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Application of EEG signals for prediction of delay in response time to unexpected events

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The main aim of this doctoral dissertation is to explore the relationship between EEG measurements of the subjects and their ability to make quick and precise decisions in response to unexpected events. The described research introduces and validates a comprehensive procedure for processing EEG signals, extracting relevant information, and predicting human reaction time to unexpected events. These studies expand our understanding of cognitive processes based on EEG and serve as a foundation for practical applications (such as systems improving pilot performance). Additionally, the research analyzes the use of machine learning algorithms to differentiate between two states of activity related to events: anticipation and subsequent action. The goal is to assess the utility of these algorithms in developing detection systems capable of recognizing unexpected events in monotonous tasks. The ultimate goal of this work is to assess the correlation between the band power of the examined EEG signal and reaction time, providing insights into specific brain activities during performed tasks. These results enhance understanding of cognitive processes related to decision-making during events requiring immediate response. Additionally, the study delves into the precise identification of factors contributing to a decline in performance in such critical actions.

This study establishes the following scientific theses. Firstly, predicting reaction time to unexpected events based on EEG data recordings is feasible. Secondly, statistical and data analysis methods enable the identification of brain activity associated with prompt reactions to unexpected events. Finally, applying classification algorithms to EEG data allows to distinguish states of mental alertness related to anticipation and reactions to unexpected events.

The research experiments presented in this dissertation lead to significant conclusions. The SVM-RBF algorithm demonstrated promise in predicting reaction time, achieving an average MAE of 114 ms and the lowest standard deviation of absolute errors at 68 ms. This substantiates the feasibility of EEG-based prediction of reaction time to unexpected events. Statistical methods provided insights into brain activity linked to prompt reactions to unexpected events. Positive correlations between reaction time and Theta, Beta, and Alpha Power were observed across various lobes, with no significant negative correlations. Key features for predicting reaction time included Gamma signal power in the Frontal lobe, Beta and Alpha signal power in the Frontal lobe, and Gamma range signal power in the Temporal lobe. Moreover, statistically significant alterations in brain activity due to unexpected events were evident across cerebral lobes and EEG frequencies, as measured by the ERC metrics. These findings highlight the detectability of reaction-related changes in EEG recordings. Further exploration reveals the potential to distinguish between states of anticipation and reaction using machine learning models. The neural network classifier, with a mean accuracy of 77.77%, proves to be the most effective in this research.

The dissertation comprises three main papers arranged in a logical sequence, all unified by a central theme: the analysis of EEG signals in response to unexpected events, digital signal processing, and correlation with established states of brain activity. In addition, three supporting papers are included to provide further insight into the underlying assumptions and conclusions of the main articles.

The dissertation is organized into several consistent chapters to enhance navigation and comprehension. Chapter 1 provides the background information on EEG and its applications, reviewing the current literature, and formulating the three main theses of the work. Chapter 2 delves into fundamental concepts, structures, challenges, and methodologies in EEG signal processing and predictive analysis, exploring theoretical principles, experimental details, and materials and methods. Chapter 3 comprises a compilation of six scientific publications, offering a comprehensive view of the scientific theses and empirical investigations. Chapter 4 involves a detailed analysis of key findings, comparing them with the latest literature. Finally, Chapter 5 contains conclusions, a summary of achievements, and outlines potential future work.