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Research Article

A Study on Driving Load While Overtaking on Mountainous Two-Lane Highways Based on Physiological Characteristics

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The traffic environment of mountainous highways is more complex than that of nonmountainous highways, with higher driving loads, which increases the risk in overtaking. The changes in the driver's pupils, eye gaze behavior, and heart rate can be used to evaluate the level of driving tension and safety. To analyze the driving load while overtaking on two-lane highways in mountainous areas, an actual vehicle test was conducted. Twenty-one drivers were divided into a skilled group and an unskilled group. The gaze time, gaze transfer characteristics, heart rate changes, and pupil area changes during the three stages of overtaking (intention, execution, and return) were compared and analyzed. The comprehensive evaluation of driving load during the overtaking process used the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method and Rank Sum Ratio (RSR) method. The results show that the two groups of drivers had the highest driving load during the overtaking execution stage and the lowest driving load during the intention stage. The driving load of overtaking on sections with poor-sight distance was significantly higher than that on sections with good-sight distance, and the risk in overtaking during the execution and return stages was highest on sections with poor-sight distance. It is possible to reduce the driving load if the driver is familiar with the road conditions or has a rich driving experience. Compared to the unskilled group, the skilled group had lower driving loads at all stages of overtaking. The research results can provide a theoretical basis for optimizing traffic safety prevention and control technology on mountainous highways and for designing intelligent driving assistance.

Keywords: driver physiology; driving load; mountainous two-lane highways; overtaking behavior

1. Introduction

The environment of two-lane highways in mountainous areas is complex, and traffic accidents occur frequently. Two-lane highways in mountainous areas are characterized by no central divider, multiple bends with small radii, a high density of access points, a high proportion of road sections crossing villages and towns, and a lack of roadside protection facilities. Two-lane highways in mountainous areas have low alignment indicators, poor road alignment, more roadside interference, and obvious mixed traffic. The difficulty of overtaking on mountainous highways is higher than that on nonmountainous highways and urban roads. Improper overtaking often occurs, leading to frequent traffic accidents on mountainous roads. Research has found that indicators such as the capacity of two-lane roads in mountainous areas, road service levels, and the number of road traffic accidents mainly depend on complex and diverse overtaking behaviors [1]. The driving process is a complex activity involving perception, decision-making, and operation. Any perceptual deviation, judgment and decision-making error, or operating error during driving may lead to traffic accidents.

However, on mountainous roads, the overtaking process is more complex and difficult than operation on ordinary sections. Drivers bear greater psychological and physiological loads while overtaking. When the driver's load state is affected by factors of the driver, vehicle, road, and environment, incorrect judgments or operations may be made, which seriously threaten driving safety [2]. Therefore, it is necessary to study the physiological and operational characteristics of drivers during the overtaking process and to evaluate the driving load of drivers at various stages of overtaking.

In this study, the fixation durations of skilled and unskilled drivers while overtaking were compared and analyzed. The K-means clustering method was used to dynamically cluster drivers' fixation points, and Markov theory was used to calculate the one-step transfer probability between different regions of interest. The spatial distribution and transfer characteristics of the fixation points of the two types of drivers while overtaking were compared. The changes in pupils and heart rate during the overtaking process of the two types of drivers, combined with the gaze duration, were analyzed using the entropy weight Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method and the Rank Sum Ratio (RSR) method to evaluate the driving load of drivers in each stage of overtaking, and the level of risk in overtaking in each stage was evaluated. The research results can provide a theoretical basis for optimizing road traffic safety measures in mountainous areas and for developing intelligent driving assistance products.

2. Research Review

2.1. Driving Safety While Overtaking on Mountainous Roads. Musicant and Bar-Gera [3] studied the relationship between the differences in vehicle speed, drivers' personal attributes, the overtaking distance, the overtaking type, and the overtaking frequency. Kaber [4, 5] found that both visual and cognitive distractions increase drivers' workload, but they affect vehicle control and gaze behavior in different ways. Eleni [6] divided the overtaking process into stages such as lane changing, acceleration, and returning to the original lane. Different analytical models for calculating the required line-of-sight distance for safe and comfortable traffic on two-lane highways were reviewed and studied, and a modified model that increases with the increase in design speed was proposed. Dutta [7] explored the behavioral patterns of drivers performing overtaking maneuvers on wide single-lane roads in an unorganized traffic environment. They particularly focused on the initiation and termination of overtaking behavior, which can be used to develop microsimulation models to analyze driver behavior while overtaking in disorderly traffic streams. Xu [8] obtained the trajectory of vehicles driving on dual-vehicle roads in mountainous areas through actual vehicle tests. Based on the characteristics of the LDRT curve, they determined the behavioral mode of driving on the turning curve section of mountainous roads and established a speed model for the entering, turning, and exiting stages of the turning curve section. In the study of overtaking behavior on two-lane highways, Choudhari [9] analyzed 117 accelerated overtaking maneuvers performed by 28 drivers, considering various types of vehicles and recording various parameters during the overtaking process. It was found that overtaking heavy vehicles required the greatest distance and time. Yamada [10] proposed a novel optimal trajectory generation scheme for autonomous vehicles to perform overtaking maneuvers based on the solution to an optimal prediction problem. The goal is to minimize driving costs while maximizing safety by limiting the collision risk, even in the presence of oncoming vehicles in the overtaking lane. Through simulation validation, it was found that the proposed scheme effectively obtains the optimal trajectory by considering various constraints such as road curvature, oncoming vehicles, and slow lead vehicles, demonstrating its efficacy even in challenging overtaking situations. Zhang [11] analyzed the overtaking trajectory on a two-lane highway and found that female drivers had better safety performance than male drivers; additionally, the longer the overtaking distance was, the better the performance of female drivers. In the field of autonomous driving, Ehsan [12] proposed an optimized sigmoid-based path-planning algorithm. Simulations and real-world experiments were conducted with the autonomous shuttle iseAuto. The results indicated that the sigmoid A-star algorithm produces smoother and more reliable motion compared to two standard methods, approaching the maneuver quality of an experienced driver. Zheng [13] found that the longer a driver's gaze is away from the road surface, the poorer his or her lateral control ability of the vehicle. After realizing that their gaze has been away from the road for too long, drivers will balance the longitudinal accident risk caused by visual distraction by reducing their speed and increasing their following distance. To address the issue of blind spots caused by limited perception systems during the overtaking process, Andersen [14] proposed a trajectory optimization method based on Model Predictive Control (MPC) that generates safe trajectories by maximizing the visibility of autonomous vehicles. The effectiveness of the proposed method was verified through experiments in simulated environments and real-world traffic scenarios. Mertens [15] used queuing technology to exchange data about braking maneuvers via V2X (a communication system for vehicle–environment interaction) and automatically react to them, proposing a method of safe distance optimization to ensure trucks make safe and efficient overtaking on the highway. Qin [16] used the overtaking rate as a quantitative indicator of overtaking behavior on urban roads, combined with MYSQL (an open-source relational database management system) and Visual Basic for Applications (VBA) to extract massive video overtaking data, and studied and analyzed the differences in the impact of travel time, speed, and the number of vehicles on working days and nonworking days on overtaking behavior. Taking one-way two-lane overtaking as the object, Yu [17] optimized the artificial potential field algorithm by improving the repulsion potential field function and introducing the repulsion angle rotation. Through the Simulink/CarSim cosimulation platform, the results show that the improved path-planning model successfully realizes the safe overtaking behavior of intelligent vehicles. Zhang [18] established the overtaking model under the background of vehicle–road coordination, analyzed the influence of different driver personalities on the safety potential field during overtaking, and established the overtaking model based on the safety potential field. The results of numerical analysis reveal the relationship between driver type, overtaking distance, and the time and speed of the overtaking vehicle. By improving the shape parameter covariate modeling method, Ji [19] proposed a full-parameter accelerated failure time (AFT) model, combined with the overtaking trajectory data collected by the unmanned aerial vehicle (UAV) for case analysis, and found that the evolution time of overtaking risk is divided into two stages: increasing risk and decreasing risk, and the overtaking phenomenon is serious, and the key covariates of the model are the mean overtaking speed, overtaking distance and relative lateral deviation standard deviation. Reference [20] proposed an approach to autonomous driving based on MAPPO (multiagent reinforcement learning), which aims to ensure that autonomous vehicles can operate safely and efficiently in the event of an emergency vehicle. A risk indicator was introduced in the study to summarize potential collision risks under a single index. The proposed approach aims to generate collaborative strategies that enable emergency vehicles to travel at higher average speeds while maintaining a safe distance.

Although there have been many researches on overtaking safety on mountain roads, there are still few researches on driving behavior in the rugged terrain and complex environment unique to mountain roads, especially the in-depth analysis of drivers' decision-making process and reaction mechanism in mountain roads is insufficient. In addition, according to the characteristics of mountain roads, there is still a lack of comprehensive overtaking safety evaluation index system. Most of the existing studies are based on the standard of flat roads, which cannot effectively reflect the overtaking risk in the special conditions of mountainous areas. At present, there are few research studies on the application of intelligent transportation systems, autonomous driving technology, and other advanced technologies in mountain road overtaking safety, and it is urgent to explore how to integrate new technologies to improve safety. Future research can strengthen the empirical analysis of overtaking behavior on mountain roads, establish targeted theoretical models, improve the evaluation index system, and combine advanced technologies to improve overtaking safety.

2.2. Research on Driver Physiology and Behavior. In the study of driving load, the sensitivity of response tasks is typically used to evaluate the degree of driving load, and parameter calibration is generally carried out through physiological indicators such as visual, tactile, auditory, or electrodermal signals [21–26]. To determine the main factors affecting the driving load, Jiang [27] analyzed the effects of driving experience and temperament types on drivers' driving speed, acceleration, following distance, time interval, and other aspects and established a relationship model between drivers' physiological and psychological characteristics and driving behavior characteristics. Lv [28, 29] found that there is a significant change in mental load when drivers suddenly overtake from a long straight and free driving state on grassland roads. Zhu [30] found that more experienced drivers perceive more danger, and experienced drivers can grasp the deeper characteristics of danger. Using a driving simulator, Zhang [31] collected the eye movement parameters of 30 drivers while overtaking on a highway. The study found that the probability of the driver's gaze staying in both lanes exceeded 70%, and the proportion of gazes on left and right rearview mirrors was 7%. Wang [32] collected driver eye movement behavior data in ultrahigh-altitude areas and found that during the overtaking process, drivers paid the most attention to the current lane and failed to fully observe the driving environment. Liu [33] conducted simulation experiments on 24 drivers and found that as traffic density increased, drivers' willingness to change lanes and overtake increased. The initial overtaking distance decreased with increasing traffic density. Liu [34] conducted a natural driving experiment to study the relationship between drivers' mental stress and writing skills in mountainous road environments and found that the heart rate of drivers while overtaking was significantly higher than that under normal driving conditions. In addition, the heart rate when overtaking large vehicles was significantly higher than that when overtaking small vehicles, and drivers' heart rate significantly increased before overtaking began. Volkan Sezer [35] proposed a new formula for the bidirectional road overtaking problem using Markov decision processes. Vérane Faure [36] found that in general, the blink frequency of drivers can be used to characterize their visual load. However, when driving difficulty increases or drivers are required to complete other tasks simultaneously, the effect of the blink frequency on the characterization of their visual load decreases. Meng [37] recorded visual parameter indicators such as the percentage of the driver's gaze time and other visual parameters in mountainous highway curve sections through actual vehicle tests. The results showed that the visual psychological load of drivers increased with the decrease in turning radius. By monitoring the physiology and behavior of Type 1 diabetes (T1D) drivers in real time, Pranamesh [38] found that they have a higher risk of collision during driving, proposed relevant hypotheses, and monitored T1D drivers with sensors and blood glucose monitors, and the results showed that T1D drivers have impaired vehicle control behavior, especially during hypoglycemia, which helps to detect driving risks in advance. To ensure the safety of high-risk drivers, Zahabi [39] used a combination of driver behavior and eye-tracking measures to classify officers' driving situations. This study compared the use of random forest (RF), support vector machine (SVM), and random Fourier feature (RFF) algorithms on officers' driving conditions and onboard technology.

Abundant research on overtaking safety and driving load has been conducted, and many scientific research results with theoretical and practical significance have been obtained. However, research conducted on mountainous highways has focused on the impact of curved and long downhill road alignments on drivers, neglecting the impact of other vehicles. At the same time, most studies on driving load are conducted by combining a single indicator with linear conditions, while there is relatively little research on the combination of multiple physiological indicators and driving behavior.

Based on the analysis above, this study conducted real vehicle tests on two-lane highways in mountainous areas, analyzed the psychological characteristics and behavioral differences between skilled and unskilled drivers while overtaking under conditions of poor and good-sight distance, and comprehensively evaluated the driving load while overtaking. Furthermore, the significance of this research lies in the following three points: First, identify high-risk factors that can lead to traffic accidents, such as excessive driving load, concentrated gaze, and delayed judgment. Second, based on the research results, corresponding road traffic safety prevention and control measures can be formulated, such as optimizing road design, improving the visibility of traffic signs, and strengthening driver training, in order to reduce the incidence of traffic accidents. Finally, it can help designers better understand the needs of drivers and design driving assistance systems that better meet their actual needs.

3. Method

A field survey was conducted on five mountainous two-lane highways in Guizhou, China. By comparing the traffic volume, traffic composition, and environmental characteristics of each section, the section between the Kaiyang County Huaxing Oil Factory and Wudang District Lihua Wood Factory on Guiyang X129 Road was selected as the experimental section. This section has a total length of 35 km, a design speed of 30 km/h, and a road surface width of 8 m. Traffic signs and road markings are relatively clear, with complex changes in road alignment and rich scenes such as curves, turning curves, continuous curves, and long downhills. Some experimental scenarios are shown in Figure 1.

3.1. Overtaking Process. Due to the lower level of two-lane highways in mountainous areas and the significant differences in linear conditions, the length of the following time before each overtaking process varies greatly, and the driver's state is greatly affected by road conditions. Therefore, this paper does not discuss the long-term following process. Due to the lane change behavior involved in the overtaking process, which results in a change in the driver's gaze reference system, the overtaking process is divided into three stages: the intention stage, execution stage, and return stage.

3.1.1. Intention Stage. The driver's willingness to overtake refers to the process in which his or her vehicle's driving speed is limited by slow-moving vehicles ahead in a following state, resulting in a lower driving speed that cannot meet the driver's expected speed. The overtaking vehicle approaches or presses the centerline of the road, waiting for an opportunity to overtake, as shown in the diagram from T_0 to T_1. Research [32] has shown that drivers intend to overtake for approximately 5 s. This article takes the 5 s before the driver turns the steering wheel to change lanes as the overtaking intention stage, which is shown in Figure 2.

3.1.2. Execution Stage. The driver makes an overtaking decision by turning the steering wheel to the left, changing lanes from the right lane to the left lane, and accelerating the vehicle by pressing the accelerator until the rear of the driver passes the front of the target vehicle. This is the process where the driver turns the steering wheel to change lanes and the rear of the driver passes the overtaking vehicle as the starting point of the execution phase. As shown in Figure 3, from T_1 to T_2, this process lasts 4–5 s.

3.1.3. Return Stage. After the rear of the vehicle passes the front of the target vehicle, the driver turns the steering wheel to the right and changes lanes from the left lane to return to the original lane. That is, the starting point of the return phase is when the rear of the vehicle passes the overtaking vehicle, and the endpoint is when the vehicle returns to the original lane until the body is aligned. As shown in Figure 4, this process lasts 3–4 s from T_2 to T_3.

3.2. Participants. We distributed flyers to social enterprises such as taxi companies, ride-hailing companies, and universities, recruiting skilled and unskilled drivers with a balanced gender ratio, and cover aged across all age groups. The number of test drivers needs to be determined based on a comprehensive consideration of expected variance, target confidence, and error margin. The required sample size should be calculated using a certain statistical analysis method [26]. The calculation formula for the sample size of the experiment is shown in the following equation:

$$n = \frac{z^2\sigma^2}{E^2}. \quad (1)$$

Among them, σ represents the standard deviation, Z represents the standard normal distribution statistic, and E represents the maximum error. At a 90% confidence level, the standard normal distribution statistic is set to 1.25, with a maximum error of 10%, and σ should be between 0.25 and 0.5. Considering the actual experimental road environment and the influence of test time, the standard deviation is set to 0.35. The required sample size for the experiment is calculated to be 20.

There were 21 test drivers with at least 3 years of driving experience, excellent naked-eye vision, and no major traffic accidents. Based on their driving experience and driving mileage, they were divided into a skilled group and an unskilled group. Numbers 1–12 were the skilled group, while numbers 13–21 were the unskilled group. The average

Figure 1: Test environment.

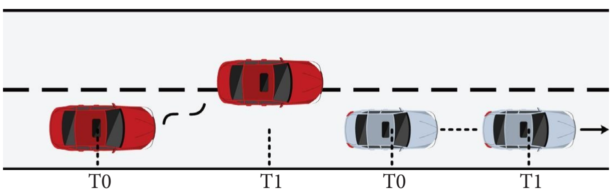


Figure 2: Intention stage.

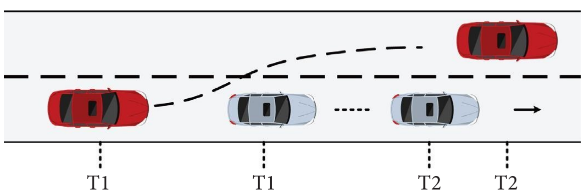


Figure 3: Execution stage.

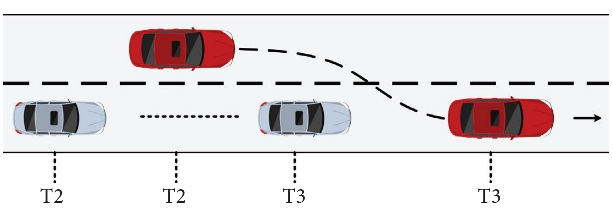


Figure 4: Return stage.

driving experience of the skilled group was 13.5 years, and they had a rich driving experience on mountainous roads and had multiple driving experiences in the experimental section. The average driving experience of the unskilled group of drivers was 6.3 years, with frequent driving on urban roads and less driving experience on mountainous roads. The driver information is given in Tables 1 and 2.

3.3. Test Equipment. A heading reference system (with a built-in high-precision GPS and gyroscope) with a sampling frequency of 10 Hz was chosen to record vehicle speed and acceleration. The PhysioLab physiological multichannel instrument was selected to record the electrocardiogram signals of the subjects during the experiment. A Smart Eye wearable eye tracker was selected, and a computer was connected to record the changes in the drivers' eye movement indicators in real time during the experiment. The experimental vehicle was selected from the Beijing Hyundai four-seat sedan model. Some of the experimental equipment is shown in Figure 5.

3.4. Data Collection and Analysis. Counting all overtaking processes of 21 drivers, a total of 170 overtaking samples were collected. Excluding overtaking motorcycle models, overtaking in rainy and foggy weather, overtaking in front of the vehicle, and overtaking without a fixation point, a total of 86 valid overtaking samples were collected. The "Technical Standards for Highway Engineering" stipulate that at a design speed of 30 km/h, the overtaking sight distance of vehicles with a length of less than 6 m should generally be no less than 150 m. Based on whether the straight length of the passing process exceeds 150 m, the passing samples were divided into sections with good-sight distance and sections with poor-sight distance for passing. Twenty-five passing samples were collected from the skilled group on sections with good-sight distance, 18 passing samples were collected from the unskilled group, 27 passing samples were collected from the skilled group on sections with poor-sight distance, and 16 overtaking samples were collected from the unskilled group. Figures 6 and 7 present the experimental scenarios of good visibility and poor visibility road sections, respectively.

4. Results

4.1. Gaze Time. The gaze time during the overtaking process is divided into two groups of drivers, with an interval of every 100 ms. The data with a single gaze time greater than 1000 ms are excluded, and the statistical results are shown in Figures 8 and 9.

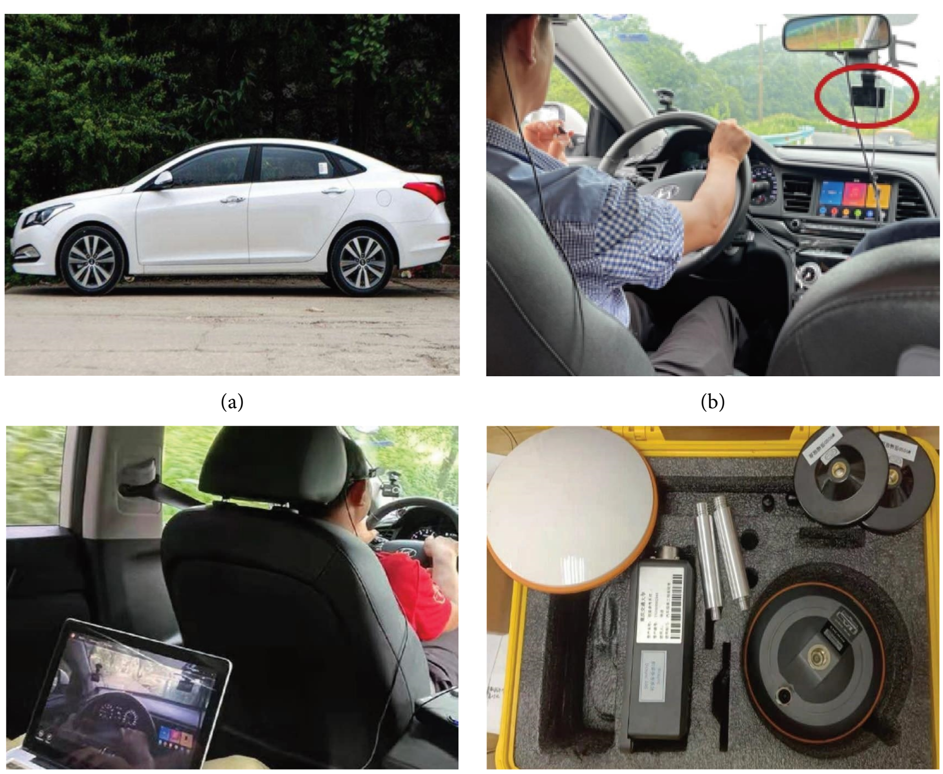
Under two different sight distance conditions, the gaze time of the two groups of drivers during the overtaking process is mainly concentrated in the range of 100–199 ms and 200–299 ms. As the driver's gaze time increases, the proportion roughly decreases. The overtaking process involves two lane-changing behaviors, which require comprehensive observation of the information on the surrounding environment, the speed of the overtaken vehicle, and the distance between oneself and the overtaken vehicle. The driver's gaze points frequently switch back and forth between the original lane and the target lane. The single gaze time of the two groups of drivers is less than 500 ms,

Table 1: Driver information.

Number	Gender	Age	Driving age	Main driving area	Occupation
1	Male	40	12	Expressway, countryside, urban	Professional driver
2	Male	35	10	Countryside	Professional driver
3	Male	49	10	Expressway, countryside, urban	Professional driver
4	Male	36	12	Expressway, countryside	Professional driver
5	Male	50	28	Countryside, urban	Professional driver
6	Male	35	10	Expressway	Professional driver
7	Male	47	15	Expressway, countryside, urban	Professional driver
8	Female	31	12	Expressway, countryside, urban	Professional driver
9	Male	35	12	Expressway, countryside, urban	Professional driver
10	Female	47	12	Expressway, countryside, urban	Teacher
11	Male	47	17	Expressway, countryside	Freelancer
12	Male	36	13	Expressway, countryside, urban	Self-employed
13	Male	48	8	Expressway, urban	Freelancer
14	Female	34	5	Urban	Bank clerk
15	Male	48	6	Expressway, urban	Salesperson
16	Female	33	7	Urban	Freelancer
17	Male	27	6	Urban	Self-employed
18	Female	29	6	Expressway, urban	Salesperson
19	Male	41	7	Expressway, urban	Teacher
20	Female	44	7	Expressway, urban	Teacher
21	Female	29	5	Urban	Bank clerk

Table 2: Driver information.

Groups	Age (Years)	Driving experience (Years)	Driving miles (10 km)	Familiarity
Skilled group	39.8 ± 7.6	13.5 ± 5.1	30.3 ± 20.9	Familiar
Unskilled group	37.0 ± 7.8	6.3 ± 1.4	6.0 ± 2.4	Unfamiliar



(a) (b) (c) (d)

Figure 5: Test equipment. (a) Test vehicle. (b) Driving recorder. (c) Eye tracker. (d) AHRS.

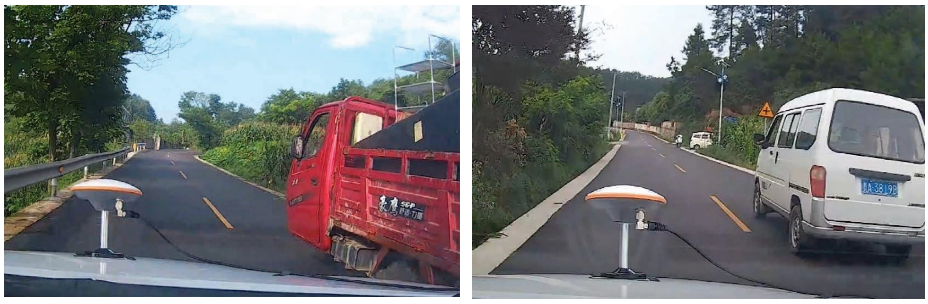


Figure 6: Good-sight distance.

Figure 7: Poor-sight distance.

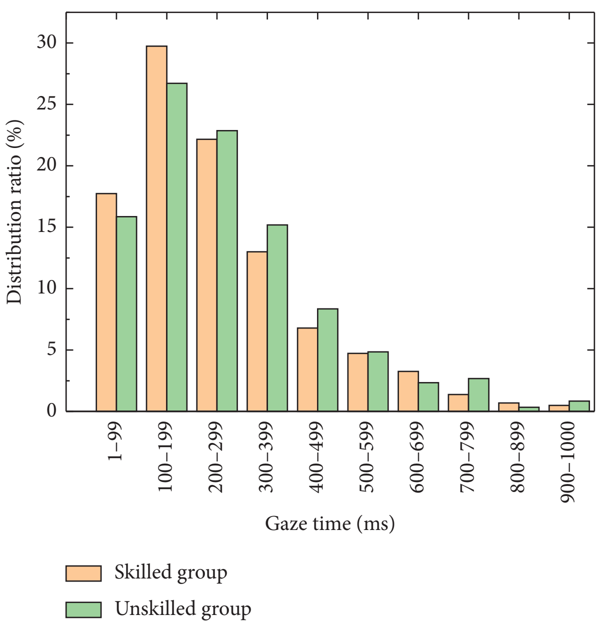


Figure 8: Good-sight distance.

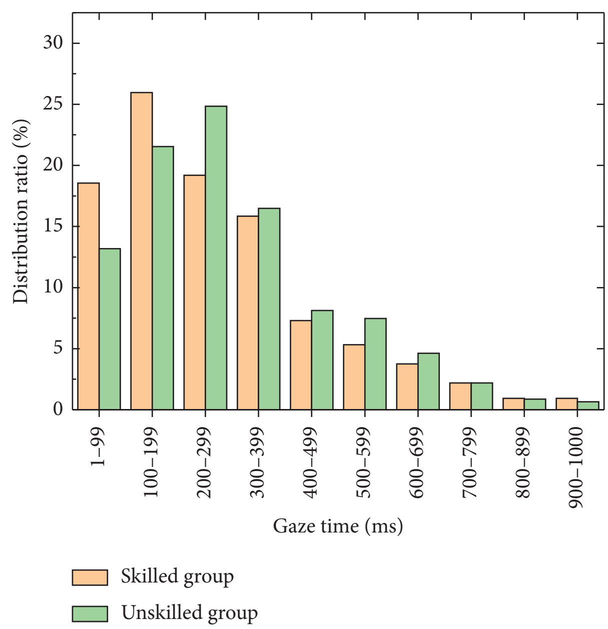


Figure 9: Poor-sight distance.

accounting for 80% of the total, and the interval above 800 ms is less than 3%.

The 1–99-ms interval mainly observes the fixation points of the left and right rearview mirrors and the roadside. During the overtaking process on sections with poor visibility, the proportion of unskilled drivers decreases significantly in the 1–99-ms interval. The fixation time of the two groups of drivers increases during the overtaking process on sections with poor visibility, and the gaze time of the unskilled group is higher than that of the skilled group. During the overtaking process, for the unskilled group, the difficulty of obtaining information is higher than that for the skilled groups, and the gaze duration is slightly longer. When overtaking on sections with poor visual distance, the difficulty of obtaining information increases. The gaze duration of both types of drivers increases slightly compared to sections with good-sight distance, and the driver's attention becomes more concentrated. The change in the unskilled group is more significant, and the highest gaze proportion range changes from 100–199 ms to 200–299 ms. The gaze point of the driver switches back and forth frequently between the original lane and the target lane, with 80% of the gaze time being less than 500 ms.

4.2. Gaze Area Division. To study the gaze transfer characteristics of drivers while overtaking, the visual regions of interest of drivers are first divided. As the overtaking process involves two lane-changing processes, to unify the reference frame, the overtaking process is divided into three stages: the intention stage, execution stage, and return stage. In this study, the K-means dynamic clustering algorithm is used, combined with the driver's gaze target and driving characteristics, to divide the driver's gaze regions of interest into six subregions during the overtaking intention stage and the execution stage. In this study, the division of interest point areas during the overtaking intention stage is shown in Figure 10, and the distribution of fixation points of skilled and unskilled drivers during this stage is shown in Figures 11 and 12, respectively; the division of interest point areas during the overtaking execution stage is shown in Figure 13, and the distribution of fixation points of skilled and unskilled drivers during this stage is shown in Figures 14 and 15, respectively; the division of interest point areas during the overtaking return stage is shown in Figure 16, and the distribution of fixation points of skilled and unskilled drivers during this stage is shown in Figures 17 and 18.

The distribution ratio of drivers' visual focus during the intention, execution, and return phases is shown in Figures 19, 20, and 21, respectively. In the intention stage, drivers increase their attention to the left rearview mirror to confirm the vehicle behind them and make overtaking decisions after meeting the overtaking conditions. The skilled group pays more attention to the target lane and left rearview mirror than the unskilled group and has a stronger overtaking intention than the unskilled group. The members of this group observe the surrounding environment more frequently, and the unskilled group pays the most attention to the right lane, which is the lane directly ahead.

In the execution stage, the driver focuses the most on the lane directly ahead. In the relative intention stage, the observation rate of the unskilled group in the left rearview mirror decreases by approximately 3%, while the skilled group still has a high level of attention to the left rearview mirror. The proportion of drivers' gaze on the outside of the road decreases, and they further concentrate on the left and right lanes to maintain a safe lateral distance from the overtaken vehicle. The skilled group has a higher interest in the gaze of the overtaken vehicle than the unskilled group.

In the return stage, the driver's gaze on the left area significantly decreases compared to the intention and execution stages, and the proportion of gaze points in the target lane and right area increases. The focus is on maintaining a safe longitudinal distance from the overtaken vehicle and the road conditions ahead to ensure a safe return to the original lane. The skilled group has a higher proportion of gaze on areas outside the lane than the unskilled group. The unskilled group's gaze distribution is more concentrated on the left and right lanes during the overtaking process, and group members' observation of the target lane is lower than that of the skilled group. The visual allocation of the skilled group is more dispersed, the observation range is wider, and the observation is more thorough compared to the unskilled group.

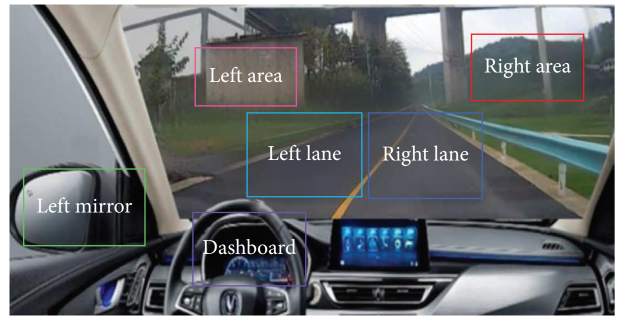


Figure 10: Dynamic clustering of regions of interest in the intention stage.

Figure 11: Distribution of gaze points in the intention stage of the skilled group.

Figure 12: Distribution of gaze points in the intention stage of the unskilled group.

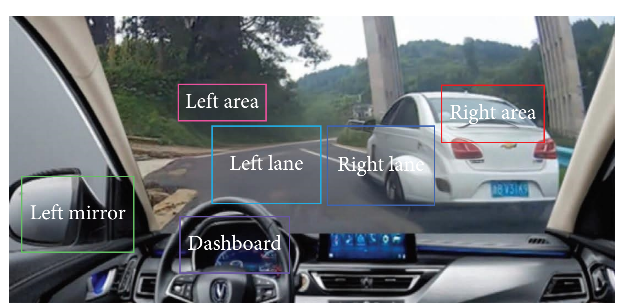


Figure 13: Dynamic clustering of regions of interest in the execution stage.

FIGURE 14: Distribution of gaze points in the execution stage of the skilled group.

FIGURE 15: Distribution of gaze points in the execution stage of the unskilled group.

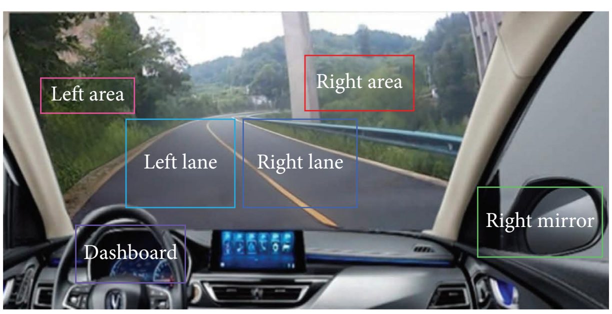


FIGURE 16: Dynamic clustering of regions of interest in the return stage.

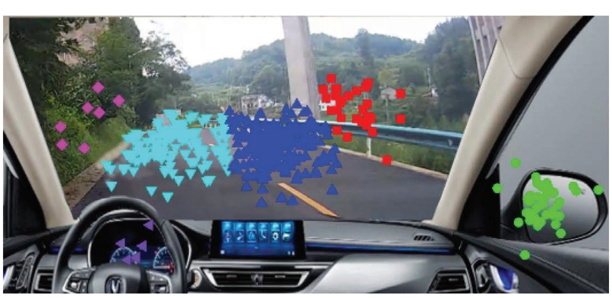


FIGURE 17: Distribution of gaze points in the return stage of the skilled group.

4.3. Gaze Transfer Characteristics. A Markov chain model is a random variable sequence that can describe the state of a certain system, and the system state at a certain moment depends only on its state at the previous moment [40]. In the driver's gaze behavior, the position of the driver's gaze at

FIGURE 18: Distribution of gaze points in the return stage of the unskilled group.

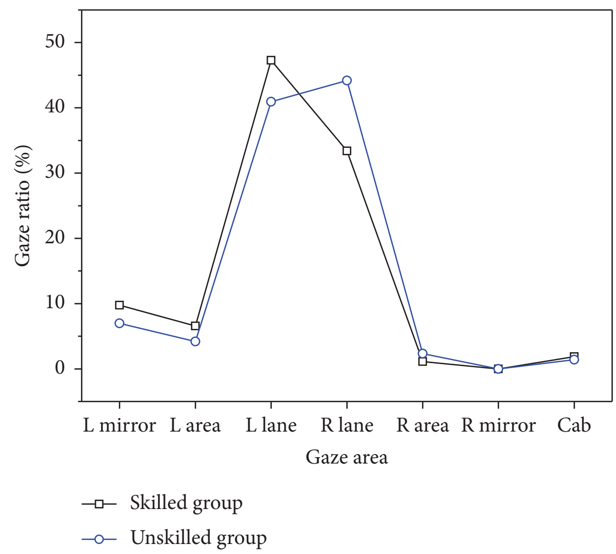


FIGURE 19: Distribution proportion of gaze points in the intention stage.

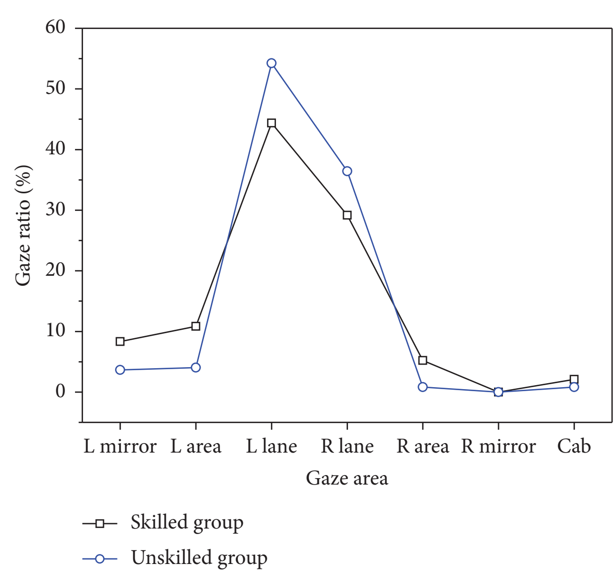


FIGURE 20: Distribution proportion of gaze points in the execution stage.

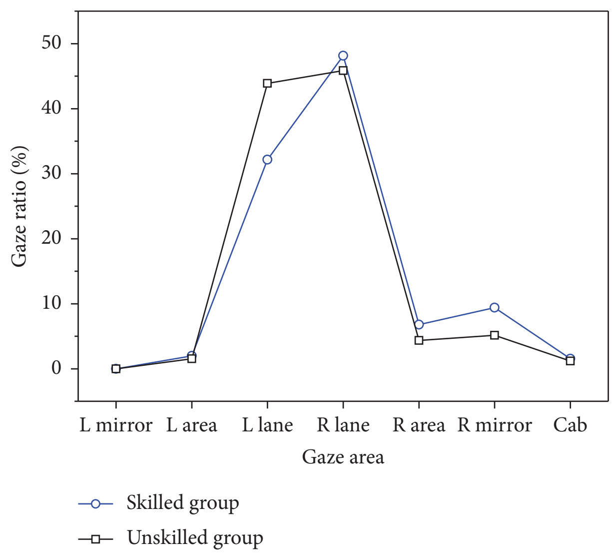


Figure 21: Distribution proportion of gaze points in the return stage.

a certain moment is related only to its position at the previous moment and is not related to the position of another driver's gaze. The driver's line-of-sight transfer characteristics conform to the basic characteristics of Markov chains. Using Markov chain theory, the one-step transition probability matrix of the driver's visual gaze transition between different regions during the overtaking process is obtained. The one-step transition probability matrix for the three stages of overtaking is shown in Tables 3, 4, and 5.

In the intention stage, the left lane is the target lane, and the probability of the unskilled group's gaze repeating the right lane is 22.3% higher than that of the skilled group. The probability of the skilled group's gaze switching between the left and right lanes is 13.4% higher than that of the unskilled group. In the intention stage, the skilled group has a stronger overtaking intention and pays more attention to the left lane.

In the execution stage, the probability of the unskilled group repeating the left lane is 10.04% higher than that of the skilled group, and the probability of the skilled group's gaze switching between the left and right lanes is 6.8% higher than that of the unskilled group. During the overtaking execution stage, both types of drivers pay more attention to the road conditions ahead and the lateral position of the overtaken vehicle, with more attention to switching between the two lanes.

In the return stage, the probability of the skilled group's gaze switching between the left and right lanes is lower than that in the intention and execution stages, and the probability of a skilled driver's gaze switching between the left and right lanes is 18.3% higher than that of an unskilled driver. The transfer probability of the two groups of drivers to the right rearview mirror and the right area increases, indicating that in the overtaking and return stages, drivers pay more attention to the right side of the vehicle and the position of the overtaken vehicle.

Among the three stages of overtaking, the execution stage has the highest probability of the two groups of drivers repeating their gaze on the left lane, followed by the intention stage. During the overtaking process on a two-lane highway in mountainous areas, the probability of the driver's gaze shifting from other areas of visual interest to the dashboard, the rearview mirror, and the outside of the road is low, and the probability of gaze repetition is extremely low. The average probability of the driver's gaze shifting from these three areas to the road ahead in the three stages of overtaking exceeds 80%, indicating that the driver's gaze will quickly shift from other areas to the lane during the overtaking process. The probability of the unskilled group repeating their gaze in the left and right lanes during the three stages of overtaking is higher than that of the skilled group, and the probability of transferring from the left and right lanes to other areas is lower than that of the skilled group. These findings indicate that the unskilled group needs to observe repeatedly to obtain road information, while the skilled group switches gazes on each area more than the unskilled group, resulting in a wider observation range and more comprehensive information acquisition.

4.4. Regularity of Pupil Change. Due to the longer daylight hours in July in the experimental area, the difference in illumination conditions between morning and afternoon under the same weather conditions is not significant. Therefore, the influence of illumination on the results under the same weather conditions can be basically ruled out. Besides, we are studying the changes in the pupil area of the driver during different stages of overtaking within a fixed time period, so the influence of brightness is temporarily ignored. The changes in pupil diameter and pupil area rate for drivers during each phase are shown in Figures 22 and 23.

The average pupil diameter of the driver in the execution stage is the largest, while that of the driver in the intention stage is the smallest. The two types of drivers have the highest visual load in the execution stage, and the driver's visual load is much higher in the overloading process under poor-sight distance than under good-sight distance. Under poor-sight distance, the driver's average pupil diameter lasts longer in the high position and has been in the high load state. The average pupil diameter of skilled drivers decreases faster, and their tension decreases faster in the return stage under poor-sight distance, but it is still higher than that in the return stage under good-sight distance. Under different sight distance conditions, the average pupil diameter of unskilled drivers is higher than that of skilled drivers, and the growth rate is also higher than that of skilled drivers.

4.5. Heart Rate Growth. The changes in the heart rate and heart rate growth rate of drivers during each overtaking phase are shown in Figures 24 and 25. During the overtaking process, the average heart rate of drivers in sections with poor visual distance is higher than that in sections with good visual distance, and the average heart rate curve shows a trend of first increasing and then slowly decreasing. In sections with

Table 3: One-step transition probability distribution of the intention stage.

Start area	Groups	Target area: Left mirror	Left area	Left lane	Right lane	Right area	Dashboard
Left mirror	Skilled	0.150	0.050	0.425	0.350	0.000	0.025
	Unskilled	0.133	0.067	0.467	0.333	0.000	0.000
Left area	Skilled	0.148	0.037	0.444	0.333	0.000	0.037
	Unskilled	0.111	0.000	0.333	0.444	0.000	0.111
Left lane	Skilled	0.113	0.088	0.423	0.361	0.005	0.010
	Unskilled	0.068	0.045	0.432	0.432	0.011	0.011
Right lane	Skilled	0.058	0.044	0.584	0.263	0.029	0.022
	Unskilled	0.063	0.032	0.379	0.484	0.032	0.011
Right area	Skilled	0.000	0.200	0.200	0.600	0.000	0.000
	Unskilled	0.000	0.200	0.400	0.200	0.200	0.000
Dashboard	Skilled	0.000	0.000	0.286	0.714	0.000	0.000
	Unskilled	0.000	0.000	0.667	0.333	0.000	0.000

Table 4: One-step transition probability distribution of the execution stage.

Start area	Groups	Target area: Left mirror	Left area	Left lane	Right lane	Right area	Dashboard
Left mirror	Skilled	0.115	0.077	0.423	0.346	0.038	0.000
	Unskilled	0.111	0.111	0.556	0.222	0.000	0.000
Left area	Skilled	0.273	0.091	0.364	0.182	0.000	0.091
	Unskilled	0.100	0.000	0.300	0.500	0.000	0.100
Left lane	Skilled	0.068	0.032	0.463	0.405	0.005	0.026
	Unskilled	0.030	0.045	0.567	0.351	0.000	0.007
Right lane	Skilled	0.047	0.007	0.547	0.333	0.047	0.020
	Unskilled	0.033	0.033	0.533	0.389	0.011	0.000
Right area	Skilled	0.000	0.100	0.200	0.600	0.100	0.000
	Unskilled	0.000	0.000	0.000	0.500	0.500	0.000
Dashboard	Skilled	0.000	0.000	0.333	0.667	0.000	0.000
	Unskilled	0.000	0.000	1.000	0.000	0.000	0.000

Table 5: One-step transition probability distribution of the return stage.

Start area	Groups	Target area: Left mirror	Left area	Left lane	Right lane	Right area	Dashboard
Left mirror	Skilled	0.143	0.857	0.000	0.000	0.000	0.000
	Unskilled	0.200	0.800	0.000	0.000	0.000	0.000
Left area	Skilled	0.041	0.418	0.459	0.041	0.033	0.008
	Unskilled	0.027	0.604	0.297	0.036	0.018	0.018
Left lane	Skilled	0.005	0.297	0.495	0.099	0.082	0.022
	Unskilled	0.009	0.276	0.603	0.034	0.069	0.009
Right lane	Skilled	0.000	0.154	0.654	0.077	0.115	0.000
	Unskilled	0.000	0.364	0.273	0.182	0.182	0.000
Right area	Skilled	0.000	0.208	0.667	0.042	0.083	0.000
	Unskilled	0.000	0.231	0.615	0.077	0.077	0.000
Dashboard	Skilled	0.000	0.333	0.500	0.000	0.000	0.167
	Unskilled	0.000	0.333	0.667	0.000	0.000	0.000

poor visual distance, the average heart rate of drivers remains at a high level for a longer time, resulting in a greater psychological burden. Under both visual distance conditions, the average heart rate of the unskilled group is higher than that of the skilled group, and the growth rate is also higher than that of the skilled group. Among the three stages of overtaking, the driver's average heart rate is the highest in the execution stage and the lowest in the intention stage.

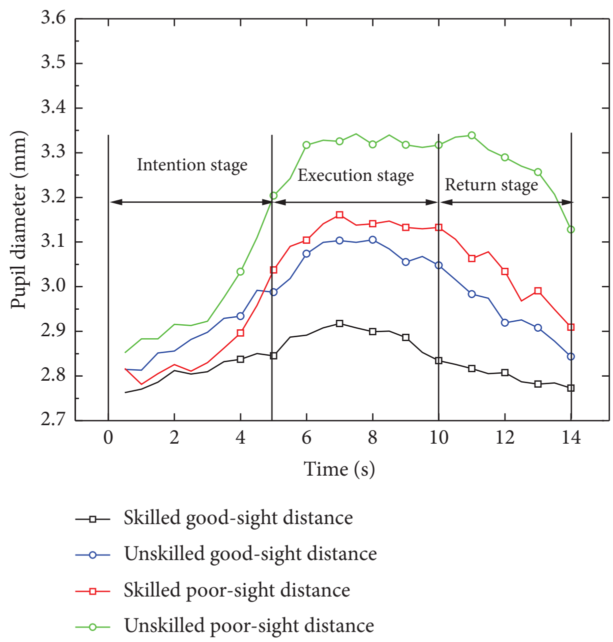


FIGURE 22: Pupil diameter at each stage.

FIGURE 24: Average HR at each stage.

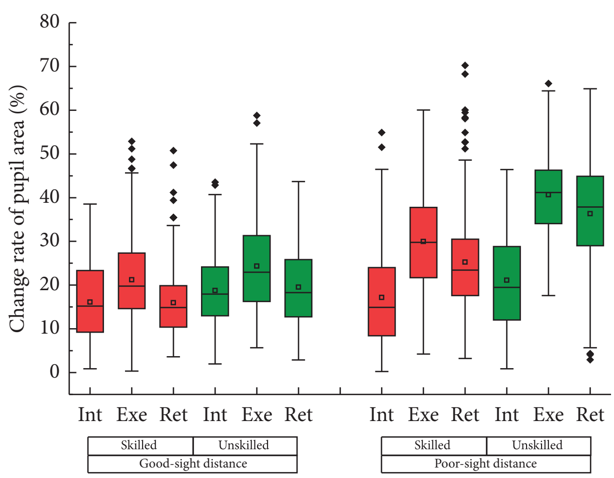


FIGURE 23: Box plot of the pupil area change rate. Note: In = intention stage; Ex = execution stage; Ret = return stage.

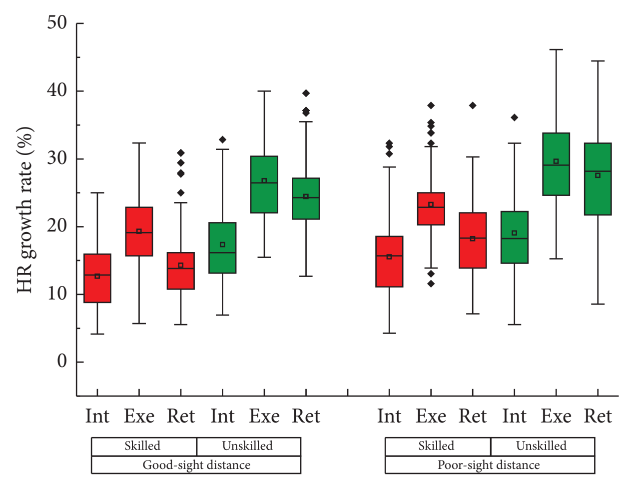


FIGURE 25: Box plot of the HR growth rate. Note: In = intention stage; Ex = execution stage; Ret = return stage.

5. Driving Load Evaluation

5.1. TOPSIS Method. The evaluation object set is established as two types of overtaking and the driving load at each stage, with a total of 12 evaluation objects, $N = (N_1, N_2 \ldots N_{12})$. The evaluation index set includes the pupil area change rate, heart rate growth rate, and fixation duration, $M = (M_1, M_2, M_3)$. Then, a multiobjective matrix is formed,

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{13} \\ \vdots & \vdots & \vdots \\ x_{121} & x_{122} & x_{123} \end{bmatrix}. \tag{2}$$

The standardized decision matrix $V = (b_{ij})_{m*n}$ is constructed with the pupil area change rate, heart rate growth rate, and fixation duration as a single indicator to evaluate the driving load. All three indicators are reverse indicators. The evaluation indicator data are normalized and mapped to [0, 1], which is shown in Table 6.

The calculated results of the indicators are shown in Tables 7 and 8.

The relative closeness C value of the sample optimal solution represents the driving load evaluation results of drivers at each stage of overtaking:

1. The driving load of the two types of drivers in the process of overtaking is as follows: execution stage- > return stage > intention stage. The driving load of drivers in each stage of overtaking under poor-sight

Table 6: Evaluation index normalization table

	Pupil area change rate	Heart rate growth rate	Fixation duration
Good-sight skilled intention	0.408	0.409	0.243
Good-sight skilled execution	0.397	0.510	0.249
Good-sight skilled return	0.263	0.345	0.116
Good-sight unskilled intention	0.415	0.401	0.251
Good-sight unskilled execution	0.351	0.443	0.269
Good-sight unskilled return	0.409	0.360	0.251
Poor-sight skilled intention	0.311	0.402	0.022
Poor-sight skilled execution	0.459	0.460	0.013
Poor-sight skilled return	0.333	0.435	0.021
Poor-sight unskilled intention	0.442	0.442	0.276
Poor-sight unskilled execution	0.473	0.466	0.315
Poor-sight unskilled return	0.539	0.529	0.289

Table 7: Indicator calculation results.

	IE e	IU d	Weight w (%)
Pupil area change rate	0.9815	0.0185	55.83
Heart rate growth rate	0.9886	0.0114	34.31
Fixation duration	0.9967	0.0033	9.86

Abbreviations: IE, information entropy; IU, information utility.

Table 8: Summary of the driving load evaluation.

	Positive ideal D^+	Negative ideal D^-	Closeness C	Rank
Poor-sight unskilled execution	0	34.843	1	1
Poor-sight unskilled return	4.937	29.935	0.858	2
Poor-sight skilled execution	11.053	24.387	0.688	3
Poor-sight skilled return	16.246	19.26	0.542	4
Good-sight unskilled execution	17.459	17.804	0.505	5
Good-sight skilled execution	21.921	12.985	0.372	6
Poor-sight unskilled intention	22.193	12.699	0.364	7
Good-sight unskilled return	23.914	10.982	0.315	8
Good-sight unskilled intention	25.958	8.956	0.257	9
Poor-sight skilled intention	26.459	8.546	0.244	10
Good-sight skilled return	29.005	5.883	0.169	11
Good-sight skilled intention	29.721	5.594	0.158	12

distance is higher than that under good-sight distance, and the driving load in the execution stage and the return stage of overtaking at the section with poor-sight distance is significantly higher than that in other overtaking stages.

2. Under the same sight distance condition, the driving load of unskilled drivers at all stages of overtaking is higher than that of skilled drivers. Compared with the section with good-sight distance, the increase in the driving load of unskilled drivers at the section with poor-sight distance is higher than that of skilled drivers.

5.2. RSR Method. The starting steps of the RSR method are the same as those of the TOPSIS method, the evaluation indices are normalized, and the entropy weight is assigned.

The RSR value of each evaluation index is calculated, the data are normalized, and the calculation results are shown in Table 9.

The comprehensive driving load evaluation value obtained by the RSR method is obtained through K-means clustering, and the driving load is divided into three categories, i.e., high, normal, and low, as shown in Table 10. Finally, the driving load at each stage of overtaking is evaluated based on the RSR value.

It can be concluded from the table above that in each stage of overtaking, the driver has the highest driving load during the execution and return stages of overtaking on sections with poor visibility, and the risk level is Level 1. These results indicate that the driver has been in a highly tense state from the execution of risky overtaking to the return process on sections with poor visibility. Especially for unskilled drivers, the driving load is higher during the overtaking process, and the driving risk is extremely high.

The driver has a high driving load during the overtaking execution stage on sections with good-sight distance, and the risk level is Level 2. These result indicate that although the overtaking process has good-sight distance, the driver needs

Table 9: RSR value calculation results.

	X1: Change rate of pupil area	R1: Change rate of pupil area	X2: HR growth rate	R2: HR growth rate	X3: Gaze time	R3: Gaze time	RSR
Good-sight skilled intention	0.18	5.25	0.05	2.13	0.48	12.06	0.24
Good-sight skilled execution	0.35	9.15	0.42	10.66	0.66	16.28	0.48
Good-sight skilled return	0.18	5.12	0.14	4.13	0.57	14.17	0.29
Good-sight unskilled intention	0.27	7.26	0.21	5.81	0.60	14.88	0.36
Good-sight unskilled execution	0.46	11.55	0.64	15.62	0.77	18.61	0.62
Good-sight unskilled return	0.30	7.87	0.36	9.22	0.68	16.63	0.44
Poor-sight skilled intention	0.22	5.99	0.31	8.15	0.52	13.05	0.36
Poor-sight skilled execution	0.64	15.80	0.84	20.29	0.75	18.25	0.76
Poor-sight skilled return	0.49	12.17	0.71	17.28	0.81	19.69	0.67
Poor-sight unskilled intention	0.35	9.01	0.41	10.35	0.73	17.85	0.49
Poor-sight unskilled execution	1.00	24.00	1.00	24.00	1.00	23.98	1.00
Poor-sight unskilled return	0.85	20.56	0.88	21.30	0.95	22.86	0.89

Table 10: RSR method driving load evaluation ranking table

Evaluation item	Probit	Fitted value	Rank	Risk level
Poor-sight unskilled execution	7.311	0.909	1	1
Poor-sight unskilled return	6.732	0.778	2	1
Poor-sight skilled execution	6.383	0.699	3	1
Poor-sight skilled return	6.150	0.647	4	1
Good-sight unskilled execution	5.967	0.606	5	2
Poor-sight unskilled intention	5.674	0.539	6	2
Good-sight skilled execution	5.549	0.511	7	2
Good-sight unskilled return	5.431	0.484	8	2
Poor-sight skilled intention	5.210	0.435	9	3
Good-sight unskilled intention	5.105	0.411	10	3
Good-sight skilled return	4.790	0.340	11	3
Good-sight skilled intention	4.326	0.235	12	3

to occupy the opposite lane to accelerate and maintain a safe lateral distance from the overtaking vehicle on narrow roads. The difficulty of driving operations has increased to some extent, and the driving load has increased. The driver has a lower driving load during the overtaking intention stage and the return stage on a road section with good visibility. The difficulty of driving in the driving sections above is relatively low, and it is less affected by other vehicles, resulting in a lower driving load.

6. Discussion

Through an analysis of the Chinese and international literature, it has been found that scholars in China and elsewhere mainly select indicators such as steering performance, road parameters, and physiological changes to analyze the psychological load of drivers while overtaking. Compared to nonmountainous highways, the road conditions of mountainous highways are more complex. This study analyzed the driving load of drivers overtaking under good- and poor-sight distance conditions based on five types of physiological indicators, and it studied the differences between proficient and unskilled groups. The TOPSIS method and RSR method were used to comprehensively evaluate the driving load of the two types of drivers in the three stages of overtaking.

During the execution stage of overtaking, the visual load of both groups of drivers significantly increased, with a single gaze time within the range of 100–199 ms. In the case of a poor visual range, the probability of a single fixation time within the range of 100–199 ms in the unskilled group significantly decreased, while the probability of a single gaze time distribution within the range of 100–199 ms in the skilled group did not decrease significantly. At the same time, the average heart rate of the unskilled group was higher than that of the skilled group. The reason is that drivers need to frequently observe road information during the overtaking process. Under poor visibility conditions, the unskilled group takes longer to collect road information, which can exacerbate the generation of tension. Frequent repeated observations also affect driving safety during the overtaking process. The worse the sight distance condition is, the longer the driver's gaze duration at a single point.

As shown in Tables 3, 4, and 5, the probability of drivers repeatedly fixating on the same area varies significantly during the three stages of overtaking. The results indicate that the difficulty of obtaining information during the execution phase of overtaking is higher than that during the intention and return phases, and the probability of repeatedly staring at the target is higher. During the execution phase, the driver's attention range is limited due to the faster speed while overtaking, the shorter driving time while overtaking, and shorter line-of-sight transfer paths. The probability of one-step gaze transfer can reflect the gaze transfer behavior. The probability of one-step transfer from the driver's gaze to the left lane is the highest, which is related to the specific environment of overtaking. Moreover, the probability of a skilled driver's gaze shifting to the left lane in one step is significantly lower than that of an unskilled driver, indicating that the unskilled group needs to repeatedly confirm the area. As the overtaking process continues, the interest in the right lane of both groups of drivers gradually increases, and the probability of transferring from each visual area to the right lane increases significantly, with this situation being more significant in the skilled group.

In the intention and execution phases of overtaking, the probability of one-step transfer from each visual area to the left lane of the skilled group is generally higher than that of the unskilled group. In the return phase, the probability of one-step transfer from each visual area to the right lane of the skilled group is generally higher than that of the unskilled group, which can be explained as follows. In the intention and execution stages, drivers need to pay more attention to the information on the left lane of the road. The skilled group has a higher probability of one-step transfer, indicating that skilled drivers have collected more information during the overtaking process. As the overtaking process continues, both types of drivers pay more attention to the dashboard and are more concerned about the speed changes during overtaking. On the surface, drivers are eager to end the overtaking process. As the overtaking distance increases, the driver's attention to the right side of the road increases, with the skilled group being higher than the unskilled group. However, drivers overly focus on these two aspects, and as a result, they neglect other aspects. However, a lack of attention to traffic speed and surrounding traffic conditions can easily cause visual fatigue and safety hazards, leading to traffic accidents. Generally, when the overtaking distance is less than 20 m, there is almost no difference in fixation time and fixation point transfer between the skilled and unskilled groups. Therefore, in this case, the safety of the overtaking process does not require special consideration. However, on mountainous roads, the surrounding environment is more complex, and the skilled group has a higher probability of repeated gaze than the unskilled group, indicating that the special environment of mountainous roads has a significant impact on drivers' gaze characteristics. Therefore, on mountainous highways, special attention must be paid to driving safety, and the design and management methods of single tunnels cannot be directly applied. In particular, there are many continuous curves and long downhill sections on mountainous roads, and the combination of road alignments is unreasonable. Therefore, drivers driving on mountainous roads for a long time cannot effectively release the accumulated visual pressure. Considering that the combined effects of psychology and vision can easily increase driving risks, further research and analysis are needed.

7. Conclusion

To investigate the driving load during the overtaking process on two-lane highways in mountainous areas, this article conducted a real vehicle test. The experimental results indicate that the highest driving load during the overtaking process is in the execution stage, and the lowest driving load is in the intention stage. The driving load of two types of drivers in different stages of overtaking on sections with poor visibility is higher than that on sections with good visibility. The driving load in the execution and return stages of overtaking on sections with poor visibility is significantly higher than that in other overtaking stages. Under the same sight distance conditions, the driving load of the unskilled group at each stage of overtaking is higher than that of the skilled group. Compared to sections with good visibility, the unskilled group experiences a higher increase in overtaking driving load on sections with poor visibility than the skilled group. Therefore, in the process of overtaking on two-lane highways in mountainous areas, it is necessary to further consider overtaking safety, especially for the three stages of overtaking on sections with poor visibility, which require special attention. The methods and technologies to improve the safety of overtaking on highways have been widely studied, but there is less research on overtaking on two-lane highways in mountainous areas. Therefore, this study can provide a useful reference for understanding the safety aspects of overtaking on two-lane highways in mountainous areas, and the research results can also provide a theoretical basis for the design and management of two-lane highways in mountainous areas.

The main limitation of this study is that it did not consider the impact of mountainous highway alignment on drivers' visual characteristics, and curve segments on highways can be considered in future work. In addition, considering safety factors, in the actual vehicle test of this article, drivers were not allowed to overtake while passing through curves. If conditions permit, further research can be conducted on samples of drivers passing through curves in future work through simulated driving.

Data Availability Statement

Some data, models, or codes that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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References

[1] X. F. Ji, B. Y. Dai, Y. M. Pu, and J. J. Hao, "Overtaking Duration Model for Two-Lane Highways in Mountainous Areas Based on Survival Analysis," *Transportation System Engineering and Information* 22, no. 6 (2022): 183–190.

[2] T. J. Xiang, *A Study on the Physiological and Operational Characteristics of Drivers under Overtaking and Meeting Scenarios on Mountain Roads* (Chongqing Jiaotong University, 2023).

[3] O. Musicant, H. Bar-Gera, and E. Schechtman, "Impact of Speed Limit Change on Driving Speed and Road Safety on Interurban Roads: Meta-Analysis," *Transportation Research Record: Journal of the Transportation Research Board* 2601, no. 1 (2016): 42–49, https://doi.org/10.3141/2601-06.

[4] M. Zahabi, C. Pankok, D. B. Kaber, et al., "On-road Visual Sign Salience, Driver Attention Allocation, and Target Detection Accuracy," *Transportation Research Record: Journal of the Transportation Research Board* 2663, no. 1 (2017): 40–47, https://doi.org/10.3141/2663-06.

[5] K. Salamati, B. Schroeder, N. M. Rouphail, C. Cunningham, Y. Zhang, and D. Kaber, "Simulator Study of Driver Responses to Pedestrian Treatments at Multilane Roundabouts," *Transportation Research Record: Journal of the Transportation Research Board* 2312, no. 1 (2012): 67–75, https://doi.org/10.3141/2312-07.

[6] E. I. Vlahogianni, "Modeling Duration of Overtaking in Two Lane Highways," *Transportation Research Part F: Traffic Psychology and Behaviour* 20 (2013): 135–146, https://doi.org/10.1016/j.trf.2013.07.003.

[7] B. Dutta, P. Chakroborty, and V. Vasudevan, "Study of Overtaking Maneuvers on Wide One-Way Roads in Weak Lane-Disciplined Traffic Using Naturalistic Driving Data," *Transportation Research Record: Journal of the Transportation Research Board* 2677, no. 3 (2023): 565–582, https://doi.org/10.1177/03611981221116365.

[8] J. Xu, Y. P. Wang, H. Y. Chen, and X. B. Zhang, "Longitudinal Driving Characteristics and Operating Speed Prediction Model of Cars on Hairpin Curves of Mountainous Roads," *Journal of Jilin University (Engineering and Technology Edition)* 53, no. 12 (2023): 3432–3445.

[9] T. Choudhari, A. Budhkar, and A. Maji, "Modeling Overtaking Distance and Time along Two-Lane Undivided Rural Highways in Mixed Traffic Condition," *Transportation Letters (The International Journal of Transportation Research)* 14, no. 2 (2022): 75–83, https://doi.org/10.1080/19427867.2020.1815142.

[10] Y. Yamada, A. S. M. Bakibillah, K. Hashikura, M. A. S. Kamal, and K. Yamada, "Autonomous Vehicle Overtaking: Modeling and an Optimal Trajectory Generation Scheme," *Sustainability* 14, no. 3 (2022): 1807, https://doi.org/10.3390/su14031807.

[11] R. Zhang, Q. Bao, K. Brijs, E. Hermans, and Y. Shen, "Identification and Comparative Safety Analysis of

Overtaking Patterns on Two-Lane Highways: A Simulator Study with Novice Drivers," *Transportation Research Record: Journal of the Transportation Research Board* 2677, no. 1 (2023): 541–553, https://doi.org/10.1177/03611981221100240.

[12] E. Malayjerdi, R. Sell, M. Malayjerdi, A. Udal, and M. Bellone, "Practical Path Planning Techniques in Overtaking for Autonomous Shuttles," *Journal of Field Robotics* 39, no. 4 (2022): 410–425, https://doi.org/10.1002/rob.22057.

[13] Z. X. Zheng, P. H. Li, M. X. Hu, and Y. B. Li, "Effects of Visual Distraction on Drivers' Following Behavior," *Journal of Highway Traffic Science and Technology* 37, no. 01 (2019): 122–130.

[14] H. Andersen, J. Alonso-Mora, Y. H. Eng, D. Rus, and M. H. Ang, "Trajectory Optimization and Situational Analysis Framework for Autonomous Overtaking with Visibility Maximization," *IEEE Transactions on Intelligent Vehicles* 5, no. 1 (2020): 7–20, https://doi.org/10.1109/tiv.2019.2955361.

[15] J. C. Mertens, J. Hauenstein, and F. Diermeyer, "Reduced Safety Distance during Cooperative Truck Overtaking," in *Fifteenth International Conference on Ecological Vehicles and Renewable Energies, Monte Carlo, Monaco* (September 2020).

[16] Y. Q. Qin, H. R. Zheng, and J. S. Li, "Influencing Factor Model of Urban Road Overtaking Behavior Based on Video," *Journal of Chongqing Jianzhu University* 40, no. 1 (2021): 17–22+52.

[17] Z. Yu, "Overtaking Trajectory Planning Strategy for Intelligent Vehicles Based on Improved Artificial Potential Field Method," *Agricultural Equipment & Vehicle Engineering* 59, no. 9 (2021): 64–68.

[18] X. L. Zhang, Y. T. Fu, Y. Yu, J. Gu, Y. Yang, and Y. Wei, "Research on Overtaking Model Based on Safety Potential Field," *Transportation Energy Conservation and Environmental Protection* 18, no. 6 (2022): 49–54.

[19] X. F. Ji, Y. H. Xu, J. J. Hao, and W. W. Tan, "Modeling of Time Covariates for the Evolution of Overtaking Behavior Risk on Two-Lane Highways," *Journal of Southwest Jiaotong University* (2024): 1–10.

[20] L. Parada, E. Candela, L. Marques, and P. Angeloudis, "Safe and Efficient Manoeuvring for Emergency Vehicles in Autonomous Traffic Using Multi-Agent Proximal Policy Optimisation," *Transportmetrica: Transport Science* (2023): 1–29, https://doi.org/10.1080/23249935.2023.2246586.

[21] P. H. Li, Y. B. Li, Y. Yao, C. Wu, B. Nie, and S. E. Li, "Sensitivity of Electrodermal Activity Features for Driver Arousal Measurement in Cognitive Load: The Application in Automated Driving Systems," *IEEE Transactions on Intelligent Transportation Systems* 23, no. 9 (2022): 14954–14967, https://doi.org/10.1109/tits.2021.3135266.

[22] K. Stojmenova, G. Jakus, and J. Sodnik, "Sensitivity Evaluation of the Visual, Tactile, and Auditory Detection Response Task Method while Driving," *Traffic Injury Prevention* 18, no. 4 (2016): 431–436, https://doi.org/10.1080/15389588.2016.1214868.

[23] C. Yunuo, Z. Xia, and T. Liwei, "How Does AR-HUD System Affect Driving Behaviour Evidence from an Eye-Tracking Experiment Study," *International Journal of Vehicle Design* 92, no. 1 (2023): 1–21, https://doi.org/10.1504/ijvd.2023.133262.

[24] H. X. Wang, X. Ding, and C. T. Wang, "Risk Assessment of Distracted Driving Behavior Based on Visual Stability Coefficient," *Journal of Advanced Transportation* 2023 (2023): 1–18, https://doi.org/10.1155/2023/2111532.

[25] Y. Yang, Z. Du, T. Huang, and J. Mei, "Analysis of Visual Load on Curve and Longitudinal Slope Combination of Extra-long Underwater Tunnel Based on Visual Sensitive Region," *Transportation Research Record: Journal of the Transportation Research Board* 2678, no. 5 (2024): 138–152, https://doi.org/10.1177/03611981231188369.

[26] J. Bai, Q. Lin, H. Bi, and B. Tang, "Drivers' Eye Movement Characteristics in a Combined Bridge-Tunnel Scenario on a Mountainous Urban Expressway: A Realistic Study," *Journal of Advanced Transportation* (2022): 6403277.

[27] J. Jiang and J. Lu, "Following Behavior Analysis Based on Helly Model Calibration Parameters," *Journal of Wuhan University of Technology* 39, no. 02 (2015): 242–245.

[28] Z. Lv, C. H. Qi, and S. L. Zhu, "Dynamic Visual Characteristics and Load of Drivers under Overtaking Conditions on Grassland Highways," *Chinese Journal of Safety Sciences* 32, no. 4 (2022): 15–22.

[29] Z. Lv, C. H. Qi, and S. L. Zhu, "Dynamic Visual Characteristics of Drivers under Different Distractions on Grassland Highways," *Journal of Chongqing Jianzhu University* 41, no. 09 (2022): 45–52.

[30] H. Y. Zhu, Z. H. Jiang, and Q. Zhang, "A Study on the Differences in Hazard Perception Among Drivers with Different Experiences," *Ergonomics* 21, no. 02 (2015): 43–49.

[31] W. H. Zhang, P. H. Li, M. X. Hu, and Y. B. Li, "Visual Behavioral Characteristics of Overtaking Process for Highway Drivers," *Journal of Tsinghua University* 54, no. 09 (2014): 1204–1208.

[32] F. Wang, H. T. Cheng, J. B. Liu, and Y. Li, "The Gazing Characteristics of Drivers Passing in Ultra High Altitude Regions," *Chinese Journal of Highway Engineering* 31, no. 4 (2018): 10–17.

[33] L. Yang, X. M. Li, W. Guan, H. M. Zhang, and L. Fan, "Effect of Traffic Density on Drivers' Lane Change and Overtaking Maneuvers in Freeway Situation—A Driving Simulator–Based Study," *Traffic Injury Prevention* 19, no. 6 (2018): 594–600, https://doi.org/10.1080/15389588.2018.1471470.

[34] T. Z. Liu, M. A. Bekele, W. Chen, and J. Xu, "Relationships between Drivers' Mental Stress and Cars Steering Operation on Mountain Roads Environment," *Advances in Transportation Studies* 51 (2020).

[35] V. Sezer, "Intelligent Decision Making for Overtaking Maneuver Using Mixed Observable Markov Decision Process," *Journal of Intelligent Transportation Systems* 22, no. 3 (2018): 201–217, https://doi.org/10.1080/15472450.2017.1334558.

[36] V. Faure, R. Lobjois, and N. Benguigui, "The Effects of Driving Environment Complexity and Dual Tasking on Drivers' Mental Workload and Eye Blink Behavior," *Transportation Research Part F: Traffic Psychology and Behaviour* 40 (2016): 78–90, https://doi.org/10.1016/j.trf.2016.04.007.

[37] Y. W. Meng, "Field Experiments on the Distribution of Visual Attention of Drivers on Mountain Curve Roads," *Advances in Transportation Studies an international Journal* no. 41 (2017): 25–36.

[38] P. Chakraborty, J. Merickel, V. Shah, et al., "Quantifying Vehicle Control from Physiology in Type 1 Diabetes," *Traffic Injury Prevention* 20, no. sup2 (2019): S26–S31, https://doi.org/10.1080/15389588.2019.1665176.

[39] M. Zahabi, Y. S. Wang, and S. Shahrampour, "Classification of Officers' Driving Situations Based on Eye-Tracking and Driver Performance Measures," *IEEE Transactions on Human-Machine Systems* 51, no. 4 (2021): 394–402, https://doi.org/10.1109/thms.2021.3090787.

[40] T. Shang, H. Qi, A. Huang, and T. Liu, "A Comparative Driving Safety Study of Mountainous Expressway Individual Tunnel and Tunnel Group Based on Eye Gaze Behavior," *PLoS One* 17, no. 2 (2022): e0263835, https://doi.org/10.1371/journal.pone.0263835.