# Investigating the Influence of Multilingual Humour on Stress Reduction after Inducing with TSST: An EGG Study

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## AUTHOR'S DECLARATION

I Maria Ilyas Malik hereby state that my MS thesis titled "Investigating the Influence of Multilingual Humour on Stress Reduction after Inducing with TSST: An EGG Study" is my own work and has not been submitted previously by me for taking any degree from National University of Sciences and Technology, Islamabad or anywhere else in the country/ world.

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# DEDICATION

I dedicate this piece of hard work to my beloved parents, siblings, friends, teachers and my nano Khalida Ashraf. Their continuous support and encouragement have been my beacon of hope along this journey.

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All praise be to **ALLAH the almighty**, nourisher and the cherisher of the whole world, who has bestowed knowledge and wisdom upon all mankind. Countless blessings and salutations on the noble figure of **Hazrat Muhammad ﷺ,** and peace and mercy upon His noble companions, family members, and true followers till the day of judgment.

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# ABBREVIATIONS

| | |
|---|---|
| EEG | Electroencephalogram |
| TSST | Trier Social Stress Test |
| FFT | Fast Fourier transform |
| EEG | Electroencephalogram |
| PSD | Power Spectral Density |
| CRH | Corticotropin-Releasing Hormone |
| ACTH | Adrenocorticotropic Hormone |
| DASS | Depression Anxiety Stress Scale |
| WHO | World Health Organization |
| COTS | Commercial Off the Shelf |
| PNS | Parasympathetic Neural Systems |
| SNS | Sympathetic (PNS) Neural Systems |
| ANS | Autonomic nervous system |
| BVP | Blood Volume Pulse |
| HRV | Heart Rate Variability |
| PPG | Photoplethysmography |
| GSR | Galvanic skin response |
| ECG | Electrocardiogram |
| MEG | Magnetoencephalography |
| ECoG | Electrocorticogram |
| fMRI | Functional Magnetic Resonance Imaging |
| BP | Blood Pressure |
| EMG | Electromyography |
| FP1 | Frontal Location |
| TGAM | Thinkgear Application-Specific Integrated Circuit Module |
| ICA | Independent Component Analysis |
| Q-Q plots | Quantile-Quantile Plots |

# ABSTRACT

One of the major health issues is mental stress which often begins at a minor level and gradually builds up pressure, ultimately leading to stress. Electroencephalogram is a non-invasive method that evaluates the workings of the human brain and can be used for calculating stress. EEG detects the electrical activity in the brain by placing small electrodes on the brain's scalp. The study aims to use the Trier Social Stress Test (TSST) to induce stress in participants, followed by exposure to either native or non-native comedy videos as a potential stress-reduction intervention. In this study, the sample size of EEG signals was collected using one channel from 40 subjects aged 18-25 years with a gender split of 50% male and 50% female. This data only included students from the university. They were all healthy individuals without any known mental health conditions. All the subjects were shown one native comedy video clip and one non-native comedy video clip as their audio-visual stimuli that helped reduce different stress levels after taking the stress test. The brain's electrical activity was recorded while the participants performed TSST and watched comedy clips. This data was pre-processed using filters to remove environmental, biological, or technical artifacts. Specifically, the study used Fast Fourier Transform (FFT) and Power Spectral Density (PSD) analysis to determine changes in brainwave patterns mainly on the Delta, Theta, and Alpha waves. Increased delta and theta power after exposure to humor is found to represent the reduction of stress and cognitive relaxation. In the comedy video shown in the native language, there was a greater increase in Delta and Theta power, which induced a greater stress-reducing effect compared with non-native humor. Therefore, cultural familiarity plays an important role in stress management, and native-language humour may be more effective for reducing stress.

**Keywords:** Electroencephalogram (EEG), Trier Social Stress Test (TSST), Fast Fourier transform (FFT), Power Spectral Density (PSD).

# CHAPTER 1: INTRODUCTION

Currently, in the era of technological advancement, the growing concern is stress which has more recently been investigated in terms of its effects on mental health. The media has featured its strategies for preventing and managing the levels of stress [1].

As stress has a significant impact on social, physical, and mental health, henceforth it continues to be a point of discussion. There are several uses for stress research, for example measuring stress throughout the day, assessing stress to boost well-being and productivity at work, delaying the development of major illnesses, and much more. This research area is equally beneficial for the entire society and its individuals. Using the available electroencephalography (EEG) headset, this thesis brings an objective understanding of stress by emphasizing the key features and regions of brain activity.

## 1.1 Overview

Stress negatively affects one's capacity to function and overall health, as it makes them more susceptible to sickness and slows down the body’s ability to recover [2]. When a person encounters a stressor their neurons in the hypothalamus are activated. A corticotropin-releasing hormone (CRH) is discharged from the pituitary gland and subsequently, it releases adrenocorticotropic hormone (ACTH) where the blood carries ACTH, which has an impact on the adrenal glands. Cortisol, adrenaline, and norepinephrine are a few of the stress hormones that in response are released [3]. The production of cortisol is caused by stress, which helps a person deal with an immediate threat. Chronically the increase in levels of stress may result in depressive symptoms. According to several studies human stress, which may also increase anxiety and mood problems, has been linked to depression [4]. Nearly 350 million individuals worldwide suffer from depression, and it appears that these things are becoming worse in Pakistan [5]. In a study, 820 participants were contacted or interviewed, and out of which, about 46 percent had depression or symptoms associated with it [6]. There are several reasons for the prevalence of mental illness in Pakistan, including natural catastrophes, internal wars, economic instability, political unrest, increased rates of crimes and poverty, and much more.

Less than 350 psychiatrists, or 0.2 per 100,000 people, are estimated to exist in Pakistan by the World Health Organization (WHO) [7]. The current condition of psychiatric wards and mental institutions is terrible where there are only five psychiatric recognized hospitals in the entire nation. One of our most important goals should be to educate people about mental illness, but the harder challenge is to eliminate the stigma and guilt connected with it [3].

Psychological techniques have been used to evaluate stress and these techniques heavily rely on human interaction because these techniques are known as observer-reported or self-reported measures in the literature [8]. When a person chooses to conceal their stress status out of shame, personal reason, or stigma, it affects the outcome, these objective measures become less successful in reflecting the amount of stress. Most of the people who have mental health problems get misdiagnosed because sometimes hide their condition in shame and stigma. Technology has advanced to the point where EEG headgear is readily accessible as Commercial Off-the-shelf (COTS) equipment in some form. To produce a result where the stressors can use these EEG headsets to assess stress objectively. Such a metric might help a psychologist identify stress before it has any major health consequences. It can give a direct assessment of brain activity to reduce the stigma associated with mental examinations in patients. This might also aid in studying how stressful circumstances affect cognitive processes and enable us to educate with progressive development.

This study of human stress measurement is a fast-developing field in EEG data processing. There is a literature on stress measurement that uses EEG in response to various stressors. The characterization of human stress based on baseline EEG has not received much attention which is why particularly in poor nations with limited access to mental health institutions, wearable EEG stress measurement is of relevance. Thus, EEG was used in these regions as an objective measure for stress classification to become more important. It is a relatively inexpensive and simple method to identify stress. Human stress and mental states have been successfully evaluated with success using machine learning algorithms.

## 1.2 Impact of Stress on Mental Health

Life itself presents physical and mental difficulties that are presented by life itself and unavoidable pressures enter daily life because of society and technology's rapid advancements. Numerous pressures might cause someone to feel stressed out in their daily lives. [9]. According to the standard definition of stress, this reaction pattern is complex and frequently consists of behavioural, psychological, and cognitive components [9]. It is a description of the decline in how a body processes, evaluates and responds to sensory stimuli [10]. An additional description is provided as Environmental pressures surpass an organism's ability for adaptation, causing biological and psychological alterations that may put people at risk for illnesses [11]. This is why the phrase "computational stress" was very recently coined, and it implies measuring stress at a given moment in time while taking stress symptoms into account [8].

## 1.3 Classification of Stress Types

There is a severity of the sickness and its symptoms which are used to classify the different forms of stress. Each kind has distinct indications and effects; Chronic, Acute, episodic, and long-term stress are examples of these categories [12].

### *1.3.1 Chronic Stress*

Chronic stress can be described as an ongoing issue lasting for a minimum duration of four weeks, with at least one significant life event before commencement [13]. It can be brought on by exposure to horrific events as well as by daily tensions that aren't properly managed. Ignoring chronic stress can have serious consequences, including depression, cardiovascular disorders, and anxiety. People's health is harmed by chronic stress on a daily and even yearly basis. Chronic stress is brought on by dysfunctional families, poverty, unpleasant marriages, and undesirable jobs. When someone is confined in a bad circumstance, it is set off. It happens because of surpassing demands for what appears to be an endless amount of time.

Nine basic types of chronic stress exist i.e., demands, under-load, structural limits, unpredictability, complexity, under-reward, choice restriction, conflict, and resource deprivation [14]. The danger is the persistent possibility of damage that cannot be prevented or managed, and it develops when a person's reputation is in danger. A constant and independent aspect of the actual threat is how it is perceived. It draws attention to the stressful aspect of the issue. When a person is under the strain of several urgent, uncontrollable duties, and independence that cannot be avoided, demands and overload occur. This kind of overload is one of several factors that contribute to chronic stress, including a lack of time for oneself, a disproportionate quantity of work compared to other people, and unrealistic expectations from others [15].

Despite having distinct qualities, complexity is a type of excessive demand. Demands of this kind are interrelated, creating a level of complexity that causes chronic stress. Social duties give a complicated schedule to fulfill, which puts someone under constant stress. As an issue that is closely tied to complexity, uncertainty is said to exist. Scaling back the impact of complexity is uncertainty. If uncertainty lasts longer than expected, stress will be brought on. Uncertainty turns into chronic stress when getting the problem resolved takes priority above getting the desired outcome.

In many circumstances, discrimination is widely seen as stressful. Structure-related characteristics are present in the underload. When someone lacks an alternative, boredom is their only available condition. There are several types of demands, such as monotonous work that is slow-moving and frequent. Problems arise when an individual is forced to make choices from a limited range due to structural restrictions in their social context. These issues can take on a variety of shapes, from how regulations are interpreted to the reality of severe societal disadvantages like discrimination. Access restrictions are likewise seen as a type of stress.

### *1.3.2 Acute Stress*

The most prevalent type of stress is acute stress, which is driven by unfamiliar, frightening, unpredictable, and unmanageable conditions. Acute stress is typically brought on by the demands of the future and the past. Examples of everyday events that can be stressful include losing a significant contract or being on the verge of a deadline. Instantaneous stress can be beneficial since it causes the body to generate stress hormones to deal with the traumatic period. However, if these stress hormones are released in abundance, the body's defense mechanisms may get worn out. Acute stress is less harmful than long-term stress since it lasts for a shorter period. Whereas excessive short-term stress can cause physical and psychological issues. such as headaches, discomfort, digestive problems, and other symptoms that indicate stress. Most acute stress patients may quickly recognize its symptoms.

It is defined as acute stress that frequently occurs and has self-inflicted demands and disorganization as its main symptoms. During episodic acute stress, one might also notice short-temperedness, impatience, nervous energy, tension, and worry. Occasionally, irritation can result in aggression, which can harm social relationships. The workplace might thus become unpleasant for the sufferer. In this condition, patients forecast doom in each situation. People suffering from episodic acute stress view the world as scary and joyless, are reluctant to change, and feel endless worry, over-arousal, and despair.

Under-reward is a concept that comes from Equity Theory [16]. According to this idea of social exchange, each relationship's participants should get an equivalent number of outputs relative to inputs. The phenomenon of under-reward is described as occurring when playing the victim is more stressful than playing the opponent. Every Aspect of social life, business, and family is fraught with conflict. They happen because of various goals and morals. If the parties cannot agree on shared aims and goals, they tend to last for a longer amount of time. Chronic stress is caused by both the anxiety of bringing up the dispute and the problem itself.

### 1.4 Methods of Stress Measurement

The symptoms that can be identified with the stress response could be used to measure stress in people in a variety of ways. Humans exhibit signs of stress reaction on the psychological, physical, and physiological levels. Measures of stress may be divided into three categories based on these symptoms. In the subsections below, the measures are explained briefly.

### *1.4.1 Subjective Measures of Stress*

Subjective measures of stress, categorized as 'Psychological' and 'Physical,' are explained below.

- **Psychological Stress**

The measurements that do not require activation and instead focus on the mental state. The Measurements obtained from physiological measures or sensors are validated using these stress measures. Measurements of abstract ideas like language, intellect, and emotion are the focus of psychology. It is commonly acknowledged that psychological factors play a role in stress response. As a result, psychological surveys can be used to measure stress [8].

Numerous surveys have been created by psychologists that can evaluate a person’s degree of stress based on their reported symptoms. A relative stress scale [17], brief symptom inventory [18] positive affect and negative affect schedule [19], daily stress inventory [20], and the life stress interview, as well as the visual analog mood scales [21], the trier inventory for evaluating chronic stress and others may be among these questionnaires. A psychological tool called the STAI is mainly employed to measure perceived stress [22].

Although psychological questionnaires that measure perceived stress can assess stress subjectively, there are some situations where objective measurements of stress are more useful than self-reported measures since self-report may be skewed. In general, using checklists cannot approach the accuracy of a skilled interviewer in examining research questions [23]. Interviews can be used to get more accurate data than self-reports, which are produced independently. Even when responding to unfavorable questions on surveys, individuals describe pleasant occurrences [23]. Although these techniques are useful, there are cultural and language difficulties. but because competent interviewers may elicit descriptive information on the intensity of events across time, interview approaches offer various insights into stress assessment.

Interviewers with training can make connections between similar problems and situations.

- **Physical Stress**

Physical measurements are observable from the outside since they are related to one's behavior. Any attribute visible to the naked eye is called a physical quality. However, measuring stress and anxiety related to studying mathematics requires sophisticated tools and sensors, relying on gesture recognition [24]. Another research looked at pupil instances, yawning, and facial expressions during the day and night to gauge how tired the drivers were [25]. The detection of stress utilizing both internal and external stressors has been accomplished using video-recorded facial expressions [26].

The distinction between the valid pupil diameter and the blink is the most recent and may potentially be an indication of stress [27]. While a lower blink frequency is thought to be the cause of stress. Another study shows a higher blink frequency has been linked to stressful situations [28]. Recently, an objective measure of depression and stress was developed in aphasia patients by using speech features [29]. The two main speech features for detecting stress are rapid fluctuation and an expansion of the frequency range [30]. Table 1 presents the physical techniques used to measure stress.

**Table 1: Physical Techniques Used to Measure Stress**

| Physical Measures | Technology |
|---|---|
| Facial Expression [25] | Facial Movements |
| Body Language [24] | Automated Gestures Recognition |
| Lip, Mouth, and Head Movements [26] | Camera-based photoplethysmography |
| Communication Disorder [29] | Speech Pattern Analysis |
| Infrared Eye Tracking [27] | Eye Movement |

### *1.4.2 Objective Measures of Stress*

Objective measures of stress categorized as ‘Physiological’ are explained below.

- **Physiological Stress**

Since they are automatic, it is challenging to measure them, the physiological measurements are related to a person’s typical bodily functions. Since they are automatic, it is challenging to measure them, the physiological measurements are related to a person’s typical bodily functions. These entail the affixing of certain instruments to a person to track alterations in the body’s physiological characteristics. The autonomic nervous system (ANS) oversees controlling the body's involuntary movements. This ANS comprises sympathetic (SNS) and parasympathetic (PNS) neural systems. The activity rates in SNS and PNS are inversely proportional. So, an increase in SNS during stressful situations decreases the activity rate in PNS, which represents the body's resting state. SNS and PNS control blood pressure, brain waves, galvanic skin response (GSR), and heart rate variability. These are the important variables to consider while assessing stress [31]. To accurately assess stress, galvanic skin response (GSR) can be employed [32]. It is an illustration of how well electricity flows through the skin. Electrodes are positioned on the hand’s first and middle fingers to measure it. The body’s skin resistance diminishes when a person is under stress. This situation occurs because of the skin’s increased moisture [23]. Julius et al. explain the physiological alterations that stress causes in the skin [33]. GSR might be seen as a crucial metric for workload evaluation [34]. GSR characteristics have been used to calculate stress in a variety of scenarios [35].

It is common practice to evaluate ANS activity using heart rate variability (HRV) [36]. It is considered one of the key measures of stress [37]. An ideal way to test HRV is with an electrocardiogram (ECG), which is extremely sensitive to heartbeat detection [38]. The graph of ECG is used to depict the electrical activity of the cardiac muscles that are being recorded. It is determined by attaching electrodes to a person’s body on each side of the heart. Stress is often assessed using HRV's low- and high-frequency bands. Shorter-term HRV is a good indicator of acute stress [39].

Researchers have found a link between rising stress levels and rising blood pressure. Recent research [40] found that acute stress tasks had an impact on blood pressure. Photoplethysmography (PPG), which is obtained from a finger, can be used to calculate an individual's Blood Volume Pulse (BVP). By projecting infrared light, a PPG measures the light that is reflected off the finger. Depending on how much blood is within, this light is reflected. PPG sensors are used in industrial stress monitoring systems [41]. A measurement of muscular action potentials is electromyography (EMG). To detect stress, EMG electrodes are positioned on the shoulder. Another stress indicator for people used to monitoring by having a belt around their chest is respiration. However, compared to HRV and GSR, respiration monitoring is invasive and does not function well as a stress indicator [42].

Stress and brain activity are strongly correlated [43]. EEG is often employed in published studies on the human brain in the modes listed above [44]. It is the most widely utilized method for studying brain disorders and functioning economically. It is a technique that measures brain activity objectively and precisely. From electrodes positioned on the human scalp, it obtains various waves [45]. High temporal resolution and superior mobility are features of EEG sensors and since the brain is where the stress reaction originates, EEG becomes an important signal for the analysis, recognition, and accurate measurement of human stress [46].

**Table 2: List of Physiological Techniques Used to Measure Stress**

| Technology Name | Physiological Measures |
|---|---|
| Galvanic Skin Response (GSR) [32] | Skin Response |
| Electrocardiography (ECG) [39] | Electric Activity of Heart |
| Photoplethysmography (PPG) [41] | Blood Volume Pressure |
| Electrodermal Activity (EDA) [47] | Skin Response |
| Electroencephalography (EEG) [44] | Brain Electrical Activity |

Numerous techniques have been created to measure and evaluate the amount of stress, whether they are based on questionnaires, surveys, or the observation of persons who measure changes in physiological signals as depicted in Table 2.

These two techniques are well known for their accuracy and contributions to both spatial and temporal resolution. Invasive treatments have drawbacks in some cases, such as hormone analysis, which highlights the need for non-invasive, efficient, accurate, and trustworthy methodologies. Table 3 shows different non-invasive procedures can identify stress from human physiological signals.

**Table 3: List of Non-Invasive physiological Techniques Used to identify Stress**

| Non-Invasive Methods | Advantages | Limitations |
|---|---|---|
| Magnetoencephalography (MEG) | High spatial resolution | Very high cost |
| Galvanic Skin Response (GSR) | Affordable and readily available | Diurnal fluctuations can affect results based on the time of assessment |
| Functional Magnetic Resonance Imaging (fMRI) | Good to high spatial resolution | Slow temporal response due to blood supply delay |
| Blood Volume Pulse (BVP) | Non-intrusive and cost-effective | Requires individual calibration and is prone to drift over short periods |
| Electroencephalography (EEG) | Excellent temporal resolution, low cost, and safe | Limited spatial resolution and susceptibility to noise |

| | | |
|---|---|---|
| Electrocardiography (ECG) | Widely accessible equipment validated accuracy across populations | Lower sensitivity compared to other stress imaging techniques, poor specificity |
| Blood Pressure (BP) | Easy to use, reproducible results, sensitive measurement, normative data available | Lack of prospective mortality data, limiting its use for treatment decisions |
| Electromyography (EMG) | Reliable and accurate for measuring muscle activity | Lower clinical yield in some cases, technical challenges with obesity and advanced age, complex signal interpretation |

## 1.5 The Evolution of Comedy as a Cultural Phenomenon

Comedy generation and perception is a biological process, a cognitive phenotypic attribute likely dependent on a genetically grounded neural substrate. Comedy has undoubtedly existed for thousands of years if not millions of years. Early anthropologists overheard an amusing conversation, during their first encounter with Australian Aboriginal people. Second, for at least 35,000 years, Australian Aboriginals appear to have been genetically isolated [48]. If genetic factors determine the fundamental ability to perceive or make comedy (and convergent evolution does not apply), 35,000 years may be the minimum age for comedy.

### *1.5.1 Understanding the Role of Comedy in Social Dynamics*

The ability to recognize Humour appears to be "instinctive", and so reliant on genetic mechanisms. Comedy is difficult to learn without the aid of a network of specialized brain pathways and a corresponding cognitive module. It is generally a combination of precise language wording and a thorough understanding of current social dynamics that determines whether something is hilarious or not. Most of the literature focuses on internal techniques for detecting comedians' appraisals via physiological markers. Given the complexity of comedy as a cognitive activity, it is no surprise that the bulk of comedy research based on physiological measurements has used brain-imaging techniques. The evaluation of stand-up comedians, as well as comic production, has been widely examined utilizing fMRI tests [49]. Another approach that has been effectively employed in stand-up comic research is magnetoencephalography (MEG), which has been used to locate humor-specific brain activations and investigate their temporal sequence [50]. One advantage of MEG over fMRI is its superior temporal resolution. While these discoveries shed light on the brain activity associated with comedian appraisal, both fMRI and MEG need room-size sensors, making them unsuitable for real-world use.

Although Electrodermal Activity (EDA) is one of the most normally employed signals in psychophysiology, there has been little research into how it might be used to detect comedians' assessments. Finkelstein et al. [51], classified emotions using EDA in conjunction with several other physiological markers, one of which was amusement. The ECG depicts the electrical activity of the heart. The heart rate and heart rate variability (HRV), which are connected to both parasympathetic and sympathetic nervous system activity and have been related to mental workload [47], are the most common parameters extracted from ECG. Fiacconi and Owen [52] investigated the temporal profile of Humour evaluation, finding that it was associated with a slowing in heart rate followed by an acceleration in heart rate.

### *1.5.2 Humour as a Tool for Stress Management*

Stress plays a significant role in our daily lives since it is involved in almost every action, yet we tend to pay only a little bit of attention to it. [53] Humour then plays an important role in the field too, that it can serve as a healing tool. [54] Study says that both Humour and exposure to humorous events can be found to reduce anxiety and produce positive effects as a response. [55] but the ability to demonstrate this response through a sense of Humour has yet to be explored and stated with confidence. [56] and using Humour socially can be a helpful tool for people too thus they will obtain social support [57].

## 1.6 Research Motivation

Now stress and anxiety are growing more and more dangerous for Pakistani youth. According to a report by Tribune Pakistan, over 34 percent of Pakistanis experience anxiety [58]. The stigma associated with common mental diseases persists in Pakistan despite the grave condition.

Whereas stress exists in everyday life and sometimes can last for a very short period, it becomes a concern when it starts interfering with the productivity and health of a person. Excessive stress or anxiety results in fundamental changes in behavior and cognitive function and may culminate into serious mental health issues such as depression if left unheeded early. It is, therefore, very important to detect early warning signals of stress to avert such consequences. EEG is suitable for this investigation process due to its affordability and non-invasive nature, hence one of the most common tools employed in various stress-detection research.

## 1.7 Problem Statement

Our research aims to profile participants by investigating whether stress that TSST first induces can be later reduced through watching Native Language, and Non-Native language, standup comedy clips while using the Neurosky Mindwave Mobile 2, an EEG device to capture brain signals and apply statistical analysis to test their significance.

## 1.8 Research Objectives

The thesis aims to use a commercially accessible EEG-based brain-computer interface to evaluate and classify human stress. The objectives of this study are:

- To record a real-time dataset of EEG signals by inducing stress using the Trier Social Stress Test (TSST) and investigate the impact of exposure to English and Hindi comedy videos on stress reduction.

- To analyze changes in EEG patterns, particularly focusing on frequency bands, before and after exposure to comedy videos.
- To compare EEG data between participants exposed to English and Hindi comedy videos to determine potential differences in stress reduction efficacy.
- To study which brain waves are associated with stress levels in the brain.

## 1.9 Thesis Structure

The thesis is structured in a way that Chapter 2 forms the core of the previous work about stress analysis using EEG. More detailed information is provided on the types of stimuli used for inducing and reducing stress. It also refers to the existing gaps in the literature that the current research study will aim to fill. Chapter 3 outlines the proposed experimental methodology, detailing the tools and techniques that would be used to collect data, which broadly includes the usage of the Trier Social Stress Test along with the pre-processing steps, such as noise removal techniques and signal filters, to prepare the collected EEG data for analysis. Chapter 4 will present and discuss those findings derived from the application of the methods described above, thereby showing evidence of the reduction in stress utilizing multilingual Humour through data provided by EEG devices. Finally, the last chapter, Chapter 5, will draw conclusions about the results found, discuss the limitations found in the development of research work, and suggest future lines that, after solving limitations, may help deepen the knowledge of the use of EEG as an intervention methodology for the management of stress.

# CHAPTER 2: LITERATURE REVIEW

Stress is measured in a variety of ways, such as psychologically, physically, and physiologically. An EEG is a physiological tool that accurately measures brain activity. EEG signal processing is a new and exciting area of brain-computer interface technology. This chapter discusses the types and paradigms of brain-computer interfaces as well.

## 2.1 Multilingual Humour and Emotional Processing

The relationship between Humour and sentiment or emotions has also been explored [59]. This way a single task can show improvement in both monolingual and multilingual settings [60]. It is seen that Humour serves as a form of mastery over a given language [61]. The main purpose is to understand the difference between how people take Humour [62].

### *2.1.1 Cognitive Impacts of Multilingualism*

Multilingualism has also been related to heightened cognitive flexibility, especially a 'switching ability' from one task to another or between mental sets following changing demands [63]. This type of cognitive flexibility is of special relevance to problem-solving and adjusting to novelty and provides people with multilingual competence with enhanced adaptability in handling complex environments. Indeed, overall, bilingual and multilingual participants exhibit performance benefits relative to monolingual participants when performing tasks that tap aspects of cognitive control and flexibility, such as tasks modelled on task-switching paradigms and working memory tasks [64].

Several studies have also indicated that multilingualism promotes problem-solving since multilingual individuals can view problems from different perspectives. For example, in the study [65] it was found that in comparison bilingual children had a higher cognitive flexibility than monolingual children, suggesting that managing multiple languages enhances brain function. Also, in another study, [66] it was pointed out that multilingual persons tend to show a higher degree of performance in solving logic puzzles, along with other cognitive tasks that require the person to think outside of the box and be flexible.

Overall multilingualism not only helps in proficiency in languages but provides much greater cognitive flexibility, better problem-solving ability, and more brilliant expression of emotions those factors that are so important in both individual and professional life in a world with increasingly global intercourse [63], [65].

### *2.1.2 EEG-Based Studies on Stress and Humour*

Research has found that individuals with higher dispositional optimism showed that positive Humour reduces anxiety levels [67]. Electrode position and EEG parameters can be differentiated between tasks and relaxation periods with the θ and α bands being particularly significant [68] and the demonstration can show a negative effect, tension, and psychological reactivity to stress regardless of an individual's use of Humour [69] The best positions for the use of electrodes to distinguish between the performed tasks and arousal levels were F3 and P4 [70]. Lastly, it is found that a sense of Humour can easily moderate the effects of stressful events of depressive symptoms but not anxiety [71].

## 2.2 Applications of EEG in brain-computer interface (BCI) Systems

Designing BCI applications for both healthy and impaired people is now viable because of the accessibility of inexpensive commercially available EEG headsets. Data collection, preprocessing, feature extraction, selection, and classification are all steps in processing EEG signals. The basis of a brain-computer interface system consists of these actions. EEG is the modality that non-invasive BCI devices employ the most. These BCIs fall into one of three categories: spontaneous, evoked, or passive BCIs. Evoked BCIs operate on EEG signals that are produced in reaction to certain environmental stimuli. In [52], the invasive method was used on a human subject for the first time. Signals from the electrodes inserted under the skull are recorded using the electrocorticogram (ECoG), a less invasive method that is less noisy than EEG signals due to the position of their electrodes, although they still need surgery [72].

### *2.2.1 Using EEG for Stress Detection and Reduction*

Comedy clips or emotion detection can be used for stress reduction through EEG because they can elicit different emotional responses that can be measured through EEG signals. EEG signals are frequently employed in stress detection research and are one of the most used techniques for stress and other mental state assessments. However, there is only one study to the best of our knowledge that uses FFT in response to horror video clips and then uses an IQ test to evaluate their stress level [73]. This study proposes a system for stress classification using EEG signals acquired from an Interaxon Muse headband device. The EEG signals were recorded from stress and non-stress subjects while they watched four movie clips, two of which were chosen to induce stress and the other two to induce relaxation. The recorded signals were then used to build the stress classification model, and the classification of stress was achieved with a maximum accuracy of 80.5% using the theta/beta ratio. From these studies, it can be suggested that comedy clips can influence the stress levels of every individual participating in this study [73].

Additionally, there is another recently published study that analyzes EEG recording during and after TSST of 44 healthy men [74]. The study found that during TSST, there was an increase in low-frequency Delta band frequency, while Beta bands, Theta, and Gamma 1 oscillations decreased, particularly in the frontal region. Additionally, the study observed changes in nonlinear features such as approximate entropy, spectral entropy, and Katz fractal dimension. These changes indicated that stress increased low-frequency oscillations and decreased high-frequency oscillations and complexity indices during TSST. However, all changes returned to baseline after TSST except for an increase in Katz in the F3 channel after the recovery period. From this study, it can be implicated that TSST can be used as a stress inducer.

The use of stand-up comedy clips to reduce stress in a diverse population is not just a novel approach to EEG research, it is an essential one. This fact is intended to be used to create a sufficiently large open-source raw EEG dataset, as standup comedy clips are viewed by people of all ages and genders worldwide. The primary objective of this study is to offer a multimodal dataset that modulates both effective stress and emotions. The simultaneous regulation of effective stress and its effects on mental state and artifact generation have not yet been studied in publicly available datasets. The second objective of this research is to build a dataset that replicates real-time brain signal recording with the help of a single channel headset and a realistic task environment (by watching stand-up comedy clips and performing TSST), with the help of BCIs, this task can be accomplished.

## 2.3 Measuring Stress Using Questionnaires

Measuring stress using questionnaires is one of the most widely accepted tools in psychological research [75]. These self-report questionnaires allow for quantifying subjective perceptions about individuals feeling stress, anxiety, and other allied emotional states [76]. An overview of some of the commonly used measures of stress assessments and a comparative study of work using different questionnaires are presented here [77].

### *2.3.1 Overview of Common Stress Assessment Tools*

Various standardized questionnaires exist to measure the stress levels in populations [78]. First, these were validated and then used clinically and in research to assess stress and psychological effects. They ensure data is reliable and consistent, thus deepening health outcomes regarding stress [79]. The main assessment tools include:

- **Perceived Stress Scale (PSS):** The PSS, by Cohen et al., was developed in 1983 to give the ability to measure the perception of a person concerning stress [80]. It captures the degree that persons feel their life is unpredictable, uncontrollable, and overloaded [81]. The PSS has gained wide acceptance since it gives reasonably reliable results across wide populations, even among those with multilingual backgrounds [81].

- **State-Trait Anxiety Inventory (STAI):** The STAI was developed by Spielberger et al. in 1983 to differentiate between state anxiety and trait anxiety. It is especially effective in measuring immediate emotional reactions to situations that may cause stress [82].

- **Depression Anxiety Stress Scales (DASS):** This set of self-questionnaires addresses the emotional states of depression, anxiety, and stress. Its comprehensive nature makes it suitable for measuring the different effects of interventions like multilingual Humour on stress such as the Trier Social Stress Test [83].

### *2.3.2 Comparative Analysis of Questionnaire Studies*

A comparison of various studies carried out with the use of these questionnaires indeed brings many important insights into the efficiency of Humour as a coping mechanism during stress management [84]. For example, research has established that multilingual Humour may drastically lower perceived levels of stress and anxiety, according to PSS and STAI, in contrast with the control groups, which did not experience any Humour treatment [85].

Comparing stress questionnaires across cultures has suggested that the efficiency of these questionnaires might vary between cultural contexts, thus underlining the relevance of culturally sensitive approaches to stress measurement [83]. For instance, the DASS performed differently in multilingual populations, and specific adaptations had to be made for it to be valid and reliable [86].

## 2.4 Measuring Stress Using EEG

Electroencephalography is considered a meaningful way of quantifying stress since the electrical activity it measures in the brain is directly produced by different types of stressors [87]. This tool has a higher degree of accuracy compared with self-report questionnaires, which are prone to subjective elements and biases, for it provides direct measurements of neural responses; hence, this is a very powerful tool in investigating states of stress [88].

### *2.4.1 Advantages of EEG in Stress Measurement*

EEG provides very high temporal resolution and, as such, allows rapid changes in brain activity related to the stress responses to be captured [89]. This is a very important ability when investigating immediate consequences of stress-inducing stimuli, for example, those included in the Trier Social Stress Test [90].

Various patterns of brain waves concerning different frequency bands-for example, delta, theta, alpha, beta-have been considered where studies indicated that EEG is quite effective in recognizing the different states of stress in mental states [91]. While increased theta and alpha activities have already been attributed to high levels of stress, beta activity may reflect general relaxation or active engagement [92].

EEG will present a closer look and completeness of how stress acts on the brain over time, in comparison with generally applied methods like HRV and skin conductance [93]. By tracing changes in brain wave activity, EEG can reveal the processing of the brain behind the stress responses [94].

### *2.4.2 Integrating EEG with Self-Report Measures for Stress Assessment*

Besides understanding stress responses, EEG data is often combined with self-reported levels of stress derived from questionnaires. The two-pronged approach allows researchers to check EEG findings against the subjective experiences of stress and make a well-rounded judgment of stress levels [95].

Previous studies indicate that when EEG is integrated with self-report measures, accuracy in the detection of stress improves compared to relying on either method in isolation.

For example, [91] achieved a 98.76% classification accuracy stress by manipulating EEG signals with self-reported levels of stress.

Further, this integration helps to overcome several of the potential limitations of self-report methods, which are inherently subjective and vulnerable to anchoring biases while also confirming the validity of EEG as a means of quantifying the level of stress. Combining objective physiological measures with subjective ones provides the researcher with a broader perspective on the reactions underlying stress responses [96].

## 2.5 Overview of Social Stress

Social stress refers to a mixture of both psychological and physiological responses whenever a person feels he or she is being evaluated in any given situation. This type of stress is viewed as surfacing ultimately in the forms of anxiety, with a racing heart, and hormonal changes. Grasping social stress may be regarded as of significance because it might lead to severe mental problems, such as anxiety disorders and depression, in addition to general health effects.

### *2.5.1 The Trier Social Stress Test (TSST) Protocol*

The Trier Social Stress Test is a well-known experimental laboratory technique for the induction of moderate psychosocial stress. The method was developed in 1993 by Kirschbaum, Pirke, and Hellhammer. TSST belongs to the basic tools of investigation for the acute stress response in humans, offering a chance to research its physiological, psychological, and behavioral effects [97].

- **Description of TSST**

Research has proved that TSST is a proper induction procedure for HPA and SAM axes activation, with an increase in cortisol and other stress hormones. This has been applied to a very wide field of research investigating different factors modulating stress responses—including gender, genes, and personality—but it can be used more broadly in psychobiological research.

Also, multiple variations of the TSST have been developed, such as group versions of the TSST and virtual reality versions, further expanding the applicability of the paradigm and meeting special research requirements. These modifications, therefore, share the key elements of the original paradigm but increase the number of participants that can be tested at one time and reduce variability in the stress responses by including social interactions.

- **Physiological and Psychological Impact**

It has been demonstrated that the TSST is a reliable activation procedure for both the HPA axis and the SAM axis, giving rise to increased cortisol and other stress hormones. The paradigm has been applied in investigating multiple factors modulating the stress response, variables that range from things like gender, genetics, and personality, thereby underlining the versatility of the tool in psychobiological research.

Finally, several adaptations of the TSST have been made to increase its general applicability and better address specific research needs, including a group version, TSST-G, and virtual reality versions, TSST-VR. These retain the basic elements of the original procedure but allow greater participant throughput and, due to social interactions, reduce variability in stress responses.

## 2.6 Scalp EEG and Signal Processing Techniques

Now since EEG data directly reflects the electrical activity of the brain, stress levels may be classified using this information [98]. Most often, a dense placement of EEG electrodes is necessary for an accurate assessment of stress using EEG [99]. A wearable EEG that is discrete, portable, and may be utilized for extended periods is needed to monitor stress in the activities of everyday life. Clinically dense EEG systems with 32, 64, or 128 channels do not meet these criteria. However, it has been demonstrated that a single-channel EEG headset can also be used to detect stress satisfactorily [100].

Numerous free and paid resources are available to support the advancement of BCI. Every platform offers benefits of its own based on what is needed for an experiment. A wide range of tools for BCI development is available either for free or for purchase. Every platform offers benefits of its own based on what is needed for an experiment. Online processing on DataSuite, FieldTrip, BCI2000, or OpenViBE systems uses the BCILAB toolkit [101]. To do this, it might be thought of as an EEGLAB plug-in extension. A toolset called BioSig is built on MATLAB/Octave [102]. Table 4 gives a list of BCI headsets that are marketed and easily accessible.

**Table 4: Specifications of commercially available BCI headsets**

| Headset Companies | Sampling Rate (samples/sec) | No. of Channels | Data Transfer Mode | Operating Time (hours) |
|---|---|---|---|---|
| Freedom 24D | 300 | 20 | Bluetooth | 12 |
| EMOTIV (Insight) | 128 | 5 | Wireless | 4 |
| quasar DSI | 240 or 960 | 12 | Wireless | 24 |
| COGNIONICS | 1000 | 20 | Bluetooth | 8 |
| EMOTIV (Epoc+) | 128 or 256 2048 (internal) | 14 | Wireless | 12 |

Commercial BCI headset systems based on EEG are on the market. Many businesses have produced their headset systems, including PLX Devices, Neurosky, Myn- dPlay, IMEC, g.tec, Emotiv, OCZ Technology, and Congnionics. These businesses provide a variety of tools and apps in addition to these headset systems.

## 2.7 Identification of Research Gaps

While the stress effect on brain activity is relatively well documented, the interaction between these established techniques—the Trier Social Stress Test, EEG, and various forms of stress reduction, among them humor—is virtually unexplored. These areas have been studied in isolation from one another: that of TSST-induced stress responses, and that of the effects of Humour on mood and brain function. In the current review, effects have generally been considered in isolation, either in terms of stress induction or the potential benefits of humor.

Notably, no research has combined stress induction with subsequent reduction through Humour to study their joint effect on brain activity. More specifically, no study has been conducted so far to examine whether the stress caused by the TSST can indeed be effectively attenuated by exposure to comedy, as indexed by changes in EEG power across different frequency bands to the best of our knowledge.

This important gap will be filled by the current study, which aims to investigate the neural mechanisms of both the induction and reduction of stress using EEG. In this study, the TSST was combined with a design in which participants were exposed to comedy videos in two languages (native vs. non-native), providing a new window into how Humour might exert modulatory effects on the brain's response to acute stress. These findings may enhance our understanding of stress control techniques and support the development of EEG-based interventions for stress alleviation.

# CHAPTER 3: METHODOLOGY

This chapter describes the research methodology of the thesis in detail. The tools and techniques used to implement the research are described below.

## 3.1 Overview

This study employed a systematic approach to analyze EEG data to explore the effects of multilingual Humour on stress reduction. The proposed methodology consists of the following main modules:

- Data Exploration
- EEG Data Collection and Acquisition
- Signal Pre-processing
- Feature Extraction
- Statistical Analysis

The EEG data was sourced from participants exposed to the Trier Social Stress Test (TSST) and subsequent Humour intervention, processed to minimize noise and artifacts, and analysed to extract meaningful spectral features. Statistical tests were then applied to determine the effects of Humour on stress indicators in EEG signals.

While previous studies have explored the effects of the TSST on brain activity using EEG and the potential of Humour to modulate brain function, no study has combined these elements to examine the neural mechanisms underlying stress induction and reduction using comedy videos. This research aims to fill this gap by investigating whether comedy videos can effectively reduce stress induced by the TSST as measured by changes in EEG activity.

## 3.2 Data Exploration

This study processes data which mainly falls into time-series EEG signals obtained from each subject. Numerical is the main data type used in the dataset, and its mainly integer data with a floating data type. In this dataset, discrete values are represented by using an integer datatype while continuous variables are represented by using floats, especially in the measurements of EEG signals for precision. The following section lists specific Python packages and modules used in processing and analysing these data types.

## 3.3 Python Libraries

Python is a prevalent programming language, particularly in data science. Numerous libraries are open to the public. In addition, it is being developed and maintained by a larger community. Therefore, if anyone encounters a problem, there is a greater chance of finding a solution [103, 104]. Multiple libraries have been employed in this study to analyse and predict client behavior based on purchases. Libraries with their applications are mentioned below in Table 5.

**Table 5: Detail of python libraries that are used in this project and mentioning the purpose of utilizing the packages**

| Library | Usage |
|---|---|
| Numpy | Facilitates efficient operations on multi-dimensional arrays. |
| Pandas | Essential for data analysis tasks such as importing, cleaning, and integrating datasets. |
| Seaborn | Enhances data visualization with visually appealing graphs. |
| Matplotlib | Core tool for plotting and data visualization. |
| Plotly | Offers extensive customization and interactivity for data visualization. |

## 3.4 EEG Data Collection and Acquisition

### *3.4.1 Participants Details*

The case study recruited a total of 40 healthy volunteers of which 20 were male and 20 were female aged between 18-25 years. All the subjects were students in a public sector higher education institute enrolled in different programs. They were all healthy individuals and had no known mental health conditions. A written consent was signed by all the individuals to participate in the case study. To minimize any biases, the participants were equally divided between male and female, and there were an equal number of people who watched native-language comedy videos and native-language comedy videos.

- **Participant Demographics**

The demographic composition of samples is thus relatively homogenous and balanced, and hence results are generalizable. The participants came from a wide range of academic disciplines, including sciences, engineering, humanities, and social sciences, helping to illustrate diverse sources of stress responses across groups. This is essential for examining differences in stress levels and Humour perception across different academic environments.

### *3.4.2 Selection of Video Stimuli*

Stand-up comedy videos were used in both native (Urdu) and non-native (English) languages as an external stimulus for estimating whether stress can be reduced after inducing it, based on EEG signals. Both video clips were selected on the same topic, "Parents," using YouTube ratings from their respective countries to minimize potential biases. For the English experiment, we used a popular comedy clip of Jimmy O Yang, who is regarded as one of the most important and influential stand-up comedians of all time in America, and for the Urdu experiment, we used a comedy clip of Zakir Khan, who is known professionally as one of the most acknowledged comedians. A clip of one minute from each video track was utilized as a stimulant to avoid boredom during the experiment.

### *3.4.3 Procedure of TSST*

The standard TSST procedure comprises two key phases: an anticipation phase followed by a test phase. Participants are briefed on the impending stress during the anticipation phase, which increases anxiety. Note that this is followed by a test phase in which participants are requested to make a mock job interview and conduct mental arithmetic tasks in front of an audience, often consisting of evaluators who do not give any feedback. Normally, the combination of social evaluation with cognitive challenge would yield a robust stress response, marked by clearly increasing cortisol, heart rate, and other physiological markers of stress as a result.

### *3.4.4 EEG Data Recording and Signal Classification*

The procedures for recording the EEG data and various methods of signal classification are discussed below.

- **Classification of EEG Frequency Bands**

  The most common way of describing scalp EEG involves five frequency bands: alpha, beta, gamma, delta, and theta. Each frequency band corresponds to appropriate brain states at distinct moments in time [106]. These frequency rhythms are described in more detail in Table 6 below.

**Table 6: Frequency bands in the EEG signal [107]**

| Band | Frequency |
|---|---|
| Gamma | 30 - 100 Hz |
| Beta | 12 - 30 Hz |
| Alpha | 8 - 12 Hz |
| Theta | 4 - 7 Hz |
| Delta | 0.1 - 3 Hz |

Figure 1 illustrates the appearance of each frequency band in an EEG recording.

Gamma and beta waves are characterized by closely spaced, concentrated oscillations indicative of high mental activity. Alpha waves are slower, suggesting a relaxed state of mind. Theta waves reflect a dreamy or meditative mental activity, while delta waves are the slowest and are associated with sleep cycles [106].

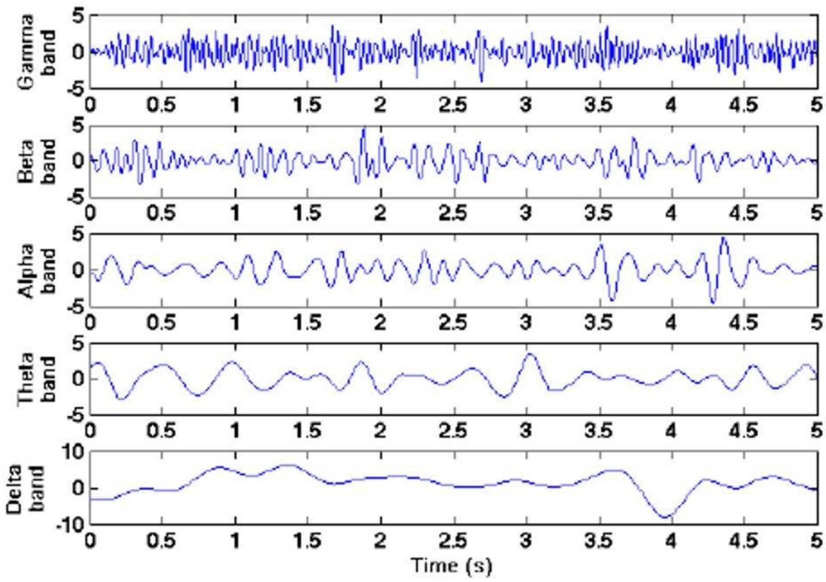


**Figure 1: Brain Waves classification [107]**

- **Apparatus: Neurosky MindWave Mobile 2 Headset**

The dataset was gathered using a single-channel device for our research on this stimulus. Before starting the experiment, the participants wore the single-channel Neurosky Mindwave Mobile 2 headset. The sensor was positioned on the $Fp1$ location by the 10-20 international EEG placement system, while the reference electrode was affixed perpendicular to the earlobe [105]. The system has made use of dry electrode technology from the Thinkgear application-specific integrated circuit module (TGAM). It has a 3-100 Hz bandwidth and operates at a minimum voltage of 2.7V. The silver TGAM electrodes are appropriate for non-hairy regions. The wearable headset is geared up to record discrete EEG data at a sampling rate of up to 512 Hz. It has a simple algorithm and the ability to capture raw EEG.

**Figure 2: Neurosky Mindwave Mobile 2 headset**

### *3.1.2 Experimental Design*

First, all the subjects were asked to come one by one into the lab, where after they wore the EEG single-channel device, they were asked to fill out the Depression Anxiety Stress Scale (DASS)-21 item questionnaire [108] and then sit in a relaxed position, close their eyes for 1 minute, and then open their eye and blink normally for 1 minute while the EEG is captured.

The single-channel EEG device was used to capture the recordings throughout the experiment. EEG was recorded before, after, and during TSST. All the schematic steps of the study are represented in Figure 3. There are three parts of TSST. To begin with, the subjects were asked to think of a topic randomly assigned to them in under 1 minute, then they had to give a speech on that topic in front of two examiners with serious expressions. Finally, they were asked to solve a mental mathematics problem in which they had to subtract 13 from 1022 continuously until they reached zero in 1 minute. When they were giving the speech, they were asked by the examiners to keep on talking and they told them how much time was still left, while they were doing the mental mathematics problem, if they got stuck in between or answered incorrectly the examiners just told them to start again. The Depression Anxiety

Stress Scale (DASS)-21 item questionnaire [108] was used before, during, and after TSST to determine the subjects' emotional state.

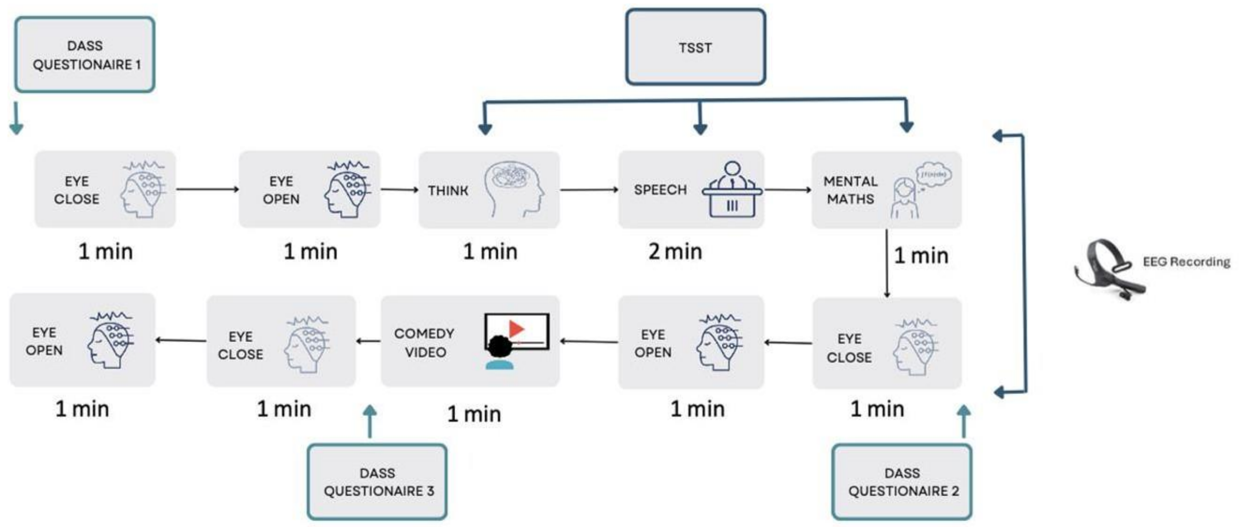


**Figure 3: Experimental procedure**

Each participant received a thorough explanation of the experiment before beginning, but to minimize the risk of bias, participants were asked not to disclose the procedure to others.

### *3.1.3 Depression Anxiety Stress Scale (DASS) Questionnaire*

The DASS questionnaire was used to record stress, anxiety, and depression levels along with each baseline. First, it was taken at the start of the experiment and then everyone filled out their questionnaire after the TSST experiment at the end after watching the comedy video the questionnaire was again filled out to check whether their answers to self-report measures had changed from the previous ones.

The scale for each level of depression, anxiety, and stress were mentioned in the questionnaire. Symptoms are scored from least to most severe as follows: The scores for the Depression scale range from a normal of 0-9, and a score of 10-13 indicates mild depression. Scores ranging from 14-20 reflect moderate depression. Scores ranging from 21-27 indicate severe depression. A score of 28 and above is ranked as extremely severe depression. The scores on the Anxiety scale range from 0 to 7, 8 to 9 for mild anxiety, 10 to 14 for moderate anxiety, 15 to 19 for severe anxiety, and 20 and above for extremely severe anxiety. Finally, the Stress scale scores have a normal range from 0 to 14, 15-18 for mild stress, 19-25 for moderate, 26-33 for severe, and scores above 34 indicate extremely severe stress.

An example of this can be if some have got above 20 for stress, more than 28 score for depression, and above 15 for anxiety as their score so it means they are under extreme stress, depression, and anxiety. The questions had already been pre-assigned to all the measures, so the respective questions with the score scale just had to be checked to match and find out their levels. After scoring, the sum for each of the three scales (Depression, Anxiety, Stress) is multiplied by 2 to make the results comparable with the full DASS, which has 42 items.

### *3.1.4 Structure and Components of the DASS-21*

The shorter alternative version of the DASS questionnaire contains 21 items in total, with seven items per emotional state. This version is designed for easy scoring but is still able to give valuable insight into the amount of psychological distress a person has experienced. In DASS-21, the scoring requires a simple computation of adding the scores of the relevant items, multiplied by two, to arrive at the equivalent scores of DASS-42.

Respondents indicate how much each symptom has applied to them over the past week on a four-point Likert scale (0 = ‘Did not apply to me at all’ to 3 = ‘Applied to me very much or most of the time’ as shown in table 7.

**Table 7: Scoring Scale of DASS-21**

| **Score** | **Severity** | **Description** |
|---|---|---|
| 0 | Did not apply to me at all | Never |
| 1 | Applied to me to some degree, or some of the time | Occasionally |
| 2 | Applied to me to a considerable degree, or a good part of the time | Often |
| 3 | Applied to me very much, or most of the time | Almost Always |

## 3.2 Signal Pre-Processing

The signal processing techniques used in our work are given below:

### *3.2.1 Noise Filtering and Artifact Removal*

The SciPy package is used as a filter to remove muscular and ocular artifacts. These were low pass, median pass, and high pass filters. Savitzky-Golay and wavelet denoising filters were used for smoothing and denoising. Firstly, Python code was used to convert the raw data into filtered data, removing the background noise. These data were further strained using high and low pass filters.

Butterworth filters were used. This is because Butterworth is used for a flat bandpass frequency response. Figure 4 depicts the first participant's one-minute EEG signals of the first activity. The effectiveness of Independent Component Analysis (ICA) in mitigating ocular artifacts in single-channel devices lacks substantial research support. As a result, the Savitzky-Golay filter [109] was utilized to address noise artifacts.

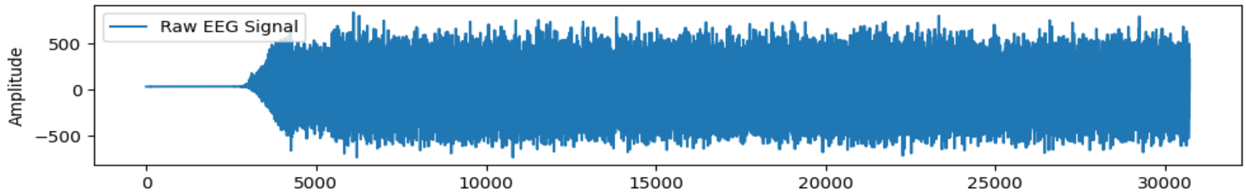


**Figure 4: Raw EEG data of subject 01**

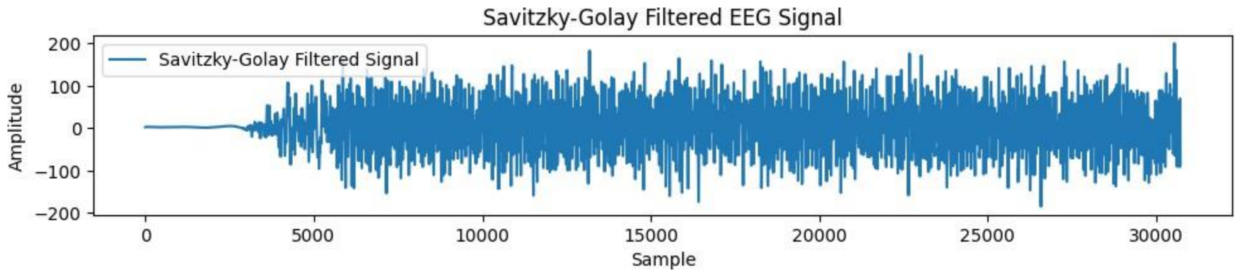


**Figure 5: Filtered EEG data of subject 01**

Figures 4 and 5 display the raw EEG signals, followed by the effects of applying the bandpass filter and the Savitzky-Golay filter, highlighting the selected settings for optimal noise reduction and artifact removal.

Everyone had 10 EEG readings each, and all 40 subjects' EEG data from all trials underwent individual signal processing steps to enhance the quality of EEG data and minimize the impact of noise and artifacts on the results. The preprocessing pipeline consisted of procedures designed to ensure the high quality and reliability of the data. DC offset removal had been initially performed to center the signal around zero. The preprocessing comprised filtering of the signals in the 0.3-48.0 Hz band, observation of the graphical visual representation of individual signals, and the removal of artifacts by application of a bandpass—highcut and lowcut— filter used for removal of the high-frequency noise and slow drifts in the signal and the Savitzky-Golay filter. The relative power extraction (each band power to the sum of total power bands) was done using linear analysis using Welch's method.

## 3.3 Data Analysis Techniques

Data analysis techniques are considered some of the most important techniques to transform raw data into meaningful insights, especially in studies involving physiological measurements such as EEG [110]. This study utilizes multiple techniques of data analysis for interpreting recorded EEG during stress induction followed by induced humor. These statistical methods, used in concert and complemented by frequency domain analyses, may provide even greater insight into neural processes involved in stress responses and the beneficial effects of Humour [111].

### *3.3.1 Feature Extraction Methodologies*

The features extracted from the EEG data were conducted through the frequency domain. While this domain provides valuable insights into neural networks and contributes to overall analysis, there is no universally standardized set of features in literature for this domain as feature selection is specific to the respective experiment setup and its objectives. The details of which are given below:

### *3.3.2 Analysis of Frequency Domain Features*

The FAST Time Fourier (FFT) was used to convert from time to the frequency domain and extract features from the frequency domain. Features are extracted from the frequency domain, in this way that it breaks down the signals in its frequencies which will help the researchers to analyze the power and distribution of these frequencies over time. Studying the frequency domain offers insights into the oscillatory activity and rhythmic patterns of brain waves which are related to various cognitive and physiological states. Understanding how different frequency components influence overall brain function and how specific frequency bands relate to processes and behaviors is crucial.

- **Power Spectral Density (PSD)**

Power Spectral Density is an invaluable tool in analytical EEG work as it approximates how the power of an EEG signal is divided between frequency components and can give insight into many different aspects of brain activity across the broad spectrum of its frequency bands.

PSD measures the power at each frequency of a continuum signal, which makes it of much importance in the study of neural oscillations such as delta, theta, alpha, beta, and gamma waves. In this work, Welch's Method was used to estimate the power spectral density (PSD) of the EEG signals, to analyze EEG data effectively. This approach gives a smooth estimate of the power spectrum and enables us to see how the power is distributed with respect to frequency. Following this, relative PSDs were obtained by normalizing each PSD to the total sum of all PSDs.

- **Band Power Extraction**

Band power is obtained by summing PSD values over specific frequency bands. The frequency spectrum was divided into delta (0–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (12–30 Hz), and gamma (30–45 Hz) bands. Band power would represent the total energy or power contained in a band. It is possible to estimate neural oscillations that underpin cognitive and emotional states based on this measure. In simpler terms, it takes the information carried by the PSD and integrates it over predefined frequency bands. That way, it provides a more detailed view about the activity of brain waves in those ranges. This step is very important for figuring out what kind of effect different states of cognition or emotion have on brain activity mostly because it allows the tracking of the time evolution of the power of specific frequency bands.

### 3.4 Statistical Analysis

For EEG data analysis, randomization tests are well-suited, as they do not require any assumptions about data distribution, making them beneficial in biomedical fields with typically small sample sizes. Additionally, these tests also offer flexibility, as they are not limited to any specific test statistic (e.g., F-statistic, t-statistic, or z-score) [112].

Comprehensive statistical analysis was performed to evaluate the effects of Humour on EEG Signals, using Python (version 3.11) within a Jupyter Notebook environment. This analysis was conducted to evaluate the distribution of data and the significance of changes in EEG features under different conditions according to given objectives.

### *3.4.1 Descriptive Statistics of EEG Power Bands*

A summary of each EEG power band across different conditions was provided. The frequency spectrum was divided into EEG power bands. Following this, relative PSDs were obtained by normalizing each PSD to the total sum of all PSDs. The meaning of each power band was calculated to understand the EEG data's central tendency under different conditions. This allows us to estimate the average power level of each frequency band for each participant during different stages of the experiment, as stress is induced and then reduced.

### *3.4.2 Data Normalization Techniques*

Data normalization is one of the most critical steps in the analysis due to which, it can be crucial to check the normality of the data distributed before moving forward with the next steps in the analysis. This step involved normalizing by the Z-score method, to keep all extracted EEG features on the same scale for different subjects. Thus, the mean was subtracted for each feature, and the result was divided by the standard deviation. This was for standardization, to have the same scale and comparability among the datasets from all subjects. This step allowed for consistent scaling and comparability of the EEG features across the study’s 40 participants.

### *3.4.3 Testing for Normality*

Normality Testing was conducted using Q-Q plots (Quantile-Quantile Plots) comparing the distributed EEG power bands to the theoretical normal distribution. The corresponding Q-Q plots for each power band were used to evaluate how closely the data conformed to a normal distribution.  Two approaches were employed:

- **Histograms**

The histograms of each EEG feature were plotted to see the data distribution. This gave an initial intuitive look at whether the data resembled a Gaussian distribution as presented with a bell-shaped curve. Histograms of each EEG features were first plotted for visual inspection of the distribution of the data. This provided a basic overview of the data, approximating a normal distribution shown by a bell-shaped curve.

- **Quantile-Quantile (Q-Q) Plots**

Q-Q plots were additionally employed to test for normality by visually comparing relative quantiles of data from EEG to those expected under the null distribution. Plotting against the reference line for deviations between the Q-Q plots indicated that there was no fit for the data to a normal distribution, mainly with the higher quantiles. Normality was further confirmed through Q-Q plots. These show how the quantiles of the observed EEG data compare to the ideal normal distribution. If major scale shifts in the plot tangent to the guideline had occurred, it would mean the data would not normally be distributed.

- **Wilcoxon Signed-Rank Test**

As the EEG data is not normally distributed, as indicated by the normality test, the Wilcoxon Signed-Rank test was used to evaluate the differences between 'pre', 'inter', and 'post', TSST, and Humour exposure conditions. This test is non-parametric and is conducted between two related samples, similarly matched samples or if some measurements are repeated on a single sample to evaluate whether their population mean will rank differently than before. When assumptions of the paired T-test such as normality are not fulfilled this test is used. The test was conducted as follows:

- **Significance Testing and Evaluation of Statistical Significance**

The differences between paired EEG scores and as well as their DASS scores for all 'pre', 'inter', and 'post' conditions were computed for each subject equally. The test statistic was then compared against a critical value from the Wilcoxon Signed-Rank table to determine if the observed differences were statistically significant. The test statistics were compared with the critical values in the Wilcoxon Signed-Rank table to assess whether any statistically significant differences existed in the EEG features between 'pre', 'inter', and 'post' TSST and Humour conditions. A significance level of

$p < 0.05$ was used to establish the results, in which the obtained values will be checked for significance.

# CHAPTER 4: RESULTS AND DISCUSSION

## 4.1 Behavioural Data and Stress Level Outcomes

It proposes a statistical analysis of stress induction and reduction using EEG signals due to TSST and comedy clips. The experimental results are provided by: (i) the statistical analysis of human stress responses to comedy clips in different languages, and (ii) the assessment of statistical significance.

## 4.2 Statistical Inferences from EEG Data

The participants were analyzed based on the DASS-21 score and assigned to either a stressed or non-stressed group. Participants with a DASS-21 score above the group average were classified as stressed, while the others were categorized as unstressed.

### *4.2.1 Analysis of Q-Q Plots and Histogram*

The Q-Q plots are graphical assessment tools that can help one determine whether this data confirms a specified distribution, usually normal. These plots test the normality of the distribution of the EEG data. The testing of normality is crucial because it forms the basis for appropriate statistical tests to be selected in comparing the patterns in the EEG before and after exposure to comedy videos and between participants exposed to both native and non-native comedy videos. Q-Q plots help verify the feasibility of applying parametric tests, like t-tests or finding out whether non-parametric alternatives should be used instead [113]. In this study, Q-Q plots and histograms for all conditions of the EEG data were developed to test the normalized distribution of the features extracted.

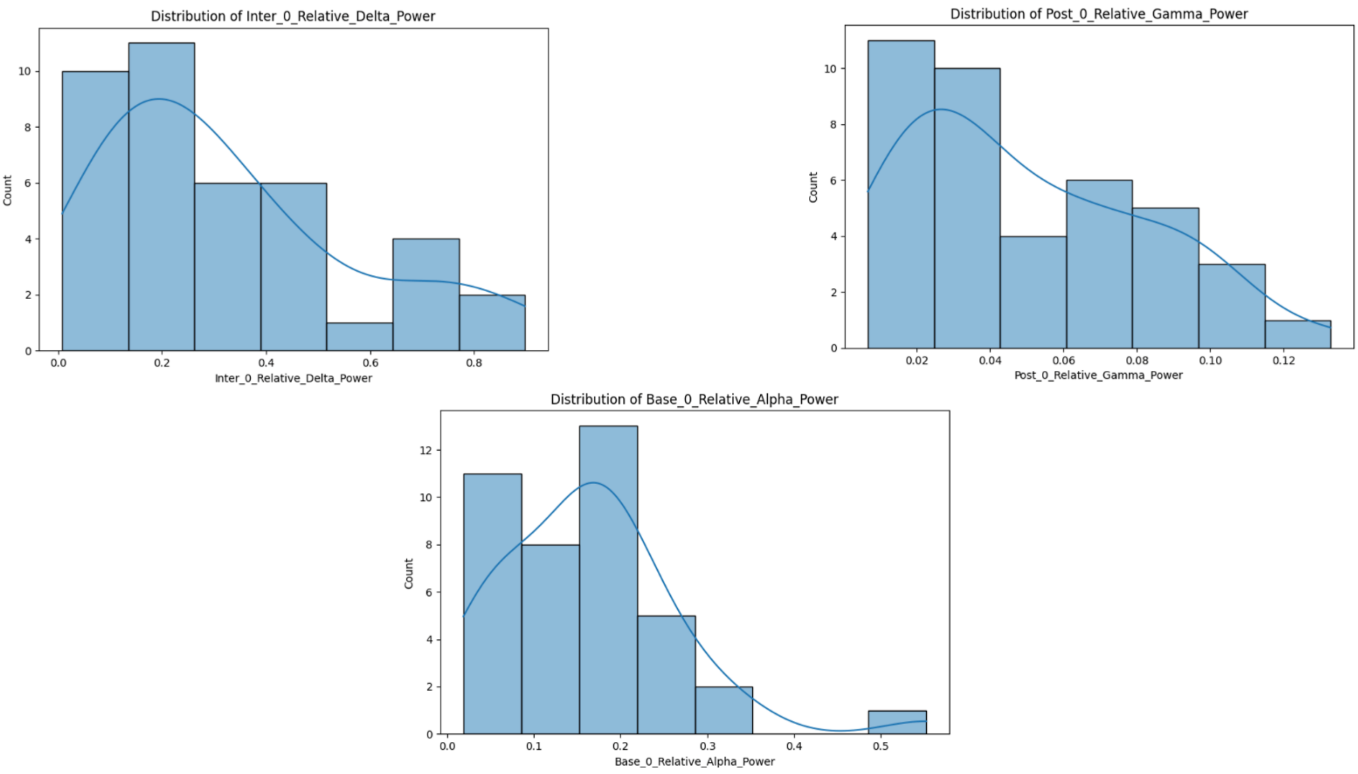


**Figure 6: Q-Q plots from EEG recording data**

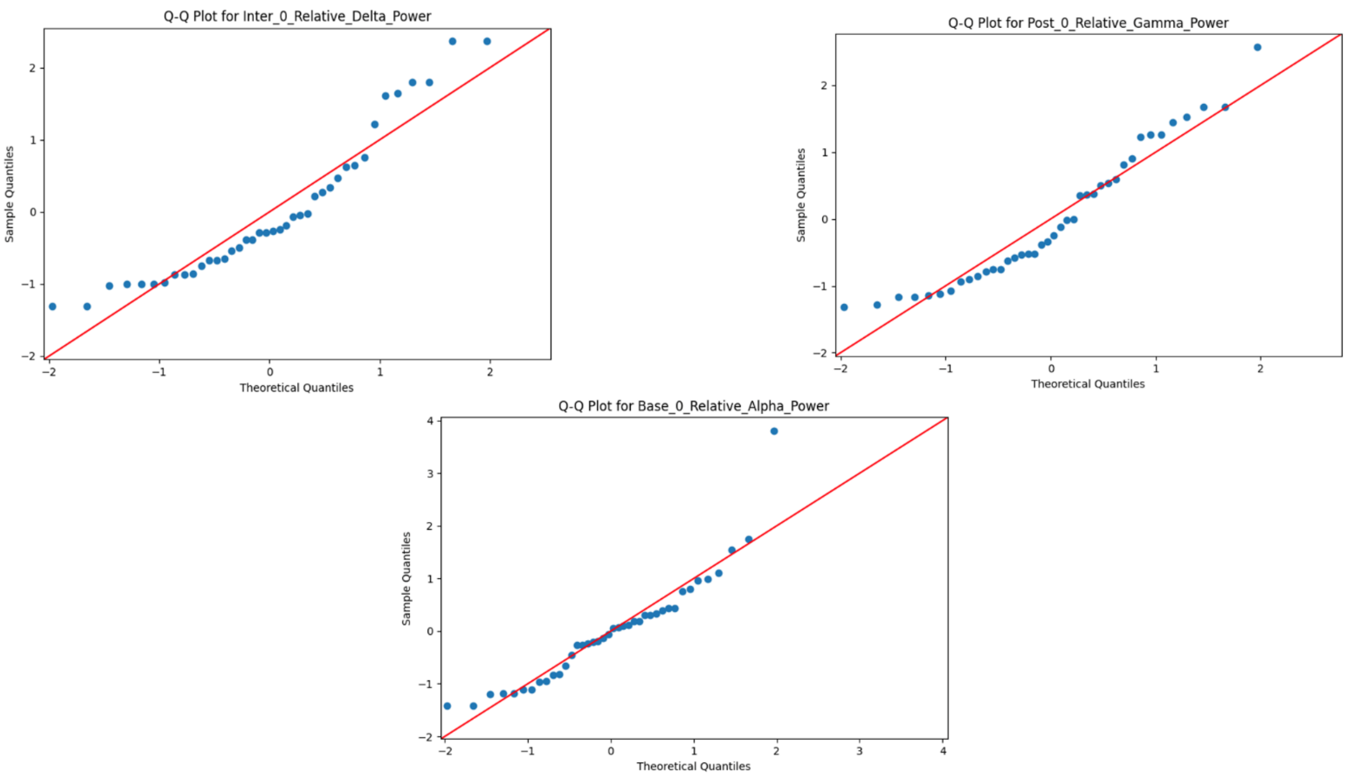


**Figure 7: Histogram from EEG recording data**

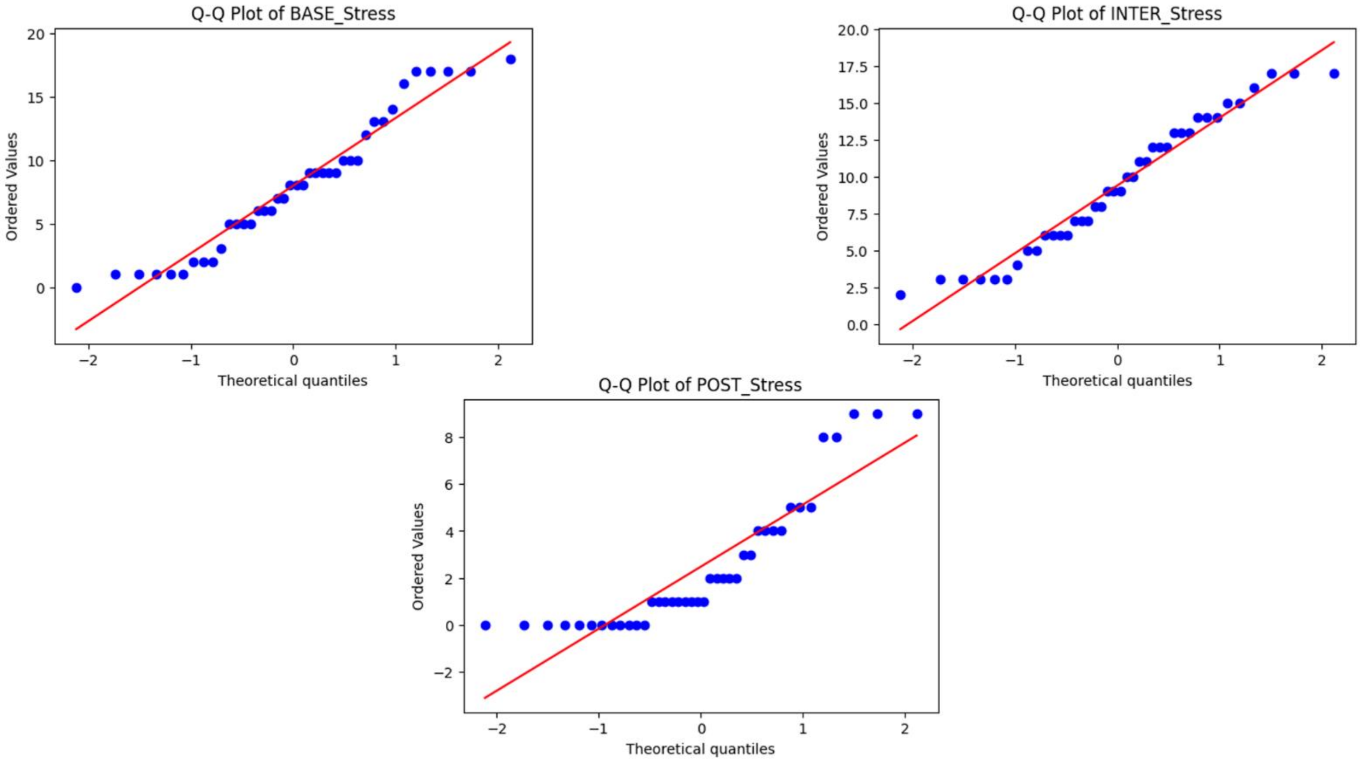


**Figure 8: Q-Q plots from DASS questionnaire data**

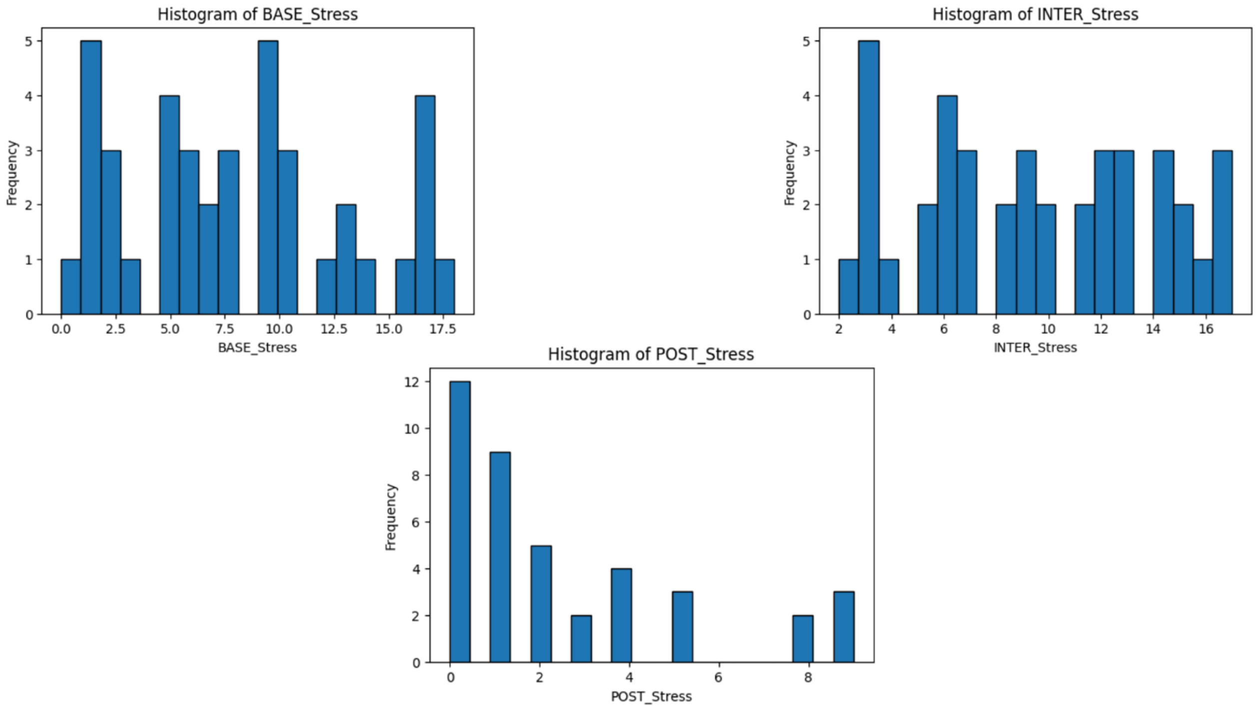

**Figure 9: Histograms from DASS questionnaire data**

As given in Figures 6,7,8, and 9, it can be observed that most points data do not follow a normal distribution in the higher quantiles of the distribution in both Q-Q plots and histograms. This was a consistent finding across multiple frequency bands, which led to the use of non-parametric statistical tests for further detailed examination for both data from EEG recording (Figures 6 and 7) and data collected through the DASS questionnaire (Figures 8 and 9).

### *4.2.2 Comparison of Mean Differences Across Power Bands*

The mean differences across power bands likely reflect the average EEG power differences between experimental conditions. This analysis would allow the investigation of changes in the EEG patterns, specifically in frequency bands, before and after the exposure to comic videos. In comparing mean differences of power across the delta, theta, alpha, beta, and gamma bands, the frequencies of brain waves that are most affected by inducing stress and experiencing Humour could be determined. This data is necessary to explore the brain wave activity that indicates states of stress [114].

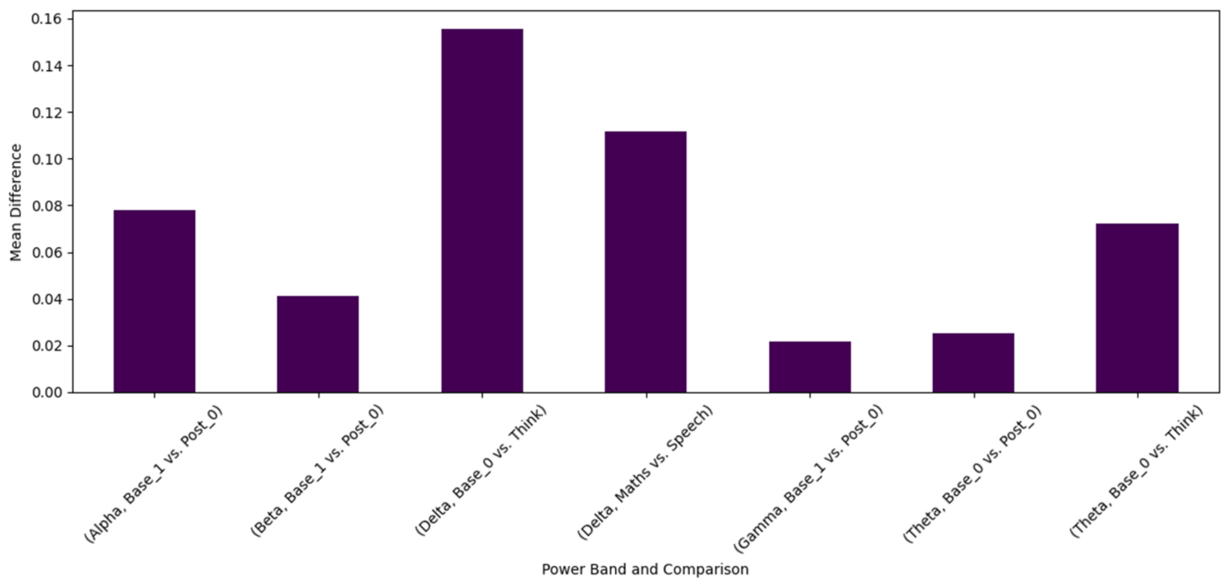


**Figure 10: Mean Difference for Native Language Video Exposure**

Figure 10 illustrates the mean differences in EEG power across various frequency bands (Delta, Theta, Alpha, Beta, and Gamma) for participants exposed to humor in their native language (Urdu). The figure shows changes in the power of these brainwave bands before and after exposure to the Trier Social Stress Test (TSST) and native-language comedy clips. An increase in Delta and Theta power indicates cognitive processing and relaxation post-humor exposure, while changes in Alpha power suggest a relaxation-related response. These observations highlight the brain's neural response to stress reduction through humor in a familiar language.

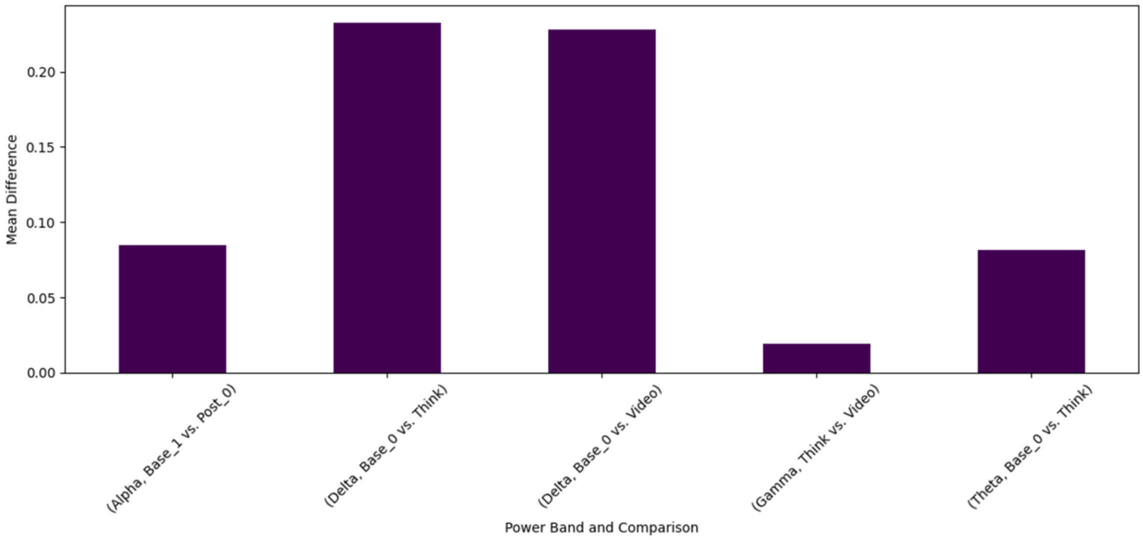


**Figure 11: Mean Difference for Non-Native Language Video Exposure**

Figure 11 presents the mean differences in EEG power for participants exposed to humor in a non-native language (English). The figure compares the ‘pre’ and ‘post’ exposure power changes across the Delta, Theta, Alpha, Beta, and Gamma frequency bands. Similar to the native language exposure, increases in Delta and Theta power suggest cognitive processing and stress relief following humor exposure, although the changes in Alpha power are more modest. This figure underscores the brain's relaxation response to humor in a non-native language, although the effect is slightly less pronounced compared to the native language group.

### *4.2.3 Heatmap of p-values*

A heatmap was plotted to visualize the difference in statistical significance of EEG power in different frequency bands between conditions. They represent the statistical significance of the changes in the EEG pattern. Plotting heatmap of p-values can provide information instantly about which regions and frequency bands exhibit significant changes following the induction of stress and exposure to humor. This would help in determining the relative effectiveness of native and non-native comedy videos in reducing stress, and the neural correlates of the processing of stress and Humour [115]. The heatmap supported the prominent significant p-values at all power bands in contrasts that included 'pre', and 'inter' versus 'post' Humour ($p < 0.05$). This underscores the statistical significance of humor's effects on these EEG features, supporting the hypothesis that Humour can modulate brain activity related to stress and relaxation.

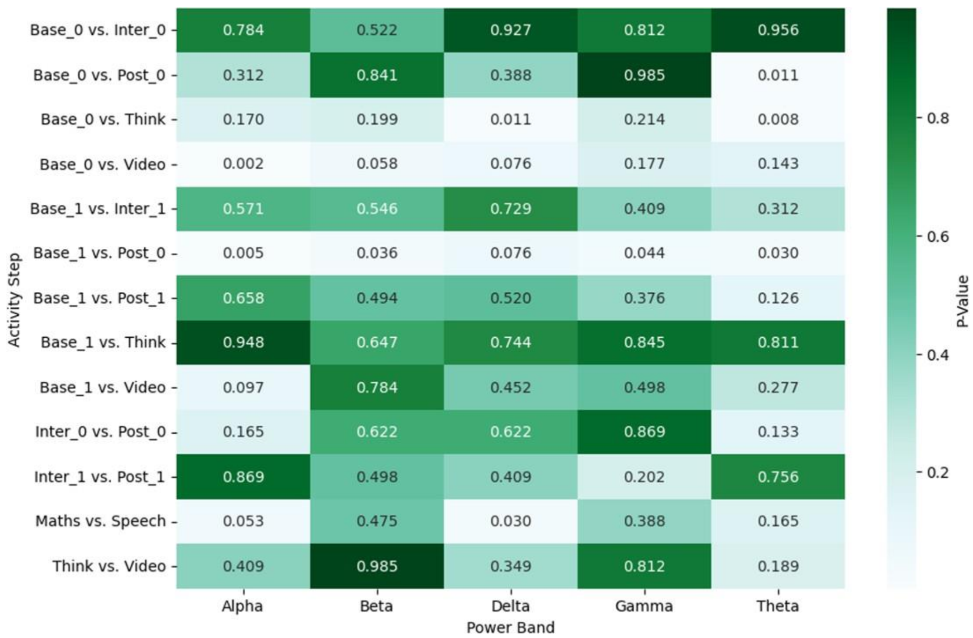


**Figure 12: Heatmap for EEG Power Bands Across Native Language**

Figure 12 reveals a less significant change in the Delta power band which suggests that the effect of Native comedy video on the Delta band is weaker compared to non-native participants. This suggests that the native subjects did not have a more relaxed effect from the comedy video. Theta power also shows moderate changes which indicates relaxation post-comedy exposure.


**Figure 13: Heatmap for EEG Power Bands Across Non-Native Language**

Figures 13 highlights the statistically significant reduction in the Delta band which indicates a strong relaxation effect from the non-native comedy videos. This shows the role of Delta waves in the relaxation process as it remains consistent with the observed drop in stress levels in non-native subjects after exposure to comedy.

### *4.2.4 Line Graph Representations of Average Stress Levels*

Line graphs demonstrate the change in the level of stress over time, such as before and during the TSST and exposure to humor. This makes it easier to track the real-time dataset of EEG signals, and how comedy videos provide stress relief. These line graphs will allow a comparison of the levels of stress between participants who were exposed to both native and non-native comedy videos. This graph most likely presents a comparison of the average stress levels directly between conditions of ‘pre’, ‘inter’, and ‘post’ TSST and Humour exposure. Here, the average scores for the ‘pre’, ‘inter’, and ‘post’ TSST and Humour conditions are plotted as a line graph taken from the DASS-21 questionnaire.

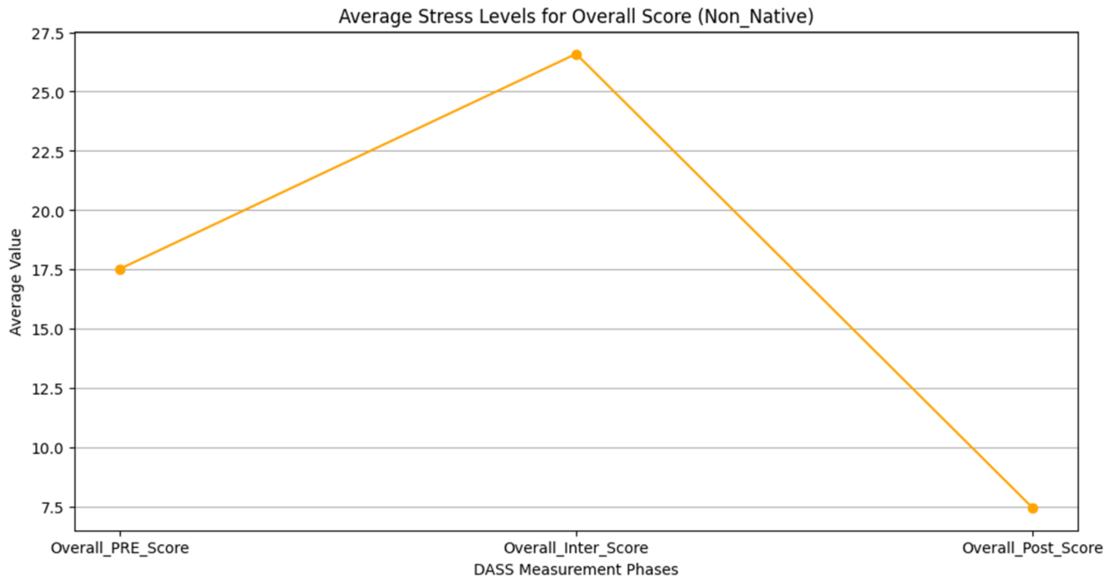


**Figure 14: Average Stress Levels for Overall Score Across Non-Native Language**

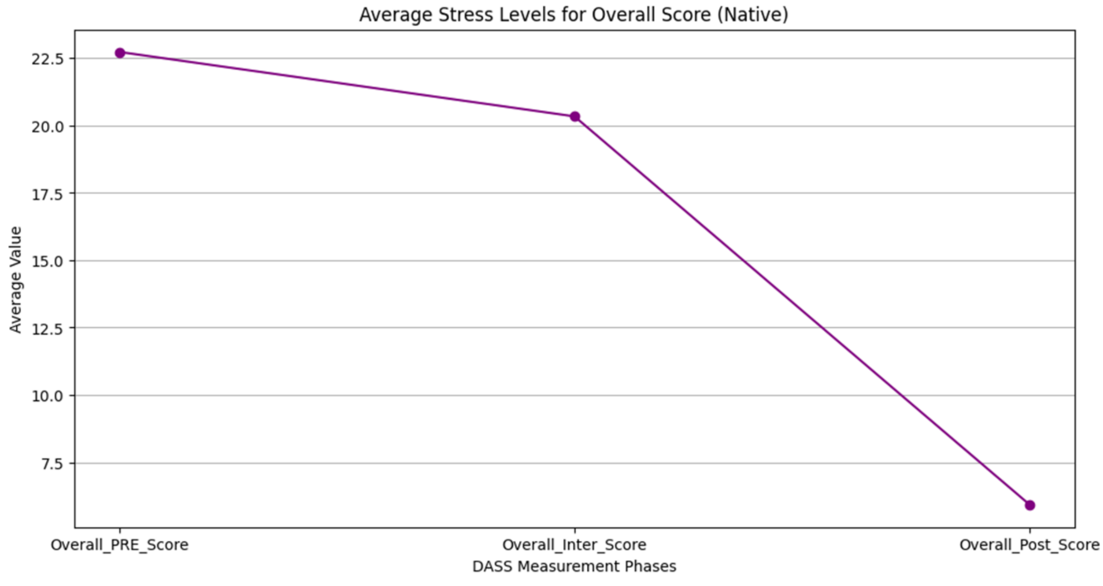


**Figure 15: Average Stress Levels for Overall Score Across Native Language**

Figures 12 and 13 show the average of the overall score of stress, anxiety, and depression of all subjects participating in the experiment. The most significant changes were noted in the non-native language as stress was first induced due to TSST and then it has been reduced due to comedy videos, while for the native language, stress couldn't be properly induced but it did reduce after watching the stand-up comedy. This finding indicates that there should be a more cognitive process running or another relaxation process that is affecting humor.

#### *4.2.5 EEG Relative Power Band Analysis: Pre, Intermediate, and Post-TSST and Humour Exposure*

Boxplots give a quick and compact representation of the distribution of EEG relative power across different frequency bands at various time points of the experiment ('pre', 'inter', and 'post' TSST and Humour exposure). Such plots will help in comparing changes in EEG patterns and in identifying brain waves associated with the levels of stress. The differential effect of Humour on the reduction of stress could also be assessed by comparing boxplots for the native and non-native comedy video groups [114]. Figures 16,17,18 and 19 below illustrate the relative power in the various EEG frequency bands (Alpha, Beta, Gamma, Delta, Theta) for non-native and native language speakers in three conditions, 'pre', 'inter', and 'post' TSST and Humour intervention along with the baselines of EEG recording during eyes kept opened and eyes kept closed.

- **Stress Induction: TSST**

  The 'pre' are the baseline EEG recordings before taking the TSST and give the reference for the neural of each participant. In the 'Inter' condition, the expected changes across all power bands occur as anticipated due to the TSST. Specifically, power in the Delta and Theta bands increases significantly during the TSST. This is typically consistent with stress-related neural activity, as low-frequency bands tend to dominate under stress.

- **Stress Reduction by Exposure to Humor**

After the presentation of TSST, the participants were exposed to Humour stimuli characterized as stand-up comedy clips. Participants were divided into two groups: one that was exposed to the Humour in their native language and the second one to which the Humour was presented in a non-native language.

- **Non-native language exposure**

The power for non-native speakers shows a slight decrease in the Delta and Theta bands after Humour exposure, specifically during the ‘post’ condition. However, the reductions are less accentuated when compared with the ones from native speakers, which still indicates a drop in the level of stress, though probably not as effectively as achieved through non-native humor.

- **Native language exposure**

In the contrast group, on the other hand, the exposure to elicited Humour in the native language exposure was associated with a relatively much higher ‘post’ exposure decrement in Delta and Theta power band dependence. That is, Humour in their native language is delivered more effectively to be able to reduce stress levels, which is further supported by these stress-associated EEG bands' substantial decrement.

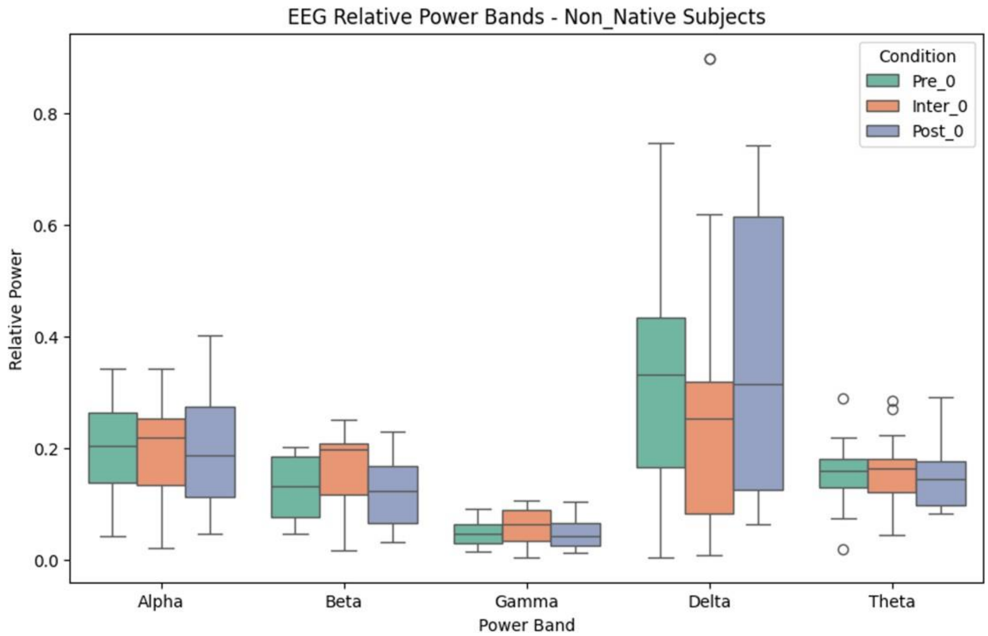


**Figure 16: EEG Relative Power Bands Across Non-Native Language with eyes close baseline**

In Figure 16, Delta power is relatively low at ‘Pre_0’, reflecting a relaxed baseline with eyes closed. There is a small increase in ‘Post_0’, indicating some stress recovery after Humour exposure, but the effect is modest since the eye-closed baseline was already relaxed. Theta power is stable across ‘Pre_0’ and ‘Post_0’ conditions, with minimal changes, indicating that the participants were in a meditative, relaxed state during the eye-closed baseline. Alpha power is high at baseline during the eye-closed condition ‘Pre_0’, with minimal changes post-Humour ‘Post_0’. This reflects the typical behavior of Alpha waves in wakeful rest when the eyes are closed. Beta power remains low and stable throughout ‘Pre_0’ and ‘Post_0’, indicating minimal cognitive engagement or stress during the eye-closed baseline and post-exposure conditions.

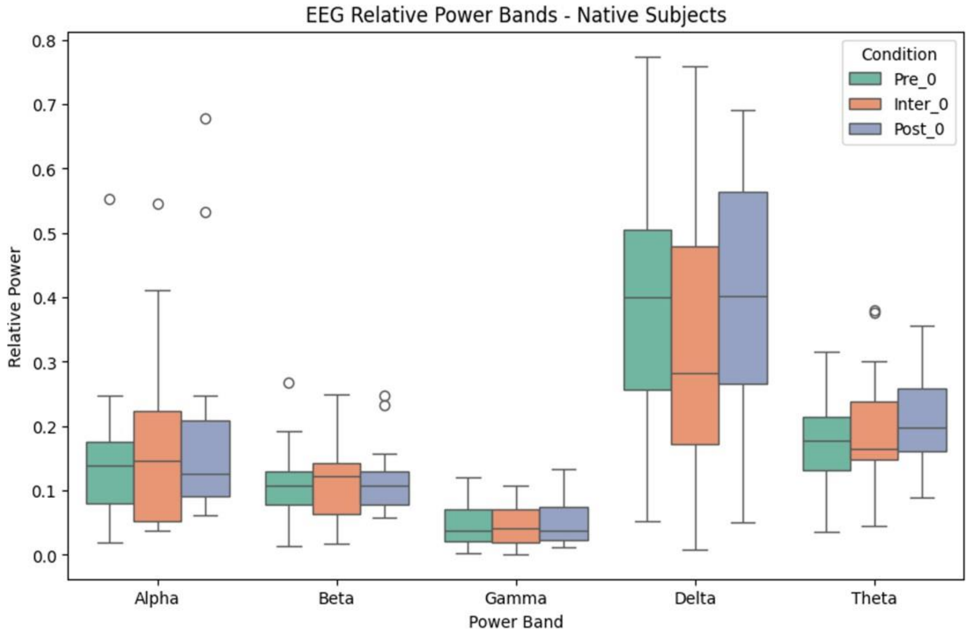


**Figure 17: EEG Relative Power Bands Across Native Language with eyes close baseline**

Figure 17 shows that the Theta and Delta bands show moderate changes across conditions, particularly between the ‘Pre_0’, ‘Inter_0’, and ‘Post_0’ conditions where 0 indicates the baseline for EEG recording while keeping the eyes closed. This represents that stress reduction was also observed, though the changes were more subtle than for non-native subjects. Alpha power is high during the eye-closed baseline ‘Pre_0’ and remains stable post-Humour ‘Post_0’. This reflects the typical relaxed, wakeful state associated with Alpha waves during eye-closed conditions. Beta power remains low and stable, with minimal changes between ‘Pre_0’and ‘Post_0’, reflecting low cognitive engagement and stress during the eye-closed conditions.

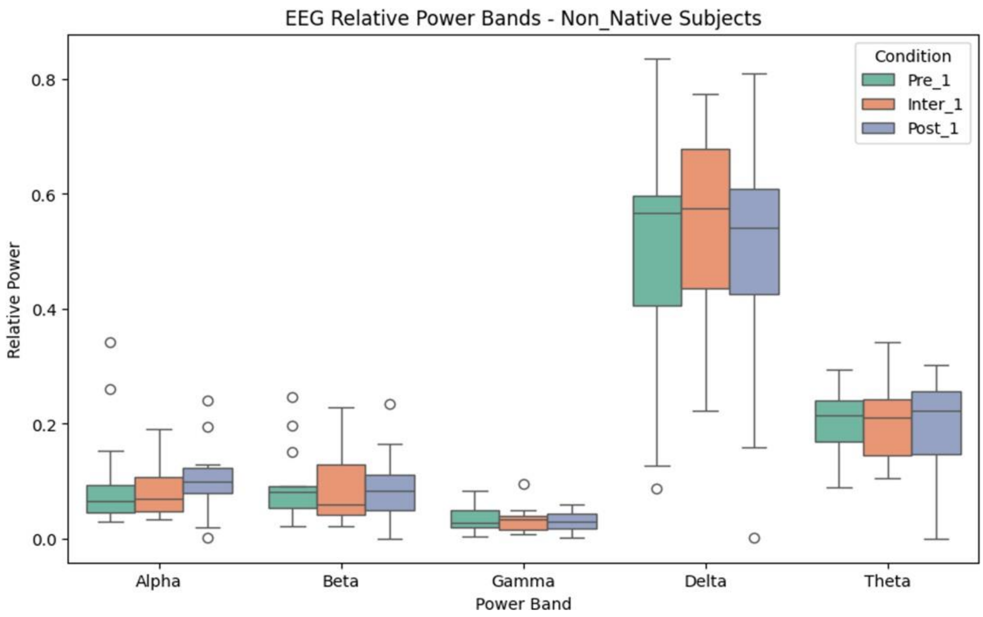


**Figure 18: EEG Relative Power Bands Across Non-Native Language with eyes open baseline**

Figure 18 shows that there are significant changes in the relative power between the ‘Pre_1’, ‘Inter_1’, and ‘Post_1’ conditions where 1 indicates the baseline for EEG recording while keeping the eyes open. Delta power increases after TSST and following the comedy video, particularly in the ‘Post_1’ condition which indicates the reduction of stress, while the Theta power shows moderate changes which reflects the cognitive processing and relaxation of post-video exposure. Alpha power remains relatively stable, with a slight increase in ‘Post_1’, indicating participants are relaxed but alert post-Humour exposure. Alpha activity is generally lower in eye-open conditions compared to eye-closed conditions. Beta power increases during TSST ‘Inter_1’, reflecting heightened cognitive processing and stress. Post-Humour exposure ‘Post_1’, Beta power decreases, indicating a reduction in stress and cognitive load as participants relax.

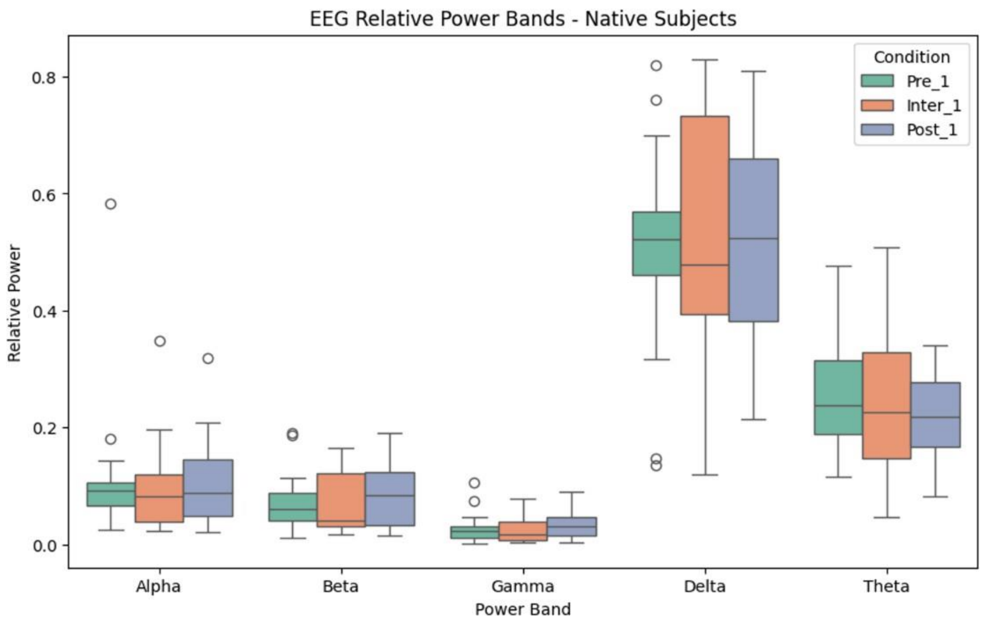


**Figure 19: EEG Relative Power Bands Across Native language with eyes open baseline**

Figure 19 shows that the Delta power has a moderate increase post-Humour 'Post_1', indicating relaxation, but the change is less pronounced compared to non-native subjects. This suggests that Humour in the native language induces a less intense relaxation response. Theta power increases slightly from Pre-1 to 'Post_1', reflecting a moderate reduction in stress after Humour exposure. The changes are less dramatic than in non-native subjects, indicating that Humour in the native language may be easier to process, requiring less cognitive effort to achieve relaxation. Alpha power remains relatively stable, with a small increase in post-Humour 'Post_1', indicating a relaxed but alert state. As with non-native subjects, Alpha activity is lower in eye-open conditions compared to eye-closed. Beta power increases during TSST 'Inter_1', reflecting cognitive engagement and stress, followed by a decrease in post-Humour 'Post_1', indicating stress relief and reduced cognitive load after the comedy video.

- **Comparative Analysis Across All Power Bands**

The comparison across all power bands reveals that the reduction of stress markers associated with native language Humour is more pronounced for both Delta and Theta bands, compared to non-native humor. Other bands, such as Alpha and Beta, show variant responses depending on the language of the humor, but the overall trend supports the general efficacy of culturally and linguistically familiar Humour in reducing psychological stress.

These results highlight the importance of cultural and linguistic factors in the effectiveness of Humour as a stress reliever. The EEG data show that even if the TSST indeed elicits stress, reduction in stress through Humour is effective when the latter is served in the native language of the participant to hold familiarity and relevance at a personal level in emotional and psychological resilience.

### *4.2.6 Impact of Humour on EEG Activity*

To evaluate the impact of Humour on EEG activity, various statistical and graphical analyses were conducted. Q-Q plots showed deviations from normality for the data; thus, using non-parametric tests. Bar graphs, used for the mean difference analysis, revealed that significant changes in EEG power occurred mainly in the Delta and Theta bands after exposure to humor. This was corroborated further by a p-values heatmap, which accentuated which bands of these values have the statistically significant difference. The findings suggest that increased cognitive processing and relaxation, reflected by these band activities, are associated with Humour exposure.

# CHAPTER 5: CONCLUSION AND FUTURE RECOMMENDATIONS

## 5.1 Summary of Key Findings

The present study tested whether multilingual Humour was able to reduce stress after the Trier Social Stress Test, using EEG data recording the neural responses to multilingual humor. This study essentially had the question of whether native or non-native comedy videos were better at reducing stress. Several key findings brought to the fore from rigorous data collection, signal processing, and statistical analysis include:

### *5.1.1 EEG Stress Indicators:*

The experiment confirmed that certain frequency bands of EEG—particularly Theta and Delta—are subject to the linear influence of TSST-induced stress and subsequent presentation of humor.

### *5.1.2 Impact of Multilingual Humour:*

In the current study, both Urdu and English have been used as stimuli to evaluate the impact of multilingual humor on stress reduction. Since Urdu was perceived as a native language for the user population, the minute difference in the efficacy of stress reduction between Urdu and English humor clips could be attributed to the participants' familiarity and comfort with both languages equally. With a bilingual society where most members understand and speak Urdu or English better, the participants would feel relatively at home with either language. This cultural and linguistic familiarity might reduce the expected distinction between the effects of humor in a native versus a non-native language. Consequently, the relaxation effect of both languages' comedy clips was probably felt to be similar by the participants, thus only with a slight difference in the relaxation response. Therefore, the minor difference in effectiveness is because the participants could connect equally to both and hence blur the effects of the native vs. the non-native language.

### *5.1.3 Practical Implications:*

The findings suggest that humor, particularly when presented within a familiar linguistic and cultural context, may be an effective tool for alleviating stress. This has potential applications in designing stress-relief programs that utilize culturally appropriate Humour as a therapeutic intervention.

In answering the question of whether multilingual Humour can help to alleviate stress immediately post-TSST, based on the measurement of neural response through EEG data, the stress level is likely to be reduced by the application of Humour bound by a native language. This deduction was made, having considered the changes in the Theta and Delta EEG frequency bands. The implications of the studies suggest that culturally relevant Humour may be of great benefit for stress management; it has clear applicability in education and health care.

## 5.2 Limitations and Future Work

As much as this research provides an important perception, it has several limitations. These include small and homogeneous sample sizes and single-channel EEG devices used in controlled laboratory conditions. Future research can expand the demographic scope, provide more detailed neural analysis by using multi-channel EEG systems, and research long-term effects under real-life conditions. These steps will provide generalizability and depth of findings, thereby offering a good account of relief from stress using humor.

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