Evaluation of EEG and EOG Parameters for Mental Fatigue and Microsleep Assessment in Drivers

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***Abstract*—Mental fatigue and drowsiness during monotonous driving can impair attention and lead to microsleep episodes, thereby increasing the risk of traffic accidents. Objective assessment based on physiological signals may complement behavioral monitoring and provide more direct information about changes in driver vigilance. Therefore, we conducted an experiment in which electroencephalograms (EEG), electrooculograms (EOG), and synchronized video recordings were obtained from 10 healthy young adults during a simulated driving task using the Desert Bus game. The analysis focused on behavioral states: Alert, Pre-Microsleep and Post-Microsleep. Microsleep episodes were identified from the video recordings, and five participants with clearly observable events were included in further analysis. The theta-plus-alpha to beta ratio (*TABR*) and the median blink duration (*MBD*) were calculated for the selected behavioral states and expressed as percentage changes relative to an additional Reference segment representing alertness. Both *TABR* and *MBD* increased in the Pre-Microsleep and Post-Microsleep segments compared with the Reference segment. Despite intersubject variability, both parameters showed a similar overall trend around the identified microsleep episodes. These preliminary findings suggest that combined EEG and EOG analysis may support the assessment of fatigue-related physiological changes and microsleep occurrence during monotonous driving.**

Keywords—electroencephalography, electrooculography, mental fatigue, microsleep, driver drowsiness

I. Introduction

Mental fatigue is a multidimensional state that can develop during prolonged cognitive activity. Usually, it is accompanied by reduced energy and changes in cognitive and behavioral performance [1]. The main effects of mental fatigue include impaired attention, prolonged reaction time, a reduced ability to recognize potential hazards, and an increased probability of errors. These changes are particularly critical during monotonous driving, where a gradual decline in vigilance may contribute to drowsiness, microsleep, and an increased risk of road traffic accidents [1], [2].

Methods for driver fatigue and drowsiness detection can generally be divided into subjective, behavioral, vehicle-based, and physiological approaches. Subjective scales are simple to administer but depend on self-assessment. Behavioral and vehicle-based systems usually evaluate facial and ocular features, head position, car position on the road, or steering wheel movements. Several of these approaches have already been incorporated into modern vehicles. However, their reliability may be affected by environmental conditions and individual behavior [1], [3]. Physiological signals provide a more objective approach to assessing internal changes associated with fatigue and drowsiness. Furthermore, combining multiple physiological modalities may provide complementary information about the driver's current cognitive state [1].

Among physiological approaches, electrooculography (EOG) and electroencephalography (EEG) are particularly relevant because they capture complementary neural and ocular manifestations of declining vigilance. EEG activity is commonly examined within frequency bands corresponding to delta (δ), theta (θ), alpha (α), and beta (β) oscillations [4]. In most studies, these bands are defined as δ at (1 – 4) Hz, θ at (4 – 7) Hz, α at (8 – 14) Hz, and β at (15 – 35) Hz. Mental fatigue and drowsiness are generally associated with a redistribution of EEG spectral power, characterized by an increase of θ and α activity and a decrease in β activity [5], [6]. These changes can be evaluated either separately for individual frequency bands or by using spectral ratios that summarize the balance between lower and higher EEG frequency bands. The theta-plus-alpha to beta ratio (*TABR*), calculated as $(\theta + \alpha)/\beta$, has therefore been investigated as a compact indicator of fatigue and drowsiness-related EEG changes [6], [7]. EOG, in contrast, measures changes in corneoretinal potential as rotations of the eye, which acts as an electrical dipole, alter the potential difference recorded by electrodes placed around the eye. Parameters commonly derived from EOG include blink frequency, blink duration, inter-blink intervals, or spectral power of ocular activity [8]. Their relationship with fatigue is not necessarily monotonic, particularly for eye blink frequency, which may vary across different stages of mental fatigue and drowsiness. However, prolonged blinks and longer eyelid closures are consistently associated with reduced alertness and an increased tendency to fall asleep [8], [9]. Median blink duration (*MBD*) may therefore provide a robust representation of blink-length changes while reducing the influence of isolated extreme values.

Thus, this conference paper investigates physiological changes associated with mental fatigue and microsleep during a monotonous simulated driving task using the Desert Bus game. Synchronized camera recordings were used to identify behavioral signs of declining vigilance and microsleep episodes, allowing the physiological data to be evaluated in relation to visually observed events. EEG and EOG were recorded simultaneously to capture complementary changes in brain and ocular activity [10]. The analysis focused on the *TABR* and *MBD* evaluated in behavioral-cognitive states: