JOURNAL OF SOUTHERN COMMUNICATION ENGINEERING
ISLAMIC AZAD UNIVERSITY BUSHEHR BRANCH

E-ISSN: 2980-9231
https://sanad.iau.ir/journal/jce

https://doi.org/10.71656/jce.2025.1194782

Vol. 15/ No. 59/2026

Research Article

Determining the Distinguishing Feature in Brain Signal Processing: A Case Study of Heroin Addicts

Atefe Tobeiha[1,2] | Neda Behzadfar[1,2] | Mohamadreza Yousefi-Najafabadi[1,2] | Homayon Mahdavi-Nasab[1,2] | Ghazanfar Shahgholian[1,3]

[1]Department of Electrical Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran.
tobeihaatefeh@gmail.com

[2]Digital Processing and Machine Vision Research Center, Najafabad Branch, Islamic Azad University, Najafabad, Iran.
n.behzadfar@pel.iaun.ac.ir,
mr-yousefi@iaun.ac.ir,
mahdavinasab@iaun.ac.ir

[3]Smart Microgrid Research Center, Najafabad Branch, Islamic Azad University, Najafabad, Iran.
shahgholiangh@gmail.com

Correspondence
Neda Behzadfar, Assistant Professor, Najafabad Branch, Islamic Azad University, Najafabad, Iran.
Email: n.behzadfar@pel.iaun.ac.ir

Main Subjects:
Signal Processing

Paper History:
Received: 28 December 2024
Revised: 11 January 2025
Accepted: 12 January 2025

Abstract

This study aims to identify and determine distinguishing features of brain signals in heroin-addicted individuals. Electroencephalogram (EEG) signals were collected from 16 brain channels for 15 addicted and 15 healthy individuals. Frequency and non-frequency features were evaluated using the Davies-Bouldin index. The results indicate that in heroin-addicted individuals, the frequency power in the upper alpha sub-band of the O1 channel decreased, while the approximate entropy in the Cz channel increased. To classify the data and distinguish addicted individuals from healthy ones, a Support Vector Machine (SVM) classifier was employed. The accuracy and precision of detection for approximate entropy were 91.50% and 91.15%, respectively, while for the upper alpha power of the O1 channel, they were 95.92% and 92.18%, respectively. The findings confirm the significance of selected features in distinguishing heroin-addicted individuals. The analysis of brain signals can provide a deeper understanding of the effects of heroin use on brain activity and contribute to improving treatment strategies and addiction prevention.

Keywords: Addiction, Brain signal analysis, Davis-Bouldin index, Power spectrum, Heroin.

Highlights

- Selecting appropriate and specific features in addicted and healthy individuals based on individual characteristics of heroin addicts or healthy individuals based on a feature selection method.
- Selecting a distinguishing feature from the Davis-Bouldin method.
- Determining a distinguishing feature for diagnosing addiction in brain signals.
- Examining time and frequency domain features to identify a distinguishing feature.
- Introducing a new database in diagnosing addiction based on brain signals.

Citation: - [in Persian].

1. Introduction

Drug addiction is a major health problem in modern society. Drug use, by affecting the neurotransmitters present in different areas of the brain, especially in the reward area, leads to a feeling of pleasure that brings about changes in other areas and functions of the brain [1,2]. Diamorphine or heroin is a highly addictive drug derived from morphine and is usually found in the form of a white or brown powder. Heroin addiction in the long term affects the body and life of a person extensively and leads to sexual and mental disorders, digestive problems, liver and kidney problems, damage to the health of the heart, blood vessels and brain. Heroin use affects the brain of the addicted person, so that they are not able to establish proper communication with their surroundings [3].

2. Innovation and contributions

The aim of this study is to identify the distinguishing features of brain signals to distinguish heroin addicts from healthy individuals using the Davis-Bouldin index. In this study, time and frequency domain features were examined simultaneously to provide a more comprehensive assessment of changes caused by addiction. The innovations of this study include the following:

• Simultaneous analysis of frequency and non-frequency features: By evaluating features such as entropy and power spectrum, EEG signal changes were analyzed comprehensively.

• Identification of effective channels such as O1 and Cz: The research findings show that a decrease in the power spectrum in the upper alpha subband of the O1 channel and an increase in the approximate entropy in the Cz channel are important features for distinguishing addicted individuals from healthy individuals.

• Use of a proprietary database: The EEG data of this study includes signal recordings from 15 addicted individuals and 15 healthy individuals with a 10-10 standard and detailed questionnaire information, which makes the analyses more valid than similar studies.

According to the results presented, this study provides a detailed framework for examining the effects of addiction on brain activity and improving diagnostic methods.

According to the research conducted and the results obtained, there is still no agreement on the type of distinguishing feature. Therefore, the aim of this article is to select appropriate and distinguishing features among addicted and healthy individuals. The structure of the article is as follows. In the second section, the research database is examined. In the third section, the proposed method for selecting distinguishing features in healthy and addicted individuals will be presented. In the fourth section, the evaluation of the results is presented along with their analysis. Finally, in the fifth section, conclusions and suggestions are expressed.

3. Materials and Methods

In this study, a database of EEG signals from addicts and healthy individuals was used [4]. In the database used, EEG signals were recorded from 16 channels and based on the international standard 20-10. The reference electrode was connected to the right ear and the ground electrode was connected to the forehead of the canal (Fpz) and the sampling frequency was set to 256 Hz. It should be noted that the gUSBamp device manufactured by g.tec medical engineering GmbH was used to record brain signals. In this study, 15 addicts (8 married and 7 single) with an average age of 27.32 who were in the stage of quitting heroin and 15 healthy individuals (4 married and 11 single) with an average age of 34.38 who had not used any drugs, alcohol or tobacco consciously and voluntarily participated in the registration process. All subjects were male and right-handed. All subjects were given an informed consent form. After that, both groups completed the 28-item General Health Questionnaire (CHQ-28). Addicts were also asked to answer the 45-item Heroin Craving Questionnaire (HCQ-45), which is designed to assess people's craving and craving for heroin abuse. This questionnaire was designed to assess the level of drug dependence and ensure that people were addicted. Physical symptoms, anxiety/insomnia, impaired social functioning and severe depression, mood disorders, anxiety and substance disorders, childhood disorders and other disorders were examined in this questionnaire. After answering the questionnaire, people with psychiatric disorders and a genetic or family history of neurological and related disorders were excluded from the experiments. The average duration of heroin use was 11.2 years and the average daily dose was 1.2 grams in addicts. Also, the duration of abstinence from drug use was 10.07.

4. Results and Discussion

In order to analyze EEG signals, non-frequency features of entropy and fractal dimension in different channels and frequency feature of power spectrum in all channels are extracted and then these features are used to separate groups from each other. Features are calculated in all participants and compared with boxplots. Boxplots show the difference in extracted features in different subbands. The comparison is made based on Davis-Bouldin criterion. The threshold for significant difference is considered to be p-value less than 0.005. There is no significant difference in channels 14, 4, 15 and 9 and at the same time a decrease in Davis-Bouldin index is evident. While in other channels a significant difference and an increase in Davis-Bouldin value are observed. Based on the study conducted in this research and the results obtained and the presented graphs, there is a significant difference in non-frequency features only in the approximate entropy feature. In other non-frequency

features such as permutation entropy, wavelet entropy feature, Petrosian fractal dimension, Katz fractal dimension, counter box, effective value feature, this difference is either not significant or not significant enough to be used as a distinguishing feature. The results obtained in approximate entropy also agree with intuition, because the effects of drugs, especially heroin, increase the disorder in the user's thoughts. Based on the results obtained, the selection of channels O1 and Cz was based on a comprehensive analysis of all EEG channels recorded in accordance with the international 10-10 standard. In the Cz channel, the increase in approximate entropy indicated an increase in disorder and a decrease in the self-organization of neuronal activity. Physiologically, this area plays a role in the processing of motor information and sustained attention, and the observed changes indicate damage to brain networks caused by heroin use. These results confirm that the selection of channels was based on data analysis and identification of meaningful indicators and is specifically related to the functional characteristics of the brain in conditions of addiction.

5. Conclusion

In this study, to identify the distinguishing features of brain signals between healthy individuals and heroin addicts, various frequency and non-frequency features of the EEG signal were extracted and analyzed. These features were obtained from different subbands of the frequency spectrum and multiple EEG channels and were examined to identify abnormal patterns associated with heroin use. The results show that there is a significant difference in some features; so that the p-value for these differences is less than 0.05. In the high alpha subband, a decrease in power was observed in the O1 channel, which indicates a decrease in mental relaxation activity and impaired occipital information processing in addicts. Also, the approximate entropy in the Cz channel increased significantly, indicating an increase in disorder and decreased neuronal coordination in the central region of the brain. These findings indicate that both of these features act as key indicators in identifying and distinguishing healthy individuals from heroin addicts. The results obtained can be used as an effective tool in developing EEG-based diagnostic methods and monitoring the condition of patients during treatment and rehabilitation. Also, the combination of frequency and non-frequency features shows greater efficiency compared to using one feature set alone and provides higher accuracy and precision in the classification process.

6. Acknowledgement

This article is an excerpt from a Ph.D. dissertation conducted at the Najafabad Branch, Islamic Azad University. I would like to thank the esteemed reviewers and the journal staff.

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Declaration of Competing Interest: Authors do not have conflict of interest. The content of the paper is approved by the authors.

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Author Contributions: All authors reviewed the manuscript.