



REVIEW

of a PhD Thesis for the acquisition of the educational and scientific degree "Doctor"

PhD Thesis Author: Gagandeep Kaur

Title of the PhD thesis: "A Neurocognitive Approach Based on a Brain-Computer Interface for Identifying Emotional and Mental States"

Professional field: 5.2 Electrical Engineering, Electronics and Automation

Doctoral programme: "Application of the Principles and Methods of Cybernetics in Various Fields of Science"

Reviewer: prof. Tanio Tanev, Institute of Robotics - BAS

1. General description of the dissertation

The dissertation has a total volume of 123 pages and is structured into 4 chapters. It contains a title page; table of contents; introduction; main exposition; conclusion; contributions of the dissertation; declaration of originality; bibliography comprising 116 cited literary sources; and a list of publications related to the dissertation topic, namely 3 publications on the topic of the dissertation. The submitted documents also include a protocol and a printout from specialized software confirming the absence of plagiarism.

2. Relevance of the problem developed in the dissertation from a scientific and scientific-applied perspective

The dissertation addresses a current and significant research problem related to the objective assessment of emotional and mental states through EEG-based Brain-Computer Interface methods, using fatigue among teachers in Suggestopedia training as the main validation case.

The dissertation has a clearly expressed interdisciplinary orientation, combining cognitive neuroscience, EEG signal processing, passive BCI methodology, and the study of teacher fatigue. Its originality lies in the attempt to derive an EEG-based assessment of fatigue and apply it in a real educational context. The use of resting-state EEG recordings before and after real teaching activity is a valuable and original study. The topic is highly relevant in the context of the rapid development of neuroscience, artificial intelligence, and digital healthcare, and it is particularly significant for the study of fatigue among teachers — a professional group subjected to high cognitive and emotional workload. The dissertation identifies a real and unexplored problem. Existing EEG-based studies of fatigue usually focus on drivers, machine operators, students, or laboratory-based cognitive tasks. The focus on teachers, and more specifically on Suggestopedia teachers, gives the work a distinctive and original research context.

3. Degree of knowledge of the state of the problem

The dissertation cites 116 literary sources, a large number of which have been published in the last 10 years. In substance, they are related to the topic of the dissertation.

The literature review examines the existing literature on EEG markers of fatigue, including theta, alpha, beta, and delta oscillations, as well as the role of BCI systems in the recognition of cognitive states. The presented review and bibliographic reference show that the doctoral candidate has a good knowledge of the problem and of the methods and techniques related to the dissertation topic, and correctly interprets achievements in this field.

4. Correspondence of the selected research methodology and the formulated goal and tasks with the achieved contributions

The selected research methodology is logical and achieves the main goal and tasks of the dissertation.

The developed and validated new BCI methodology, based on EEG, for the assessment of emotional states in working adults, its experimental verification, and the statistical analysis are connected in a logical sequence. This results in a completed study on the dissertation topic and demonstrates that the author has selected and applied an appropriate research methodology in accordance with the stated goal and tasks of the dissertation.

5. General characteristics of the dissertation

In Chapter 1, "Introduction and Literature Review of EEG based analysis of Fatigue," literary sources are analysed, and mental fatigue is discussed as a representative case for developing and validating a broader EEG-based Brain-Computer Interface (BCI) methodology intended for identifying emotional and mental states.

The chapter emphasizes the importance of fatigue assessment in educational environments, with special attention given to teachers and, more specifically, to practitioners of the Suggestopedia teaching method. The existing literature on EEG markers of fatigue is reviewed, including theta, alpha, beta, and delta oscillations, as well as the role of BCI systems in the recognition of cognitive states. The review identifies a number of unexplored scientific problems, particularly the lack of EEG-based studies of fatigue among teachers in real teaching conditions and the limited use of a resting-state pre-post intervention experimental architecture. Based on these unexplored scientific problems, the goal of the dissertation is formulated, which can be summarized as the development of a new EEG-based methodology for neurocognitive assessment, and the research tasks and structure of the dissertation are outlined. The chapter concludes that standardized and robust, context-specific approaches are needed for the objective assessment of fatigue, and the proposed methodology is positioned as a contribution toward meeting this need.

Chapter 2, "Systematic Research of EEG BCI-based methods for assessment and analysis of mental states," presents a systematic review of EEG-based Brain-Computer Interface (BCI) methods intended for the assessment and analysis of mental and emotional states. The chapter builds the conceptual and methodological foundation of the dissertation by explaining how passive BCI systems can be used to monitor cognitive and affective processes through electroencephalography (EEG). The principles of EEG signal generation, brain oscillations, and the role of different frequency bands in reflecting neurocognitive states are examined. In addition, the chapter discusses the complete EEG data-processing pipeline, including signal acquisition, preprocessing, artifact removal, feature extraction, and statistical analysis. Particular attention is paid to spectral power analysis, relative measures of band power, and estimation-based statistical approaches for investigating changes in mental states. Based on this review, a systematic EEG-based passive BCI framework is proposed, which provides the methodological foundation for the new neurocognitive fatigue assessment model developed and validated in the following chapters.

Chapter 3, "A Novel Methodology for Neurocognitive Analysis and Assessment of Mental and Emotional States Based on a Brain-Computer Interface," presents a new EEG-based Brain-Computer Interface (BCI) methodology intended for the neurocognitive assessment of mental and emotional states, using mental fatigue as the main validation case. The chapter introduces a pre-post intervention assessment framework in which resting-state EEG is recorded before and after a real cognitive activity. The methodology

design, signal preprocessing, spectral analysis of the delta, theta, alpha, and beta frequency bands, data averaging, and statistical evaluation.

A pilot study was conducted to verify the applicability and sensitivity of the proposed framework. The results show that changes in resting-state EEG activity can reflect neurocognitive alterations associated with sustained cognitive engagement and fatigue. By emphasizing resting-state recordings, relative band-power analysis, and estimation-based statistical methods, the chapter establishes a reproducible approach for assessing mental and emotional states in real-life conditions. The proposed methodology serves as the basis for the full-scale validation study presented in Chapter 4.

Chapter 4, "Implementation, Verification and Validation of Proposed Methodology for Assessing Fatigue Levels in Suggestopedia Teachers," applies, verifies, and validates the EEG-based neurocognitive assessment methodology proposed in Chapter 3, with the aim of assessing fatigue levels among Suggestopedia teachers. The study uses a pre-post intervention assessment approach, recording resting-state EEG before and after teaching sessions in order to determine whether prolonged teaching activity induces measurable neurophysiological changes associated with mental fatigue. The analysis focuses on changes in spectral power in the delta, theta, alpha, and beta frequency bands, complemented by effect-size estimation and confidence interval analysis.

The results provide an objective assessment of EEG patterns associated with fatigue and evaluate the relationships between different frequency bands as indicators of alertness, cognitive workload, and fatigue. Through statistical and visual analyses, the chapter examines whether teaching according to the Suggestopedia method leads to significant fatigue-related changes in brain activity. The obtained results represent an empirical validation of the proposed methodology and contribute evidence regarding the neurocognitive effects of teaching within the framework of Suggestopedia.

6. Scientific and/or scientific-applied contributions of the dissertation

Five scientific contributions have been formulated, which also have an applied dimension. I accept these contributions as having been genuinely achieved in the dissertation.

In summary, the contributions amount to the following: the development of a new EEG-based neurocognitive methodology for identifying and assessing mental and emotional states through a passive Brain-Computer Interface (BCI) framework; the creation of an adaptive framework for processing and interpreting fatigue, using a "pre-post intervention" experimental design; the development and implementation of an innovative experimental methodology in a real environment outside controlled laboratory conditions through the study of teachers applying Suggestopedia; the experimental validation of EEG biomarkers of fatigue through analysis of delta, theta, alpha, and beta

band activity, effect sizes, confidence intervals, and relationships between frequency bands, with the aim of objectively assessing changes in alertness and fatigue associated with prolonged teaching activity; and the identification, through statistical analysis, of an original neurophysiological pattern in EEG fatigue research, characterized by dominant right-hemisphere activity.

7. Assessment of the publications related to the dissertation

The results of the dissertation are reflected in 3 publications — 2 co-authored publications and one independent publication. In the co-authored publications, the doctoral candidate is the first author. One of the publications has an IF of 2.8 and falls within quartile Q2. A second publication has an SJR of 0.166 and falls within quartile Q4. Two citations of one of the papers for the dissertation have been noticed.

These publications show that the results of the dissertation have been reported to a broad circle of the scientific community and meet the requirements for the defence of a doctoral dissertation.

8. Abstract (Autoreferat)

The abstract has a volume of 43 pages, with each chapter of the dissertation presented briefly and correctly. The main contributions of the dissertation are presented. The abstract is presented in Bulgarian, with a short summary in English.

9. Critical remarks and recommendations

I did not find any substantial errors in the dissertation and I have no major critical remarks. Nevertheless, the following recommendations may be noted:

- An additional advantage for the dissertation would be the provision of a more precise definition of “fatigue.” What specific EEG pattern is expected to indicate fatigue, and what EEG pattern would contradict the interpretation of fatigue?
- Some narrowing of the null hypothesis could also be considered.
- In future studies and publications, it is necessary to take into account the variables present in a real teaching environment — which of these variables were controlled, measured, or left uncontrolled as part of a naturalistic research

The recommendations made do not diminish the quality of the obtained results; rather, they are suggestions for the doctoral candidate's future publications.

10. Conclusion

The topic of the dissertation is relevant and the research is original. The doctoral candidate demonstrates in-depth knowledge of the dissertation topic and of the achievements of a number of leading scientific teams worldwide, which is evident from the presented literature review. Scientific and applied contributions have been achieved in the course of the dissertation work. In conclusion, I consider that the requirements of the Development of Academic Staff in the Republic of Bulgaria Act, the Regulations for its implementation, and the Regulations of the Bulgarian Academy of Sciences have been fulfilled, and I give a **positive assessment** of this dissertation. This gives me grounds to propose that **Gagandeep Kaur** be awarded the educational and scientific degree "**DOCTOR**" in **Professional field 5.2 Electrical Engineering, Electronics and Automation**.

08.06.2026

Reviewer:

/ prof. Tanio Tanev/