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# THE DEVELOPMENT OF AN AUTOMATIC EMOTION RECOGNITION TECHNIQUE BASED ON ELECTROPHYSIOLOGICAL SIGNALS WHILE LISTENING TO QURANIC RECITATION

BY

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# ABSTRACT

Relaxation and calmness are two emotions that people continually seek. One popular method people frequently used to reduce their tension and pressure levels is listening to various types of relaxing music. However, the Quran is composed of Allah's words, which were ultimately given for the benefit of humanity. Muslims strongly believe that listening to or reading the Quran brings them comfort, pleasure and confidence that would otherwise elude them; however, scientific evidence is still required to prove that this belief has a scientific basis. Recently, researchers have used electrophysiology to explore the relationships between electrical phenomena and body processes. This research aims to study and analyse the electrical activity of people's brains and hearts when listening to Quranic recitation compared with listening to relaxing music. Two types of electrophysiology readings are used in this research: electroencephalograms (EEGs) and electrocardiograms (ECGs). An EEG measures brain electrical activity, and an ECG measures heart electrical activity. EEG and ECG data were collected from twenty-five subjects. Then, machine learning algorithms were applied to the EEG and ECG signals. In addition, EEG brainwaves were measured, focusing on the alpha and beta bands. The ECG signal analysis also involved heart rate calculation. All these types of analysis were used to measure subjects' calmness levels and to recognize their emotions while listening to Quranic recitation as compared with listening to relaxing music. With respect to the valence-arousal analysis result, we conclude that Quranic recitation demonstrated a positive transformation of the subjects' emotions: from negative precursor emotions to calmness and happiness conditions denoted by a positive valence for the EEG and ECG signals. In contrast, relaxing music showed a positive transformation with regard to the valence in the EEG analysis; however, with respect to the ECG music data analysis, the results revealed a negative transformation for most of the music tracks.

# ملخص البحث

الاسترخاء والهدوء نوعان من المشاعر التي يسعى الناس باستمرار للشعور بهما. احدى الوسائل التي تستخدم من قبل كثير من الناس لخفض مستويات التوتر والضغط هو الاستماع إلى أنواع مختلفة من الموسيقى الهادئه. على الرغم من ذلك يُعدُ القرآن الذي يمثل كلام الله ،والذي فيه صلاح الإنسانية احدى اهم هذه الوسائل. يعتقد المسلمون جزماً أن الإستماع إلى القرآن أو قراءته يجلب لهم الراحة والطمأنينة التي لا يجدوها بأي شيء اخر. ولكن لا تزال هناك حاجة إلى دليل علمي يثبت ذلك علمياً. في الآونة الأخيرة، استخدم الباحثون الدراسة الكهربية الفسيولوجية لاستكشاف العلاقة بين الظواهر الكهربائية والعمليات الحيوية في الجسم. هذا البحث يهدف إلى دراسة وتحليل آثار الأنشطة الكهربائية في الدماغ والقلب أثناء الإستماع إلى تلاوة القرآن الكريم بالمقارنة مع الإستماع إلى الموسيقى الهادئه. وهناك نوعان من القراءات الكهربية الفسيولوجية المستخدمة في هذا البحث: EEG لأنشطة المخ الكهربائية وECG لأنشطة القلب الكهربائية. وقد تم جمع البيانات من خمسة وعشرين موضوعاً. بعد ذلك، تم تطبيق خوارزميات التعلم الآلي لإشارات القلب والدماغ. بالإضافة إلى ذلك، تم دراسة وتحليل الموجات الدماغية، مع التركيز على موجتي ألفا وبيتا. وكذلك تحليل إشارة تخطيط القلب حيث يتضمن حساب معدل ضربات القلب. وقد استخدمت جميع الخوارزميات المذكوره أعلاه لدراسة وتحليل مشاعر المواضيع أثناء الإستماع إلى تلاوة القرآن الكريم مقارنة مع الموسيقى الهادئه. وأظهرت النتائج، أن الإستماع للقرآن الكريم أدى إلى تحول إيجابي في مشاعر المواضيع المدروسة لكلا الإشارات الكهربية EEG و ECG. أما بالنسبة للموسيقى الهادئه فقد اظهرت تحولاً ايجابياً بالنسبة لإشارات الدماغ EEG ولكن التحول كان سلبياَ بالنسبة لأشارات القلب ECG لمعظم المقاطع المختارة.

# APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion; it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Computer Science.

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# LIST OF ACCRONYMS

| | |
|---|---|
| BPM | Beats per minutes |
| EEG | Electroencephalograms |
| ECG | Electrocardiograms |
| HRV | Heart Rate Variability |
| IADS | International Affective Digitized Sounds |
| IAPS | International Affective Picture System |
| KDE | kernel smoothing density estimate |
| MLP | Multi-layer perceptron |
| MFCC | Mel-frequency cepstral coefficients |

# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND

The difficulties and problems that people face every day elicit states of tension, panic and anxiety; consequently, they continually attempt to combat these emotions using different means. Different religions (e.g., Buddhism, Hinduism and Christianity) have employed various types of meditation mixed with relaxing music to help relieve stress and anxiety. Numerous studies have verified this effect experimentally. For instance, one study investigated the effect of Zazen (Buddhist meditation) on the human brain. The results showed that Zazen can help the brain enter a relaxed state (Faber et al., 2014). Another study that investigated yoga meditation compared subjects who had practiced yoga for the past ten years with others who had not. The findings showed that the experienced yoga meditators exhibited higher activity at higher frequencies (beta and particularly gamma) within all experimental conditions and that this effect was significantly enhanced during yoga meditation (Thomas, Jamieson, & Cohen, 2014). Moreover, numerous studies have investigated transcendental meditation (TM) (Hindu meditation) and its positive effects (Alexander, Robinson, & Rainforth, 2010; Cahn & Polich, 2006). As a result of such scientific evidence, people of different beliefs have begun to learn various types of meditation in academic institutions.

In Islam, meditation is called Zikr or Dhikr. There are several different types of Zikr that include reciting the Quran, listening to its recitation, reading or listening to morning and evening Azkar, pondering Allah's creation, saying various special words (such as SubhanAllah and Alhumdellah), or reciting the five prayers Muslims

perform every day and night. All these types of Zikr bring Muslims to states of comfort and tranquillity. As the messenger of Allah, Muhammad (PBUH) said, “O Bilal, call Iqamah for prayer: give us comfort by it” [Sunan Abi Dawud], and Allah mentioned that the Quran is a cure for people: *“And we send down of the Qur'an that which is healing and mercy for the believers” [Isra 17: 82]*. In another verse, Allah mentions that the remembrance of Allah brings hearts to calmness and satisfaction, stating “*for without doubt in the remembrance of God do hearts find satisfaction” [Ar-Ra’d 13: 28]*.

Muslims strongly believe that listening to Quranic recitation, reading the Quran or contemplating Allah in any form brings them contentment, satisfaction and fulfilment that they would not find otherwise. Methodical research continues to be necessary to demonstrate such effects scientifically. Recent studies have applied electrophysiology to help understand the relationship between electric phenomena and bodily functions (Scanziani & Häusser, 2009). Electrophysiology is the scientific field of physiology that corresponds to the flow of ions inside organic tissue and, specifically, to the electrical recording techniques that allow measurements associated with this flow. Two particular electrophysiological signal readings, electroencephalograms (EEGs), which sense brain electrical activity, and electrocardiograms (ECGs), which sense heart electrical activity, are used in this research to collect signals from human subjects’ brains and hearts while they are either listening to Quranic recitation or listening to music. The collected signals are then preprocessed to remove noise and related artefacts. Then, various EEG and ECG analysis methods are implemented with the goal of being able to recognize the human emotions elicited while listening to Quranic recitation compared with those elicited while listening to various types of relaxing music (e.g., jazz).

## 1.2 INIMITABILITY OF THE NUMERIC AND SCIENTIFIC NATURE OF THE WORD "HEART" IN THE QURAN

The word "heart" is repeated in the Holy Quran 132 times, and the word "Fouad" and its derivatives are repeated 16 times, for a total of 148 mentions. The word heart and its derivatives in the numerical inimitability of the Quran are repeated the same number of times as those of sight and discernment. Meanwhile, the word "mind," using various terminology (such as "conceivable-learn" or "wisdom-wise"), is repeated 49 times, and the word "Albab" is repeated 16 times, yielding a total of 65 mentions.

As for scientific inimitability, the God Almighty has mentioned the heart and related it to functions of the mind such as thinking, pondering, faith, believing, denial and so on. This connection has been proven by modern heart transplantation techniques; it has been observed that post-transplant patients exhibit changes in their moods, likes and dislikes, and all of this is proof of the greatness of the Book of Allah. Some have said that the word "heart" in the Quran may just be a sign of the mind that is located in the brain, but God Almighty clearly stated that the heart's place is in the chest; it should be noted that the word “chest” and its derivatives are repeated 46 times in the Quran.

## 1.3 PROBLEM STATEMENT

The Quran is Allah’s speech as revealed to the prophet Muhammad (PBUH) more than fourteen centuries ago. It is purported to contain numerous scientific facts and miracles. While some of these miracles and facts have been verified experimentally, we believe that there is still much more to be discovered. There is, at present, little research on the effects of Quranic recitation on the EEG and ECG signals of listeners.

Consider that sound therapies have been utilized to treat several health issues (Lippi, Roberti di Sarsina, & D'Elios, 2010), particularly psychological and emotional health problems (Kim, Wigram & Gold, 2009) and anxiety and depression (Erkkilä et al., 2011). Virtually every study conducted by researchers associated with sound treatment has utilized elements of music to evoke reactions in the individuals being examined (Brotons & Koger, 2000). Moreover, there are hundreds if not thousands of papers and studies investigating music's effects on human emotions. Thus, the Quran as sound therapy can be anticipated to have effects analogous to those of music therapy (Tumiran et al., 2013). In this research, we aim to investigate how Quranic recitation, considered as sound therapy, can reduce subjects' stress and anxiety levels compared with relaxing music. This investigation is conducted by analysing subjects' acquired EEG and ECG signals.

## 1.4 RESEARCH QUESTIONS

This research aims to answer three main questions:

- What are the quantitative effects of Quranic recitation on listeners' brain and heart electrical activities compared with the quantitative effects of relaxing music?
- How does Quranic recitation, considered as sound therapy, reduce the stress and anxiety levels of listeners compared with listening to relaxing music?
- What is the correlation and relationship between EEG and ECG signals and what can be concluded from the synchronization of both signals?
- What are the best algorithms that can yield a high accuracy for building an emotion recognition model?

## 1.5 RESEARCH OBJECTIVES

The principal objectives of this research are as follows:

- To quantitatively study the effects of Quranic recitation on listeners by analysing brain and heart electrical signals (EEG and ECG).
- To investigate how Quranic recitation as sound therapy can reduce the stress and anxiety levels of listeners compared with relaxing music by finding stress markers in the brain and heart electrical signals (EEG and ECG).
- To compare and synchronize both signals (EEG and ECG) to discover patterns of correlation or relationship.
- To choose the best algorithms that can yield a high accuracy for building an emotion recognition model.

## 1.6 DEFINITION OF TERMS

Presented here is a list of various terms that are used in this research:

**Electrophysiology** is the study of physiology concerned with electrical phenomena related to the nervous system and other physiological activities.

**Automatic target recognition (ATR)** is the capability of an algorithm or machine to recognize targets or objects depending on data acquired from sensors. The target of this research is emotions.

**Emotions:** As outlined by many theories, emotions are a state of feeling that translates to bodily and mental changes that affect our behaviour. The physiology of emotion is tightly related to nervous system arousal, in which various states (as well as strengths) of arousal are related to specific emotions.

**EEG (electroencephalogram):** This is a measurement of the electrical fluctuations that occur in the brain, generated simply by positioning electrodes over the scalp to amplify the electrical potential produced. The actual EEG indicates three primary wave types: alpha, beta and delta. These waves can be distinguished based on their rates of production.

**ECG (electrocardiogram):** This is a diagnostic instrument typically utilized to analyse the electrical activity of the heart. ECG tests are commonly implemented, but interpretation of the resulting ECG traces requires significant training.

**Beats per minute (BPM)**: This is a cardiac pacing unit of measure for the frequency of heart depolarizations or contractions during each minute, often termed pulse rate.

## 1.7 RESEARCH METHODOLOGY

The entire analysis process for the EEG and ECG signals is described in Figure 1.1. After the experiment protocol is ready, the data collection (signal acquisition) stage is executed for twenty-five subjects. Then, the signal analysis begins with a data-filtering (preprocessing) step. The third step is feature extraction, in which we apply two main algorithms: Kernel Density Estimation (KDE) and Mel Frequency Cepstral Coefficients (MFCC). Following that is the classification step, in which we apply the Multi-Layer Perceptron (MLP) algorithm with five-fold cross-validation. Finally, the classification accuracy is verified based on a confusion matrix for each extraction algorithm. After the accuracy is verified and recorded, the Quran and music data are tested by the best net construct. More details on the methodology of this research will be provided in Chapter 3 and 4.

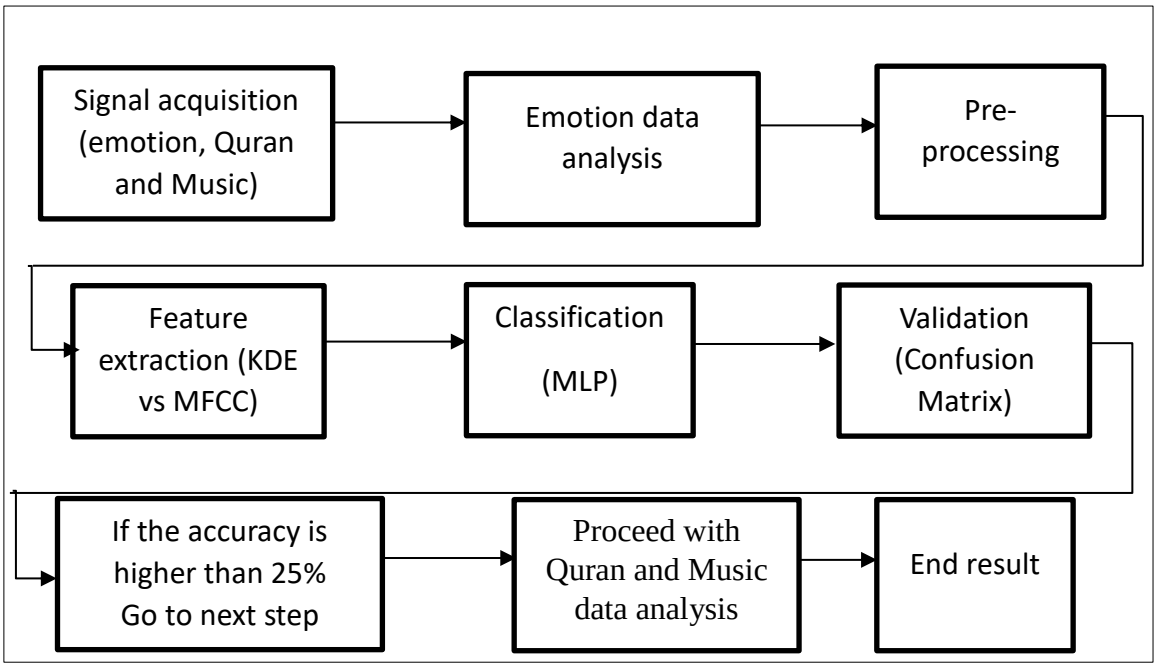


Figure 1.1 General steps of the EEG and ECG signal analysis

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

This literature review is divided into two main parts: the first covers the EEG-related studies, and the second covers the ECG-related studies. The EEG-related research focuses on the multiple points of view that will be applied in this research. In section 2.2, we explore the brainwaves and the situations they are typically associated with. We also cover EEG and emotion theories in detail and shed light on the Circumplex Model as applied in our research methodology. The next stage of investigation focuses on how researchers have applied these models and algorithms to the EEG data collected while listening to music. Finally, we investigate almost all the research related to EEG signals and Quranic recitation, and we summarize those studies in different tables, which are listed at the end of this chapter. In section 2.3, we cover the ECG studies that are related to the emotion recognition.

## 2.2 EEG-RELATED STUDIES:

According to (Abdullah & Omar, 2011), EEG signals are categorized into five types of waves: delta, theta, alpha, beta and gamma. Alpha wave frequencies lie between 8–13 Hz and are associated with relaxed awareness. Most subjects produce alpha waves while relaxed with their eyes closed. Beta waves (14–26 Hz) are associated with active thinking and external focus. Waves greater than 26 Hz are called gamma waves or sometimes fast beta waves; the amplitudes of these rhythms are very low, and they are rarely observed. Detection of these rhythms can be used to confirm certain brain

diseases. The cerebral regions with high blood flow (as well as oxygen and glucose uptake) and correspondingly high EEG frequencies are located in the front-central area. The gamma wave band has been shown to be a good indication of event-related synchronization (ERS) of the brain and can be used to demonstrate the loci for right and left index finger movement and the right toes, as well as the rather broad and bilateral area for tongue movement (Sanei & Chambers, 2013).

One major theory of emotions proposes that EEGs can be used to categorize a basic set of human emotions (Yaacob & Wahab, 2012). Each emotion is distinct from other emotions as perceived by its psychological and physiological manifestations. According to Russell, emotions are allocated in a two-dimensional circular space comprised of arousal and valence dimensions. Arousal is represented on the vertical axis, and valence is represented on the horizontal axis. As one move towards the centre of the circle, valence becomes neutral, and arousal is at a medium level. In this model, called the Circumplex model, emotional states can be represented with any specific level of valence and arousal. The most common use of this model has been to test stimuli for emotional facial expressions and audio and affective states, as shown in Figure 3.1 (Russell, 1980).

One paper proposed a new technology, focusing on how memory effectiveness can be measured by analysing the dynamic emotional trajectory with EEG after noting that memory function is enhanced by emotional response, with the consequence that implicit and explicit memory tests could be carried out using the same experimental method (Alarabi, Wahab, & Karim, 2013). Another paper proposed a new approach for understanding children's reactions during Executive Function tasks by mapping their EEG signals onto the 2D valence-arousal affective space model. The results of this study showed that children's brain signals can be a good indicator for

understanding their emotional states during Executive Function tasks (Othman, Qayoom, & Wahab, 2012).

Many researchers have investigated the emotional effects of listening to music. One popular method used is to measure subjects' ongoing brain activities as they listen to music. The methods used to analyse the acquired signals differ between studies. One study compared two types of classification algorithms (MLP and support vector machine (SVM)), and while it was found that the SVM algorithm obtained the highest accuracy, the difference was not statistically significant compared to MLP (Lin et al., 2010). Saari & Eerola (2014) correlated emotions models with different types of music based on a multi-dimensional scaling (MDS) configuration in three dimensions—valence, arousal and tension (VAT)—as shown in Figure 2.1.

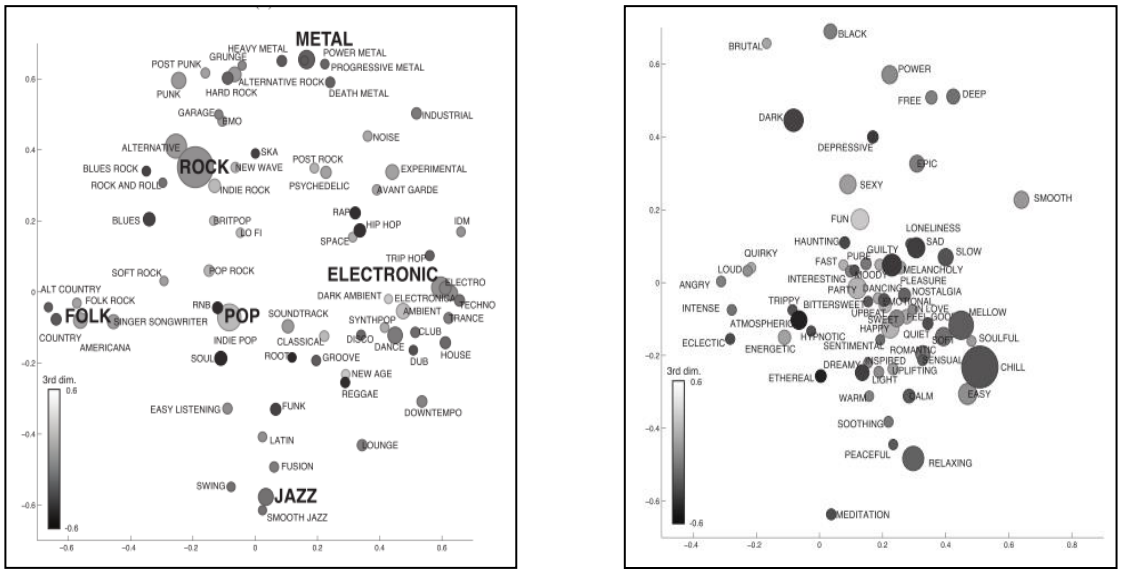


Figure 2.1 Projection between music types and moods based on MDs configuration according to (Saari & Eerola, 2014)