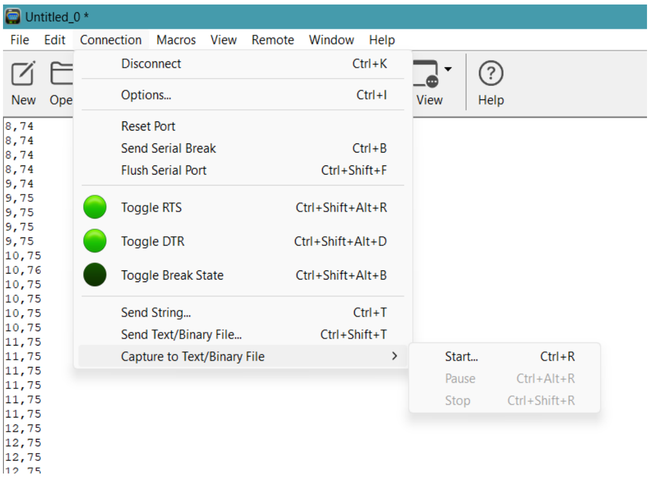

Figure 3.3.5 Data conversion into Text file

3.3.6 GSR analysis

The GSR-Data has been collected for each condition for 120 seconds for 20 participants, and after that, for all 20 participants average value was determined.

3.3.7 Statistical analysis

The statistical analysis of both EEG and GSR, is performed to determine their significant differences. Here, the paired T test is used to check the significance difference between each condition. The average values of both EEG and GSR for each condition for 20 participants are plotted, and hence, significant differences are observed between the conditions and averaged values.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Statistical analysis of GSR data

Firstly, the normal condition of the participants was measured, and then the participants was asked to watch a pleasant video and an unpleasant video for 2 minutes, and a sufficient break was also given. Then GSR values were measured. In Table 4.1.1, the overall average for all 20 participant is mentioned. In Table 4.1.2, the average and deviation of all 20 participants were taken.

No of subject	Normal	Pleasant video	Unpleasant Video
1	61.22014925	68.49253731	67.94776119
2	43.40671642	42.96268657	46.76492537
3	52.83208955	51.01119403	54.3880597
4	40.00373134	46.67910448	41
5	45.92164179	51.0858209	56.56716418
6	65.56343284	76.92910448	81.98507463
7	56.23134328	53.63059701	61.04104478
8	48.17164179	58.6380597	54.86567164
9	74.00615	77.391	83.0578
10	47.897	57.955	62.888
11	64.997	63.345	54.947
12	49.223	63.1379	73.192
13	56.36842	50.4881	55.93617
14	67.485	50.498	71.323
15	51.467	61.924	50.0088
16	52.38208955	48.93731343	56.70447761
17	59.8119403	67.0238806	74.50149254
18	51.59701493	52.74029851	52.77014925
19	79.1761194	81.62686567	85.07761194
20	67.57313433	68.10746269	72.27761194

Table 4.1.1 Overall average values of GSR data

Conditions	Normal	PLEASANT STIMULI	UNPLEASANT STIMULI
Average	56.766730	59.63019	62.863
Standard deviation	2.34	2.45	2.82

Table 4.1.2 Average and Standard deviation of GSR

Paired T-tests were used to check the significance of differences between each condition and assumed a 5% error value. In Figure 4.1.1, It was observed that $P > 0.05$, there is no significant difference between the normal and pleasant video conditions, and $P<=0.05$, there is a significant difference between the pleasant and unpleasant video conditions, and then $P<=0.05$, there is a significant difference between the normal and unpleasant video conditions. We inferred that there is a significant difference between a normal and unpleasant video condition.

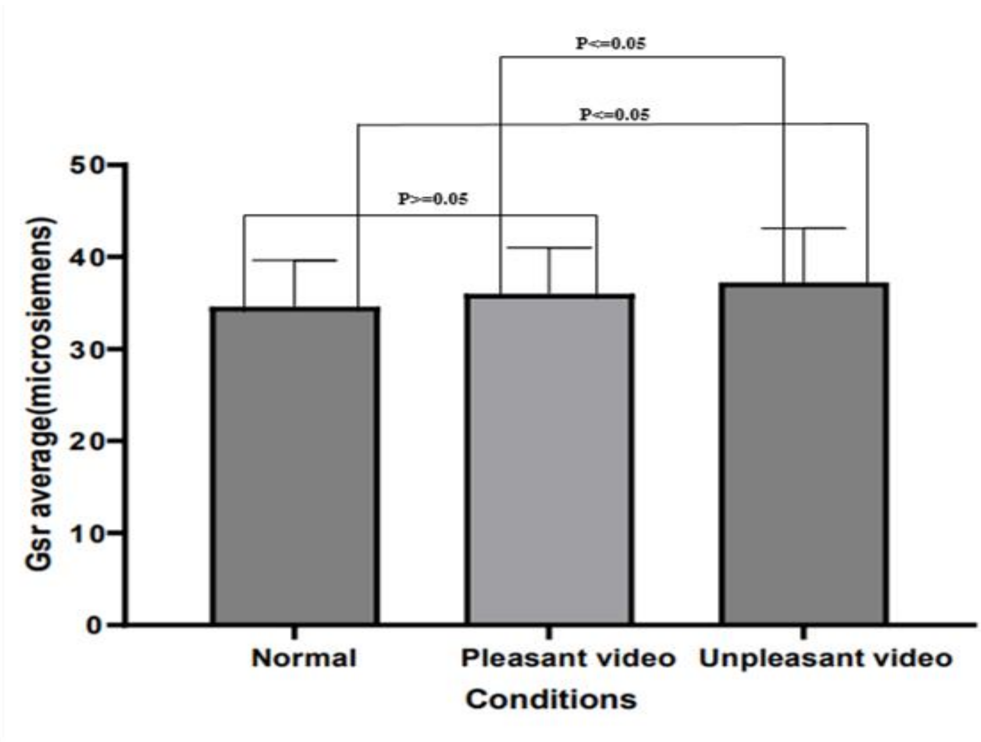

Figure 4.1.1 Statistical analysis of each condition for GSR

4.2. Statistical analysis of EEG data

For EEG data, we performed using various conditions and statistical significance were found using paired T tests at 5% as level of significance. Paired T test is a statistical method which is used to compare the two different groups, to check their significant difference. The data were taken from labchart reader and then it was changed to spectrum view. The values are taken in terms of magnitude. In EEG it records the electrical activity and different frequency bands were recorded to determine the neural activity of brain as shown in Table 4.2.1. The values are recorded based on their different wavelets i.e. Based on their frequency

Frequency wavelets	Frequency range
Delta	0.5 Hz - 4 Hz
Theta (θ) Waves	4 Hz - 8 Hz
Alpha (α) Waves	8 Hz - 13 Hz
Beta (β) Waves	13 Hz - 30 Hz

Table 4.2.1 EEG brain waves and their frequency ranges

	CONDITION: NORMAL			
SUBJECT NAME:		**FREQUENCY**	**MAGNITUDE(IN NEGATIVE)**	**100+MAGNITUDE**
xyz	**BETA**	12.695	65.171	34.829
		13.672	65.751	34.249
		14.648	65.69	34.31
		15.625	65.682	34.318
		16.602	65.688	34.312
		17.578	65.856	34.144
		18.555	64.979	35.021
		19.531	64.996	35.004
		20.508	65.358	34.642
		21.484	65.439	34.561
		22.461	65.008	34.992
		23.438	64.582	35.418
		24.414	65.373	34.627
		25.391	65.682	34.318
		26.367	65.558	34.442
		27.344	65.143	34.857
		28.32	65.403	34.597
		29.297	65.959	34.041

Table 4.2.2 Extraction of EEG values from labChart reader

Here from our work, we have taken only Beta (β) waves are considered. There will be an increase in beta values in pleasant conditions. Beta values were taken for 20 participants and all the conditions were averaged in Table 4.2.3.

No of Subject	Normal	Pleasant video	Unpleasant video
1	33.62705556	34.48966667	35.72072222
2	38.22266667	40.95722222	43.90122222
3	44.91433333	44.55477778	47.1885
4	30.25955556	33.07566667	40.31722222
5	35.81844444	37.84472222	40.22433333
6	41.97322222	44.00127778	44.54422222
7	30.8185	31.26294444	31.26294444
8	37.6985	40.66527778	44.15783333
9	34.54483333	35.057	34.72516667
10	33.55972222	32.59844444	33.467
11	32.89716667	31.26705556	32.511
12	44.57827778	44.39038889	44.38816667
13	28.25222222	31.69016667	33.95438889
14	34.6043333	34.52711111	34.45327778
15	28.54505556	29.386	25.04205556
16	30.31772222	32.28	33.3811111
17	26.54544444	30.62094444	32.17361111
18	34.26883333	34.63855456	35.35938889
19	36.1346111	42.278	43.54672222
20	34.17138889	34.23805556	34.34527778

Table 4.2.3 Overall average values of EEG data

Conditions	Normal	Pleasant stimuli	Unpleasant stimuli
Average	35.1127	35.828	36.871
Standard deviation	1.136	1.5317	1.317

Table 4.2.4 Average and Standard deviation of EEG

In Table 4.2.2 the beta values were extracted from labchart reader. The data would be in time domain, we need the data in the form of frequency domain it was done with the help spectrum view. Beta values are from 12 to 30 Hz based on this the magnitude values were extracted. The obtained magnitude values would be in negative.so to make it as positive we have added the magnitude with 100 as shown. So, it was done for each condition for normal, pleasant, unpleasant condition for 20 participants.Based on this, the average values are taken for each individual and for specific condition totally averaged the values and standard deviation were done in Table 4.2.3 and Table 4.2.4

Based on the obtained graph statistical difference were analysed. The statistical significance was observed by p value i.e.<0.05. Comparison of the mean values of EEG at each condition using the paired T-test it shows that in normal and pleasant condition, there is no significance difference were observed. Then, significant variations in EEG were observed between unpleasant and normal conditions. It shows P value as $P<0.05$. Based on the obtained statistical result we can infer that unpleasant conditions increase as compared to normal conditions as shown in Figure 4.2.1.

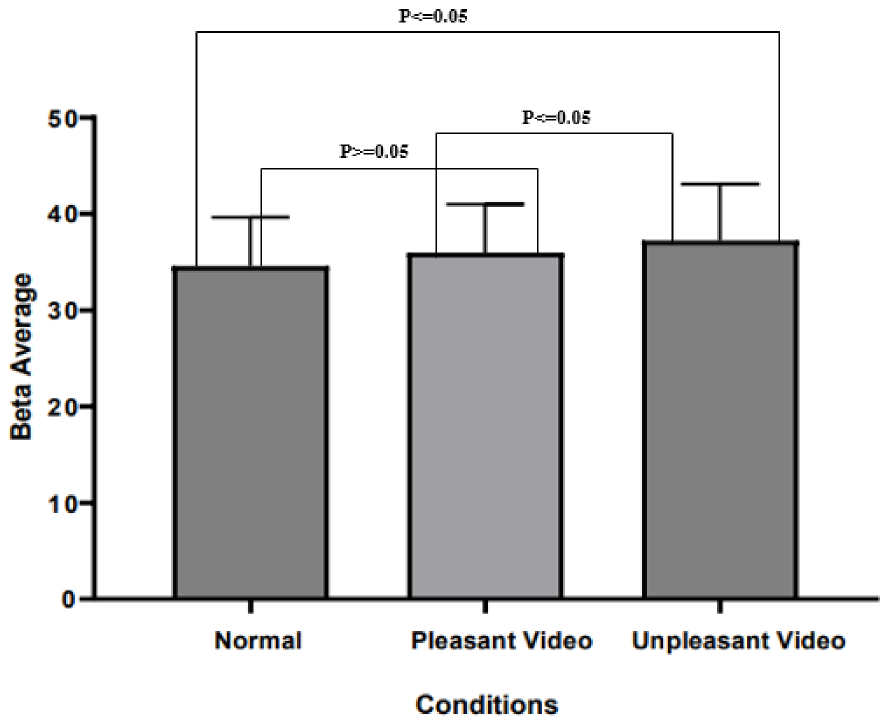

Figure 4.2.1 Statistical analysis of each condition for EEG

As result, there was an increase in the EEG under unpleasant circumstances, which was similar to the GSR result.

CHAPTER 5

CONCLUSION AND FUTURE WORK

Our study involves recording EEG and GSR simultaneously by giving unpleasant stimuli to assess the relationship between brain activity and skin conductance. we conducted simultaneous EEG and GSR recordings while exposing participants to unpleasant stimuli, aiming to explore the correlation between brain activity and skin conductance. Our findings reveal a significant increase in both EEG beta values and GSR skin conductance values during unpleasant stimuli compared to normal and pleasant conditions. In detecting stress, GSR was equally effective as EEG. Increasing the sample size can improve statistical analysis and lower the significance level. It can be analysed with machine learning and incorporated into medical equipment to monitor the stress levels of patients in clinical environments. It can be integrated into biofeedback systems to help individuals learn how to regulate their physiological responses to stress, which can be especially valuable for relaxation training and effective stress management.

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APPENDIX- A

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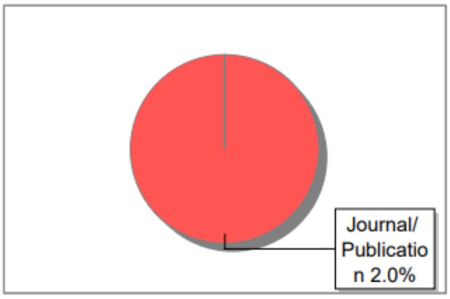

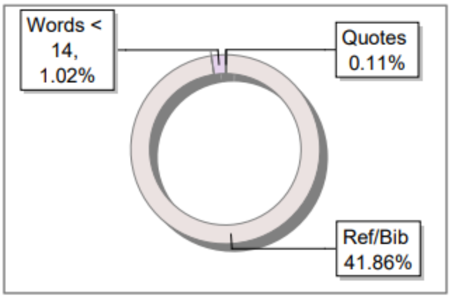

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