Impacts of Drivers’ Physiological and Psychological Characteristics on Road Traffic Safety Based on Traffic Safety Management Database

Hui-ting Cheng
Chongqing Vocational College of Transportation, Chongqing, 402247, China
e-mail: 230198689@seu.edu.cn

Abstract: As traffic accidents dramatically increased on highways, this paper aims to study how drivers’ physiological and psychological characteristics can affect traffic safety. This paper studies and analyses the physiological and psychological characteristics of drivers during highway congestions, including drivers’ eye blink rate, level of fatigue and heart rate. Moreover, the k-means clustering algorithm is used to determine the relationship between the drivers’ level of fatigue and dangerous driving paths. It is found that the drivers’ average blink rate under traffic congestion is higher than those under normal conditions, which indicates that traffic congestion can affect the driver’s visual state; The longer traffic congestion lasts, the higher level of fatigue the drivers have, and the more dangerous driving paths appear. This paper can provide a theoretical basis for the studies of how to reduce unsafe driving behavior resulting from drivers' dangerous driving convictions.

1. Introduction
Highway has become the primary transportation means for Chinese residents. The rapid development of the highway system also plays an important role in promoting China's economic growth. Due to the cost-effectiveness of highways, the highway system occupies a very important position in the overall transportation system [1, 2]. However, highway transportation also has certain drawbacks, for example, highway accidents can have dramatic consequences. Compared to a common road traffic accident, a highway accident can cause more severe personal injuries and property damage [3]. Normally the occurrence of a traffic accident is determined by the driver, vehicle, and driving environment combined. Innumerable dangerous driving cases have resulted from the change of the driver's physiological and psychological characteristics. [4]. But no matter what type of traffic accident occurs, the decisions made by the drivers play a dominant role. Therefore, the physiological and psychological characteristics of drivers are the most important factor determining whether a traffic accident would occur or not.

Chen found that when a driver was in a positive mood, the driver made negligible wrong moves during driving and had an extraordinarily high driving efficiency; however, when the driver was in a negative mood, the likelihood of the driver making wrong moves during driving was significantly increased [5]. From this study, it can be seen that the psychological characteristics of drivers have a great impact on overall driving safety, indicating that drivers need to maintain a positive attitude during driving so as to ensure driving safety. It is inevitable that drivers will encounter tunnels while driving on the highways. Zhang et al. found in a study that the overall physiological condition of drivers in a tunnel with normal lighting was significantly improved compared to that in a short tunnel without lighting, which indicates that certain physiological problems will arise when drivers are driving through
a short tunnel without lighting [6].

From the above studies, it can be found that drivers’ physiological and psychological characteristics will have a huge impact on driving safety. Therefore, based on previous researches, this paper conducts further research on the impact of drivers’ physiological and psychological characteristics on road traffic safety, in the hope of providing certain theoretical support for highway driving safety issues.

2. Methods

2.1 Characteristics of Highway Congestion
Highway congestion has several typical characteristics, which can be summarized as below.

1) Regularity. Highway congestion usually has a regular pattern. On the first day and the last day of holidays, influenced by peaks in outbound and inbound travel, highway congestion is more likely to occur.

2) Conductivity. Traffic congestion appears in one section of the highway will have a huge impact on the subsequent sections, especially when the congestion happens in toll booths, in which case the road will get more congested.

3) Unpredictability. In addition to holidays, severe weather and traffic accidents will also lead to traffic congestion. The latter two factors are unpredictable and extremely sporadic.

2.2 Impacts of Highway Congestion
Highways, as a major means of transportation, bear a certain amount of traffic pressure. Therefore, traffic congestion on highways has great adverse impacts, which can be described from the following aspects.

1) Highway congestion will increase people's travel time and cost. Traffic congestions are likely to cause traffic delays. The utilization rate of highways will be reduced substantially and the transportation efficiency of highways will be greatly decreased.

2) Highway traffic congestion will have varying impacts on the psychological and physiological conditions of passengers. On one hand, it will impact the psychological conditions of the passengers and drivers, most of whom will feel anxious and irritable during waiting. On the other hand, it will impact their physiological conditions. Some people may have physiological problems, such as back or leg pain, dizziness, nausea, and a full bladder due to traffic congestion.

3) When traffic congestions occur, a considerable amount of fuel will be wasted. During traffic congestions, cars need to be started and braked frequently, dramatically increasing the fuel consumption. Correspondingly, the emissions of car exhaust will increase, which will intensify air pollution.

2.3 Physiological and Psychological Characteristics of Drivers
During highway congestions, normally drivers will have a sense of anxiety, irritability, and other negative emotions, which will lead to non-standardized driving behavior, indirectly increasing the occurrence of traffic accidents. Therefore, this paper analyzes the physiological and psychological changes of drivers during traffic congestion.

Drivers’ driving state can be represented by drivers’ blink rate and level of fatigue. In terms of blink rate, there are three types of blinking, which are spontaneous blinking in normal conditions, reflex blinking in response to an external stimulus, and voluntary blinking resulted from personal conscious control. Blinking is not only a representation of human physiological needs, but also a reflection of their personal psychological changes. When a person is under stress or in other negative moods, the blink rate will increase significantly. When a person is in a positive mood, the blink rate will decline significantly. Besides, when a person’s mood changes from negative to positive, his/her blink rate will also decrease to some extent.

The level of fatigue refers to the percentage of eyelid closure over the pupil within a specified time frame, which can be categorized into three grades: P70, P80, and EM. P70 refers to the case when the proportion of the pupil shaded by the eyelid exceeds 70%. P80 refers to the case when the proportion of
the pupils shaded the eyelids exceeds 80%. EM refers to the case when the proportion of the pupils shaded by the eyelids exceeds 50%. Also, the percentage as well as the mean percentage of eyelid closure time within a specified time frame shall be measured separately. The level of fatigue can be obtained through the formula shown below.

\[ f = \frac{t_3 - t_2}{t_4 - t_1} \]  

(1)

Where \( t_1 \) refers to the time used for eyes to change from fully closed to 80% closed; \( t_2 \) is the time from 80% closed to 20% closed; \( t_3 \) is the time from 20% closed to 20% open; \( t_4 \) is the time from 20% open to 80% open. According to the definition of level of fatigue specified above, when \( f < 0.4 \), the driver is fully awake and when \( f > 0.4 \), the driver is fatigued.

When analyzing drivers’ physiological state, the ECG signal can be obtained to study drivers’ physiological changes based on the drivers’ heart rate, heart rate growth rate, and heart rate fluctuation. The PC-80B ECG detector was used for ECG signal detection.

2.4 Simulation Experiment
From the traffic safety management database, we obtained the data of highway sections to be studied in this paper. A total of 13 participants have met the following criteria: (1) holders of corresponding driver’s licenses with a driving history of more than three years; (2) in good mental and physical health with no major diseases including heart diseases; (3) with normal color vision, and the naked or corrected visual acuity of both eyes greater than 1.0; (4) with extensive experience in highway driving; (5) aged between 25 and 45 years old.

To achieve a more effective research result, the participants should have a good diet and sleep before the experiment, and refrain from alcohol or taking drugs that may lead to physical condition change within 48 hours prior to the experiment. Also, the drivers and other assistants in cars should turn off their mobile phones and stay quiet during the experiment to ensure the accuracy of the research result.

2.5 Dangerous Driving Path Recognition Based on Clustering Algorithm
K-means clustering: First, determine the K clusters to be partitioned and select K cluster centers. Then, assign each sample point to the cluster with the nearest cluster center based on the distance (similarity) between each sample point and each cluster center [7, 8]. Recalculate means for sample points assigned to each cluster and take them as the new cluster centers. When the cluster centers no longer change or the difference between the two cluster centers is less than a threshold value specified in advance, the clustering process stops and K clusters are formed. Take the one-dimensional data containing \( n \) observations as an example (high-dimensional data similarly). Assume the selected one-dimensional sample set to be \( \{x_1, x_2, x_3, \ldots, x_n\} \). The Euclidean distance is shown in Formula 2 and the clustering algorithm is shown in Figure 1.

\[ d = \sqrt{\sum_{k=1}^{n}(x_k - y_k)^2} \]  

(2)

Where \( d \) is the Euclidean distance between the two samples. Since each attribute in the dataset has a different meaning and contributes differently to the clustering, it is necessary to consider the weights of the attributes and express the contribution of each attribute to the clustering in terms of weights. Then the weighted coefficient of variation method can be applied to add specific value to the Euclidean distance formula [9]. The coefficient of variation of a dataset is equal to the standard deviation of all the data in this dataset divided by the absolute value of its mean. Assume there are \( n \) data \( x_1, x_2, \ldots, x_n \) and \( p \) attributes in the dataset, as shown in Formula 3, 4, and 5.
\[ S_x = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2} \quad i=1, 2, \ldots, n \]  
(3)

\[ v_i = \frac{S_x}{|\bar{x}|} \quad i=1, 2, \ldots, p \]  
(4)

\[ w_i = \frac{v_i}{\sum_{i=1}^{p} v_i} \quad i=1, 2, \ldots, p \]  
(5)

Where \( v_i \) is the coefficient of variation and \( w_i \) is the weight of each attribute. The weighted Euclidean distance formula is shown in Formula 6.

\[ d(x_i, x_j) = \sqrt{w_1(x_{i1} - x_{j1})^2 + w_2(x_{i2} - x_{j2})^2 + \cdots + w_p(x_{ip} - x_{jp})^2} \]  
(6)

2.6 Statistical Methods
During data processing, the statistical software SPSS26.0 was used to analyze the obtained data. For basic situations, the data are described in a percentile system. The single factor analysis of variance is conducted over different situations. When \( p < 0.05 \), the variance is significant, and the result is statistically meaningful.

3 Results and Discussion
3.1 Results of Blink Rate Analysis
Compare the average blink rate of the participants under normal driving conditions with that under traffic congestion. Through analysis, the results are shown in Figure 2.
From Figure 2, it can be seen that the drivers’ average blink rates increased slightly under normal driving conditions, while the average blink rate increase under traffic congestion was comparably high. The results indicate that the visual state of drivers can be affected by traffic congestions.

3.2 Results of Level of Fatigue Analysis
Analyze the relationship between the level of fatigue and the duration of traffic congestion. The results are shown in Figure 3.

From Figure 3, it can be seen that when the traffic congestion lasts less than 90s, the drivers’ level of fatigue witnessed a linear increase, and the level of fatigue increased as the congestion duration gets longer. A certain fluctuation occurred during 20-40 s followed by a steady increase in the level of fatigue. The results showed that there is a certain relationship between the level of fatigue and the duration of traffic congestion. It can also be seen from the results that the longer the traffic congestion lasts, the higher the driver’s level of fatigue is.
3.3 Results of Heart Rate Change Analysis

Average the heart rates of drivers during driving. The results are shown in Figure 4.

![Figure 4](image)

From Figure 4, it can be seen that the average heart rates of drivers varied greatly during driving. With the occurrence of traffic congestion, the average heart rate of drivers reached multiple peaks. By analyzing the average heart rate data at the time points of 30 s, 60 s, 90 s, 120 s, 150 s, and 180 s, the results can be obtained, as shown in Table 1.

| Time Points | 30s  | 60s  | 90s  | 120s | 150s | 180s |
|-------------|------|------|------|------|------|------|
| Average     | 79.84| 87.59| 83.19| 85.97| 84.96| 84.59|
| Standard deviation | 2.298 | 1.397 | 7.672 | 1.314 | 2.699 | 1.211 |

From the data in Table 1, it can be seen that the standard deviation of the drivers' heart rates reached the largest at 90 s, which indicates that the drivers' heart rates vary considerably at 90 s.

3.4 Results of Dangerous Driving Path Analysis

By means of the clustering algorithm, the average number of dangerous driving paths under different levels of fatigue can be obtained. The results are shown in Figure 5.
From Figure 5, it can be seen that when the level of fatigue of drivers increased, the number of dangerous driving paths also increased, indicating that the higher the level of fatigue, the less safe the driving process will be.

4. Conclusion
Currently, highways bear great traffic pressure. As a result, traffic congestion occurs when there is relatively large traffic flow on the highways. However, during traffic congestion, a series of physiological and psychological changes experienced by the drivers will have certain impacts on driving safety. This paper studies the impact of these characteristics on road traffic safety. Through this study, it is found that drivers' eye blink rate under normal driving conditions is different from that under traffic congestion. As traffic congestion lasts longer, the level of fatigue of drivers increases. Although this study has achieved some results, there are still some shortcomings in this study. Due to the limited number of samples, the results obtained in this study cannot be applied to all kinds of traffic congestions. Therefore, further research shall be conducted to ensure the accuracy of the results obtained in this study.

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