Research on Drivers' Behavior Characteristics of Expressway Straight Section under Moderate Rainfall

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Abstract. Understanding the behavior characteristics of highway drivers in rainy weather is of great significance to traffic safety. Based on the driving test in the middle rain environment, this paper uses the method of combining the sports index and the driver's behavior to study the characteristics of the driver's behavior in the middle rain environment. A total of 15 drivers were recruited in this test to observe the impact of the moderate rain environment on the drivers, and to analyze the correlation of various indicators to summarize the vehicle operation rules on the straight road section under the moderate rain environment. The results of the study show that the speed on straight road sections is generally higher in moderate rain weather, and the driver's recognition time for signage is longer than in sunny day. Finally, according to the behavior characteristics of drivers in rainy days, the corresponding traffic safety measures are put forward.

1. Introduction
Weather conditions are one of the important factors affecting road traffic safety. Adverse weather conditions affecting road safety include rainy, snowy, hazy, and strong winds. Statistics of traffic accidents in my country in recent years show that the number of traffic accidents under rainy conditions accounts for the highest proportion of the total number of accidents[1]. Rainy weather conditions will affect the road conditions and driving environment, and then affect the driver's ability to perceive the surrounding environment and the ability to control the vehicle, so it is easy to cause traffic accidents.

It is dangerous to drive on highways in rainy days. Schlosser LHM studied 36364 accidents on the Dutch national road from 1965 to 1966, of which 2360 occurred on highways on rainy days and 5243 occurred on other roads on rainy days[2]. At home and abroad, the research on the impact of rainy conditions on highways mainly focuses on traffic flow and road surface, and the selected experimental indicators are relatively simple. The US "Road Capacity Manual" describes the impact of rainfall on highway speed and capacity, indicating that light rain will reduce the free-flow speed by about 1.9 Km/h, and heavy rain will cause the free-flow speed to decrease by 4.8-6.4Km/h[3]. Tian Fei et al. verified through P-P charts and single-sample K-S test methods that the speed distribution in light rain and moderate rain conforms to the normal distribution characteristics, and the difference in speed between medium rain and heavy rain is small[4]. Zhang Cunbao et al. determined the distribution rules of microscopic traffic flow characteristic parameters under various rainfall types based on the actual
observed traffic flow and rainfall data of the highway. Under rainy conditions, the average speed of vehicles decreased compared with the average speed of sunny days[5]. After studying the vehicle speed under heavy rain conditions, Agarwal found that the vehicle speed was reduced by 4%-7% under heavy rain conditions, and believed that the proposed reduction value of the US "Road Capacity Manual" for vehicle speed under heavy rain was too large[6]. Zhao Liang conducted a study on the relationship between driver's physiological response and driving safety in three driving environments: sunny, rainy, and snowy. The study showed that the average gaze duration on sunny days is shorter than that on rainy days. Under rainy conditions, the driver's heart rate change rate and the number of operating errors There is a good correlation[7]. Existing studies have shown that rainy weather will affect highway traffic, but there has not been a comprehensive and in-depth study on the behavior characteristics of highway drivers under rainy weather.

This article will analyze the speed, acceleration, and driver's heart rate, blink interval, and other indicators of vehicles driving on the highway in the rainy environment, and summarize the driving behavior and driver characteristics of the highway under rainy conditions. According to the analysis results, corresponding safety guarantee measures are proposed to provide theoretical basis and suggestions for highway traffic safety management under rainy conditions. In this paper, by studying the driving behavior law and driver characteristics of the highway under the rainy environment, reasonable management and control measures are taken to minimize the accident rate of the highway on rainy days and ensure the safety of the highway traffic.

2. Measures

2.1. Experimental indicator

2.1.1. Speed. In this paper, the running speed is used to represent the driving behavior, and the 85th percentile driving speed of the vehicle on the highway is used as the running speed. Vehicle speed is one of the important factors affecting traffic safety. The speed of vehicles running on the highway, especially the speed difference of different road sections, is closely related to the accident rate and the severity of the accident[8]. According to several studies on the impact of speed on road traffic injuries, for every 1% reduction in speed, the number of injuries is reduced by 2-3%, and the incidence of fatal accidents is reduced by approximately 4-6%[9].

2.1.2. Acceleration. The index selected in this paper to characterize driving behavior is also acceleration. The running state of the vehicle during the driving process includes acceleration movement, deceleration movement, and constant speed movement. The acceleration of the vehicle is different under different running states, and the acceleration has different effects on the driver. Huang Jing mentioned in his paper that some studies believe that the peak acceleration of the body is the main factor causing occupant damage. The higher the peak acceleration, the greater the impact on the human body during the collision[10].

2.1.3. Heart rate. In this paper, heart rate is used to characterize the psychological characteristics of drivers. Heart rate refers to the number of heartbeats per minute in a normal person in a quiet state, generally 60 to 100 beats per minute. The individual's heart rate is related to age, gender and other physiological factors. During driving, the driver's heart rate will change with cognition, especially when the information load is large and the manipulation requirements are complex, the heart rate increases significantly, and the driver will be accompanied by a high heart rate response during emotional stress[11]. When the driver receives more information, intensive operations, or encounters large structures such as bridges, bridges, tunnels, etc., the heart rate changes are more obvious.

2.1.4. Blink interval. In this paper, the blink interval is used to characterize the driver's visual characteristics. The blink interval is the time difference between two blinks. Blink frequency refers to
the number of blinks per unit time. The greater the blink interval, the lower the blink frequency. The eye is a channel for the driver to obtain visual information, and can also reflect the driver's mental state. Previous studies have shown that blink frequency is related to driver fatigue.

2.2. The experiment road
The straight road section has a broad vision, but the straight road section has some safety hazards. If the straight section is too long and the roadside landscape is monotonous, it is easy to cause visual fatigue and psychological fatigue of drivers, and they cannot respond to emergencies in time. In addition, the straight section does not require too much operation, the driver is more likely to relax his vigilance, pay less attention to driving safety, and the insufficient safety risks are expected to cause frequent accidents. Therefore, a straight section of 3000m on the expressway was selected as one of the experimental sections to exclude the influence of other factors on the driver's characteristics.

2.3. Experiment
The test road selected in this paper is a highway in Shaanxi Province, with a design speed of 80Km/h. A straight section of the highway was selected for the experimental section. The test subjects were 15 drivers, 9 male drivers and 6 female drivers. Both eyes had naked vision or corrected vision of 5.0 and above, and the driving age was more than 5 years.

The test weather conditions were moderate rain. Connect the data cable to the computer and the OBD interface on the vehicle, and the speed data of the vehicle can be obtained through the Ecantools software. Installing acceleration sensors at the vehicle level can obtain acceleration data of the vehicle's driving direction. Install an angle sensor on the steering wheel of the vehicle to obtain the steering wheel angle data of the vehicle. The sensor is attached to the driver with a patch, and the driver's heart rate data can be obtained through the Biopac multi-lead physiological recorder. The driver wears the SMI eye tracker and can obtain the blink data of the driver. The driver wears the instrument without affecting the driving, and the test vehicle is installed with sensors that can record the vehicle speed, acceleration, steering wheel angle in real time.

Each driver drives the test section in a sunny environment. When the test section is in a moderate rain environment, each driver drives the test section again. Start the vehicle at a certain distance before the straight section, turn on the wiper, measure the driver's heart rate before each test, and start when the driver's heart rate is stable. Drivers are required to follow their usual driving habits while observing traffic rules. After the car is started, it will start timing and record the time when the car enters and exits the test section. In the test, the staff did not talk to the driver and did not affect the driving status of the driver. After the test, remove the test equipment and export all data.

3. Analyse
In this study, a total of 15 drivers were tested, each driver conducted a total of two sets of experiments, a total of 30 sets of experimental data. According to the validity of each index data, 24 sets of effective experimental data were finally obtained.

3.1. Correlation analysis
The vehicle movement indexes and driver physiological and psychological indexes of different drivers on straight road sections are averaged. Pearson correlation analysis was performed on each index of straight road sections, and Tables 1 was obtained through SPSS software.

| Table 1. Correlation analysis of straight section. |
|-----------------------------------------------|
| Heart rate | Blink interval | Speed | Steering wheel angle | Acceleration |
| Heart rate | 1 | -.279 | -.290* | .105 | .163 |
| Blink interval | -.279 | 1 | -.161 | -.092 | -.100 |
| Speed | -.290* | -.161 | 1 | -.269* | -.396** |
| Steering wheel angle | .105 | -.092 | -.269* | 1 | .394** |
| Acceleration | .163 | -.100 | -.396** | .394** | 1 |
It can be seen from Table 1 that in the straight line section, the correlation between heart rate and speed is significant, the correlation between speed and acceleration is significant. The results show that under rainy conditions, when a driver passes a straight section, there is a certain connection between the driver's psychological and physiological state and driving behavior.

3.2. Driver behavior analysis

![Figure 1. Driver behavior on straight roads on rainy days.](image)

![Figure 2. Driver behavior on straight roads on sunny days.](image)

Draw the change curve of the driver's driving behavior index with time during driving in sunny and rainy days, as shown in Figure 1 and Figure 2. It can be seen from the figure that the speed of the driver entering the straight road section in rainy days is about 75Km/h as in sunny days, but the driver accelerates to more than 100Km/h in 30s under rainy conditions. The deceleration behavior lags, and there is a deceleration near the end of the road. On a clear day, the driver decelerates after seeing the distance confirmation sign. The speed of the straight section on rainy days is more than 100Km/h for 65s, which is about 6 times that of sunny days. The study found that driving speeds are higher in rainy weather, and there are overspeed behaviors. However, speeding in rainy weather is very dangerous, and highway management departments should take measures to limit the speed in rainy weather.

3.3. Driver psychophysiological analysis

![Figure 3. Drivers' psychophysiological performance on straight roads on Rainy days.](image)
Figure 4. Drivers' psychophysiological performance on straight roads on sunny days.

Draw the change curve of the driver's driving behavior index with time during driving in sunny and rainy days, as shown in Figure 3 and Figure 4. It can be seen from the figure that the driver's heart rate on the straight section of the road under rain is higher than that of the sunny day, and the blink interval of the driver at the sign is significantly increased, which is about twice that of the sunny day. The study found that under rainy conditions, the driver's recognition time for straight road signs is longer than that of sunny days, and from the above conclusions, it can be seen that the driver's deceleration behavior lags behind. It shows that the signs under the rainy weather have little effect on the driver's reminder, and the signs on the rainy days should be improved, such as the use of more eye-catching LED signs.

4. Safety measures for rainy days

4.1. Infrastructure support

The highway maintenance department shall regularly inspect and maintain the highway drainage system to ensure the smoothness of the drainage system. The designer should reasonably set the location of the service area and parking area of the highway to ensure that vehicles that are still driving on the expressway in extreme weather such as heavy rain can enter the parking area or service area in time to avoid rain. During the field test, we found that under rainy conditions, the recognition distance of the signage on the highway becomes smaller, which is very unfavorable for drivers who are not familiar with road conditions. Compared with ordinary signs, red LED signs are easier to be recognized by the driver in rainy days. Especially the speed limit sign is very important for driving safety. It is recommended to enable the LED sign to remind the driver to limit the speed when it rains. In this study, the driver’s driving speed on straight road sections and small radius round curve road sections under high rain conditions should be given more attention, and speed limit measures should be taken in these road sections.

4.2. Traffic management

The highway management department should accurately grasp the road condition information of each road section, make full use of the variable information boards along the route, promptly and widely publish the weather conditions, actively carry out early warning prompts and road condition broadcasts, remind drivers to pay attention to driving safety, make good countermeasures, and guide safe travel.

When rainfall has a great influence on visibility, driving safety cannot be guaranteed, and reasonable management measures should be taken in a timely manner. Measures such as speed limit, lane management, traffic control, and traffic flow induction can be taken. The expressway management department should also strengthen the emergency response capability to ensure that the danger can be discovered in the first place when an accident occurs, and rush to the scene to deal with the danger in a timely manner to ensure smooth roads.
4.3. Precautions for Drivers
When driving in rainy conditions, the driver should pay attention to slow down, avoid frequent lane changes, and do not blindly accelerate overtaking; maintain a safe distance to ensure good front and rear vision, turn on the headlights and anti-fog lights when necessary to avoid rear-end collision; tighten the steering wheel to prevent side slipping; the road is wet and slippery in rainy weather, avoid slamming on the brakes, slamming the steering wheel, etc. Usually pay attention to regular inspection of the vehicle, and repair it in time when the wiper fails.

5. Conclusions
Through field test data analysis, the curves of various indexes with time when the vehicle is driving on the straight section of the expressway under rainy conditions are obtained, so that the behavior characteristics of rainy drivers are analyzed and obtained. Research shows that the driving speed of the straight line section is higher under rainy conditions, and speeding behavior is common. In this case, if the driver encounters a danger and cannot brake in time, it is easy to cause a traffic accident. Even in the rainy day, the straight section should be reminded to drive The crew controls the speed. In rainy days, the driver's recognition time for straight road signs is longer than that in sunny days, and the deceleration behavior lags after seeing the signs. High-speed traffic police recommended a speed of 80 to 100 kilometers per hour on rainy days. Highway management department should strengthen the speed limit management on the rainy day straight line section, and adopt more easily recognizable signs and signs to avoid the driver’s inability to take measures to cause traffic accidents such as vehicle rollover due to the speed. Based on the test analysis results, this article provides some feasible opinions and suggestions for the traffic management department and the driver, which is conducive to improving the safety of vehicles driving on the highway in rainy days.

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