



## GAZE-BASED DETECTION OF COGNITIVE FATIGUE IN E-LEARNING: STATISTICAL ANALYSIS AND MACHINE LEARNING APPROACHES

Ireti Hope Ajayi<sup>1\*</sup>

Faculty of Software Engineering and Computer Systems,  
Information Technologies, Mechanics and Optics (ITMO) University,  
Russia  
[ihajayi@itmo.ru](mailto:ihajayi@itmo.ru)

\*Corresponding Author email: [ihajayi@itmo.ru](mailto:ihajayi@itmo.ru)

Submitted: 30 June 2025

Revised: 31 August 2025

Accepted: 10 September 2025

Peer-review under responsibility of 9th ASIA International Multidisciplinary Conference (Songkhla, Thailand) Scientific Committee

<http://connectingasia.org/scientific-committee/>

© 2025 Published by Readers Insight Publisher,

Office # 6, First Floor, A & K Plaza, Near D Watson, F-10 Markaz, Islamabad, Pakistan,

[editor@readersinsight.net](mailto:editor@readersinsight.net)

This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).



## ABSTRACT

The research focuses on the deployment of gaze (eye-tracking) information to identify patterns of cognitive exhaustion in e-learning environments. Through, a continuous observation of key eye metrics like pupil diameter, fixation duration, saccadic movements, and blink rate, the study aims to give real-time insights into the level of interest, active participation as well as motivation that shows during learning process. In the research, gaze information in an online learning session were collected pre-processed using iterative imputation and label encoding. A composite fatigue score was developed from several gaze metrics, and participants were categorized into low, moderate, and high fatigue groups based on percentile thresholds. The data obtained were subjected to a statistical analyses, including ANOVA and correlation analysis, revealed that pupil diameter reflect a strong negative correlation with cognitive fatigue ( $r = -0.74$ ), whereas time to first fixation showed a moderate positive correlation ( $r = 0.48$ ). Meanwhile, this work adopts Naïve Bayes, K-Nearest Neighbors, and Random Forest Machine learning models that were trained to classify fatigue levels, with Random Forest achieving the highest accuracy (87%). The results shows that using gaze-based metrics with advanced analytics effectively monitors fatigue in real-time, this supporting the development of adaptive and personalized e-learning systems. This approach has significant implications for enhancing learner well-being and optimizing instructional strategies in online education. In future, the findings could be integrated into adaptive e-learning platforms to provide personalized interventions in real-time.

**Keywords:** *Gaze; Cognitive Fatigue; E-Learning; Statistical Analysis; Machine Learning*