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REGRESSION ANALYSIS OF DECISION-MAKING SKILLS (DMS) USING BETA WAVES FOR CRITICAL DRIVING FATIGUE FACTORS

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ABSTRACT

Driving fatigue study is becoming increasingly popular as the frequency of fatigue-related accidents rises in many nations. However, there has been little research on the role of cognitive skills such as decision-making skills (DMS) and the factors that influence them in detecting driving fatigue. The study's goal is to conduct a regression analysis to discover whether variables such as driving duration, body mass index (BMI), types of roads, and gender are relevant in impacting DMS, as well as how these variables interact to indicate driving fatigue. An electroencephalogram (EEG) was used to assess DMS using beta, β brain waves. The regression analysis was carried out using Design Expert software. ANOVA analysis revealed that all variables had significant effects on β-waves (DMS), with Prob > F values less than 0.05. As drivers fatigue, their β-waves diminish, indicating impairment in DMS. β-waves diminish with prolonged driving duration and elevated BMI. Simultaneously, β-waves decrease as the road's geometry transitions from winding to monotonous and the gender shifts from male to female.

KEYWORD

Driving fatigue, decision-making skills, Design Expert software, regression analysis

INTRODUCTION

Driving fatigue is a major cause of traffic accidents in many countries because it slows reaction times, impairs judgment, and reduces attention, hence increasing the risk of crashes, injury, and death. In wealthy nations, driver fatigue accounts for 5-50% of vehicular accidents, with median figures ranging from 15-25% [1]. To reduce fatigue-related vehicle crashes, indicators of driving fatigue, as well as the variables that influence it, must be recognized and investigated.

Research indicates that cognitive abilities, such as decision-making skills (DMS), serve as reliable indicators of driving fatigue. DMS is a sophisticated cognitive process that entails choosing a belief or action from a range of alternatives based on specific criteria [2]. For example, a sudden, unforeseen impediment (e.g., a stationary vehicle, debris, or a pedestrian) emerges in the driver's trajectory. In this constrained situation, the driver must evaluate several factors prior to deciding, such as the time to collision (typically mere seconds), the available space in adjacent lanes or on the shoulder, the presence of other vehicles or pedestrians in alternative routes, and the vehicle's capabilities (braking and steering proficiency). Consequently, drivers lacking adequate DMS are at a heightened risk of being involved in accidents. Hence, the objective of this study is to conduct a regression analysis to identify which variables, including driving duration, body mass index (BMI), types of roads, and gender, significantly influence DMS and how these variables combine to signify driving fatigue through β-waves.

MATERIAL AND METHODOLOGY

This study employed Design Expert software to perform regression analysis to investigate the relationship between driving duration, BMI, types of roads, and gender (independent variables) and DMS (dependent variable) in indicating driving fatigue. The experimental design was initially formulated according to the lowest and maximum levels of the independent variables, as detailed in Table 1.

The entire experiment in this study was performed on an actual roadway. The monotonous road driving tests were performed from Ayer Keroh Plaza Toll to Pedas Toll Plaza / Linggi Inbound, satisfying the criteria for monotonous roads, including low traffic, minimal turns, and consistent noise levels. The winding road driving tests were conducted from Kolej Al-Jazari UTeM to Jalan Simpang Gading/Kesang Pajak/Jalan Tangkak-Durian Tunggal. This route meets the criteria for winding roads, characterized by three or more curves separated by a tangent distance of less than 600 feet. A commercial 14-electrode EMOTIV EPOC X EEG headset was utilized to measure the β-waves. The EEG frequency was initially recorded for five minutes before to driving. The second recording was made in the last 5 minutes before to the completion of the driving assignment. The amplitudes of β-waves are maximal in the frontal regions [3,4]. Consequently, utilizing the worldwide 10-20 electrode placement technique, β-waves were recorded from the AF3, AF4, F3, F4, F7, F8, FC5, and FC6 electrodes. The BrainVision Analyzer software was utilized to process the unrefined EEG data.

Table 1: Minimum and maximum level of independent variables

Independent Variable	Level		
Driving Duration, minute	1-40		
Body Mass Index, kg/m²	18.5-24.9 (Healthy)	25.0-29.9 (Overweight)	30.0-35.0 (Obese)
Types of Roads	Monotonous	Winding	-
Gender	Female	Male	-

RESULT AND DISCUSSION

Table 2 presents the Analysis of Variance (ANOVA) conducted using Design Expert software. The findings indicate that the model was significant, as the sum of squares value of 73.49 was below 0.05. The Prob>F values for A= Driving Duration, B= BMI, C= Types of Roads, and D= Gender were all below 0.05, signifying that the covariates exerted significant impacts on the β-waves (DMS).

Table 2: ANOVA

Source Model	Sum of Squares	DF	Mean Square	F-Value	Prob>F	
	73.49	4	18.37	221.80	< 0.0001	Significant
A	21.35	1	21.35	257.70	< 0.0001	Significant
B	22.70	1	22.70	274.01	< 0.0001	Significant
C	17.68	1	17.68	213.42	< 0.0001	Significant
D	11.77	1	11.77	142.05	< 0.0001	Significant
Residual	3.89	47	0.083	-	-	-
Lack of Fit	2.36	31	0.076	0.79	0.7208	-
Pure Error	1.54	16	0.096	-	-	-
Cor Total	77.38	51	-	-	-	-
Std. Dev.	0.29	0.29	R-Squared			0.9497
Mean	13.36	13.36	Adj R-Squared			0.9454
C.V.	2.15	2.15	Pred R-Squared			0.9393
PRESS	4.70	4.70	Adeq Precision			66.655

A study summarised that 13 out of 19 studies showed a reduction in β-waves as individuals experienced fatigue [5]. Figure 1(a) illustrates the variation in DMS as driving duration increased, and β-waves diminished. The significant reduction in DMS observed with prolonged driving duration may be ascribed to the stress encountered when driving. Cumulative stress adversely affects brain regions associated with stress response and neurocognitive functioning, leading to diminished structural integrity and cognitive abilities, including DMS.

Figure 1(b) demonstrates that as BMI escalates from 18.50 kg/m² (healthy) to 35.00 kg/m² (obesity), the β-wave pattern diminishes, indicating that drivers with elevated BMI have significantly compromised DMS. Obese adults with significant cognitive impairment may be attributed to obesity-related health issues such as cardiovascular complications like hypertension. Individuals with hypertension experience a more rapid decline in cognitive functions, including thinking, judgment, and memory recall, compared to those with normal blood pressure [6].

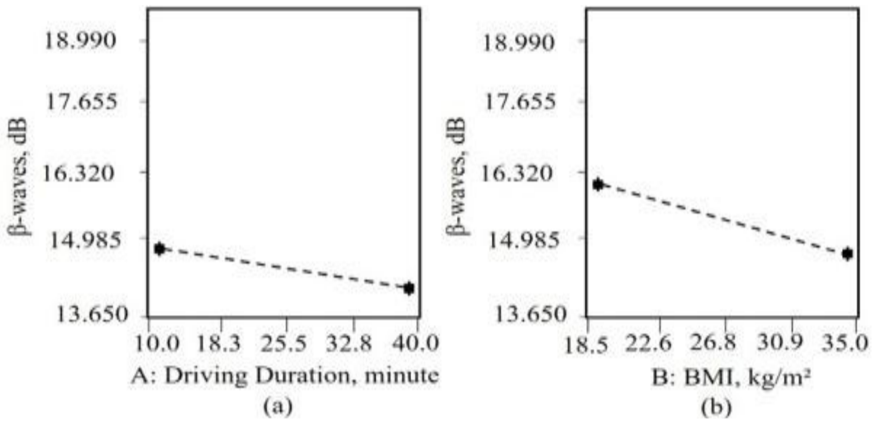

Figure 1: Interaction between independent variable and β-waves (DMS)
(a) driving duration; (b) BMI

Figure 2(a) demonstrates that β-waves diminished when the route design transitioned from winding to monotonous. The results indicate that operating a vehicle on less-challenging, monotonous roads markedly diminished the driver's DMS, signifying fatigue. DMS decreases while navigating an identical road, potentially associated with a physiological indicator of boredom when engagement diminishes due to insufficient geometric diversity and task exertion.

Figure. 2(b) illustrates the reduction of β-waves when female drivers replaced male drivers. The fluctuation of sex hormones may elucidate the reduction in β-waves. A study indicates that women exhibit a greater susceptibility to stress while driving compared to men, attributable to their distinct hormonal system, with certain gender disparities manifesting during the reproductive years and progressively diminishing post-menopause [7]. Cumulative stress adversely affects brain regions associated with stress response and neurocognitive functioning, leading to diminished structural integrity and cognitive abilities, including DMS.

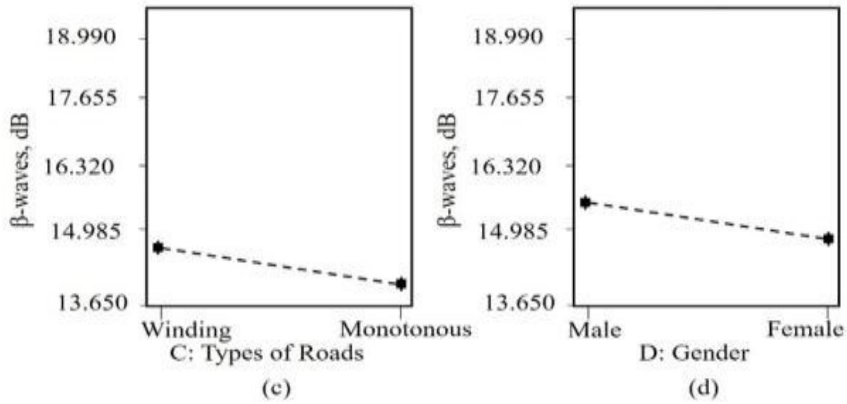

Figure 2: Interaction between independent variable and β-waves (DMS)
(a) types of roads; (b) gender

CONCLUSION

The ANOVA results indicate that all input factors (A= Driving Duration, B= BMI, C= Types of Roads, and D=Gender) possess Prob>F values below 0.05, signifying that each variable significantly influences β-waves (DMS). The results align with previous studies, since β-waves decrease with driver fatigue, signifying a reduction in DMS. Due to the stress associated with hazardous driving conditions, β-waves diminish as the time of driving extends. Simultaneously, β-waves diminish as BMI increases due to health issues associated with obesity. Physiological markers of boredom, influenced by road geometry and sex hormone variations, result in a decrease of β-waves when the route transitions from winding to monotonous and when the gender shifts from male to female.

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