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Electroencephalographic study of drowsiness in simulated driving with sleep deprivation

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Abstract

Drivers' drowsiness is one of the main causes of car accidents or near-missed accidents. This has been proven by many studies that established links between driver's drowsiness and road accidents. The objective of this study was to analyze the EEG changes in fatigued subjects while performing a simulated driving task. After a night of sleep deprivation, eight subjects were given a dose of caffeine to reduce drowsiness. During about 50 min of continuous driving, car movements and subject behaviors were recorded on video cameras, and 8 channels of EEG were also recorded. Three basic indices, three ratio indices, and two burst indices were calculated from preprocessed EEG signals. EEG α,β, β/α and $(\alpha+\theta)/\beta$ indices showed significant differences between driving periods. In the comparison of road type, EEG α,β, β/α and $(\alpha+\theta)/\beta$ indices of the straight section of the driving task were significantly different from those of the curved section. This study also analyzed EEG changes before and after car accidents, showing that β and $(\alpha+\theta)/\beta$ were related to the mental alertness level. In the analysis of burst activity, θ burst activity, which was not significant in the mean power analysis, was significantly different between driving sessions.

Relevance to Industry

Driver's drowsiness is a major cause of serious traffic accidents. This study deals with time variant EEG change of sleep-deprived drivers—an important aspect of driver drowsiness analysis.

The result of this study can be used to estimate overall alertness level of drivers.

Keywords: EEG; Driver's fatigue; Drowsiness; Driving simulator; Alpha burst

1. Introduction

Fatigued drivers cannot focus on driving and tend to commit manipulation errors. Their information

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processing speed and memory capacity are decreased and a drastic change in task performance occurs (Wylie et al., 1996). The existing statistical data and survey reports indicate that the driver's fatigue is one of the major causes of traffic accidents (Ryan, 1995; Shuman, 1992). However, research on counter-measures for traffic accidents focuses on the reinforcement of safety devices, elimination of road defects, and laws and regulations, with little attention given to the driver's human factors aspects.

Fatigue can lead to drowsiness and sleepiness. The terms 'sleepiness' and 'fatigue' are used synonymously to mean sleepiness resulting from the neurobiological processes regulating circadian rhythms and the drive to sleep (Dinges, 1995). Many studies show the close relationship among drowsiness, sleepiness, and fatigue. Sleepiness is one of the main factors of the driver's fatigue, and drowsiness can be used as a criterion for determining the driver's fatigue. There are various causes of the driver's fatigue such as duration of continuous driving, sleep deprivation, circadian rhythm, driving environment, and the driver's personal characteristics. This study focuses on the driver's drowsiness caused by sleep deprivation and its relation to car accidents.

The driver's drowsiness can be detected in several ways. It can be directly captured from video images (Summala et al., 1999), the rate and duration of the EOG (electrooculogram) (Horne and Reyner, 1996), and estimated through various analyses of EEG (Horne and Reyner, 1995; Khardi and Vallet, 1994; Lal and Craig, 2002). It can also be estimated from other biosignals such as ECG (electrocardiogram), body pressure, and respiration (Milosevic, 1997; Chung et al., 1999). This study adopted EEG as a proof of the driver's drowsiness.

It has been recognized that the changes in the EEG theta band and the alpha band reflect cognitive and memory performance (Klimesch, 1999). EEG beta band is related to alertness level, and as the activity of beta band increases, performance of a vigilance task also increases (Scerbo et al., 2000).

There have been several EEG studies related to driving. Åkerstedt and Thorsvall (1984) and Åkerstedt et al. (1991) reported that EEG power of alpha and theta bands was increased as the alertness level of the driver decreased. Petit et al. (1990) showed a close correlation between the movement of the steering wheel and the power of EEG alpha band. Waard and Brookhuis (1991) showed that the relative energy parameter ($(\alpha+\theta)/\beta$) of the driver decreased as the driving task continued. Lal and Craig (2002) showed that significant electroencephalographic changes of four bands occur during fatigue. Schier (2000) used a driving simulator to observe EEG during the driving task. Four channels (F3, F4, P3, P4) of EEG were measured from frontal and parietal lobes, and the results showed that the attention level of the driver decreased, and that the relative power of alpha waves increased as the repetitions of the same course increased. Though many studies on the driver's fatigue with EEG have been performed, most of them merely showed the binary difference between the opening part and ending part of the driving task. A few studies even showed conflicting results (Åkerstedt and Thorsvall, 1984; Brookhuis, 1995).

The objectives of this study were (1) to observe EEG changes as time proceeds, (2) to compare the EEGs of the driver on straight/curved roads, (3) to observe the EEG difference between pre-accident and post-accident, and (4) to analyze EEG alpha and theta burst and its relationship to microsleep.

2. Method

2.1. Subjects

The previous research found that there is a difference in the degree of fatigue felt by drivers older than 30 years of age and that felt by drivers younger than 30 (Brown, 1995). Ryan (1995) reported that the number of the traffic accidents caused by male driver's fatigue was different from that of women drivers. To reduce inter-subject differences, all subjects were males in their mid-20s with at least 2 years of actual driving experience. Average age of the selected participants was 26.1 years, and on the average they got up at 9:30 AM and went to bed at 2:15 AM. They drove after 10 P.M. approximately once a month.