Hindawi
Journal of Advanced Transportation
Volume 2019, Article ID 9897831, 9 pages
https://doi.org/10.1155/2019/9897831

Research Article

Effects of Highway Landscapes on Drivers' Eye Movement Behavior and Emergency Reaction Time: A Driving Simulator Study

Fengxiang Guo,[1] Mingyuan Li,[1] Yao Chen,[2] Jian Xiong,[1] and Jaeyoung Lee[3,4]

[1] *School of Transportation Engineering, Kunming University of Science and Technology, 727 Jingmingnan Road, Chenggong Campus, Kunming 650504, Yunnan, China*
[2] *Yunnan Institute of Traffic Science, No. 9, Shijiaxiang, Tuodong Road, Kunming, Yunnan, China*
[3] *School of Traffic and Transportation Engineering, Central South University, 154 Shaoshan South Road, Railway Campus, Changsha 410075, Hunan, China*
[4] *Department of Civil, Environmental & Construction Engineering, University of Central Florida, Orlando, FL 32816, USA*

Correspondence should be addressed to Jaeyoung Lee; jaeyoung@knights.ucf.edu

Received 23 January 2019; Revised 18 April 2019; Accepted 24 April 2019; Published 13 May 2019

Academic Editor: Filomena Mauriello

This study aims at investigating the effects of highway landscapes and alignments on drivers' eye movement behavior and emergency reaction time, based on a driving simulator experiment. In this study, four simulation scenarios are evaluated including open space, semiopen space, semiclosed space, and enclosed space landscapes on highways in Yunnan Province, China. Twenty-four experienced drivers participated in a 6-kilometer driving experiment in each landscape scenario. Each subject was required to drive at 80 km/h in the scenarios and the driving behavior data were collected. Three different data analysis methods were employed: (1) descriptive analysis of the characteristics of drivers' visual fixation area; (2) statistical tests of emergency reaction time with drivers' demographic characteristics, highway landscapes, and alignments; and (3) multiple linear regression analysis of emergency reaction time, highway landscapes, and alignments. The results show that emergency reaction time is significantly influenced by highway landscapes and alignments, and the multiple linear regression model built in this experiment could accurately predict drivers' emergency reaction time in different highway landscapes and alignments.

1. Introduction

It has been found that more than 70% of traffic crashes are attributed to human factors, and approximately 17% are caused by the road environment, including highway landscapes. The highway landscape has a significant impact on the physiological and psychological responses of drivers, which further affects their driving behaviors [1, 2]. A good highway landscape allows the drivers not only to feel comfortable and concentrated, but also to be more responsive and to operate the vehicle more accurately, which could lead to reduction of traffic crashes [3–5].

During the driving process, the driver's fixation point changes with different landscapes, which is mainly manifested by its position, duration, and change. The feature of driver's eye movement can better describe the driver's process of disposing visual information [6]. In recent years, more and more research has paid attention to drivers' fixation point characteristics and eye movement and gradually introduced them into the field of transportation. However, most of these studies generally focus on the suitability evaluation of road alignment [7–9], psychological load assessment of drivers [10], driver fatigue detection [11], and design of traffic safety facilities. In this study, we analyzed the characteristics of driver's fixation point in different highway landscapes.

The drivers' emergency reaction time could also be affected by highway landscapes, which is an important factor in determining driving behaviors. The emergency reaction times of drivers can be classified by condition, e.g., simple and complex [12]. The simple reaction time generally ranges between 0.3 and 1 second [13]. However, in complex situation, the reaction time would be greatly increased; especially when drivers are distracted, the emergency response time would increase to approximately 2.5 seconds [14]. It is complicated to understand the underlying reaction processes associated with the drivers since this involves handling a large amount of information within an extremely short time, including the recognition of the object, judgment of the risk and the motion characteristics of the object, and the determination of the strategy to deal with the risk.

Makishita and Matsunage [15] studied how workloads influence emergency reaction time. The results showed that the reaction time differs for different drivers for the same emergency conditions. Some drivers can quickly notice the dangerous condition and then apply the relevant emergency measure while others need more time to react. Warshawskylivne and Shinar [16] found that the gender does not have any influence on the reaction time. Guo et al. [2] discussed the characteristics of the drivers' reaction time under typical emergency conditions on urban roads using a driving simulator, and it was found that the experienced drivers' perception time is less than novice drivers', while the experienced drivers' decision-making time and operation time are longer than novice drivers'. Chen [17] investigated how the color variation of the plants, the plant locations, and the variation of diversity and quantity of the background plants affect the driver's reaction time and found that, when the background plants are green, selecting red, single species, larger space-labeled marking plants in the ramp entry area can shorten driver reaction time to entry identification, and a single type of marker plant also has a positive effect on enhancing the promptness of the marker plant.

There are numerous published studies on drivers' reaction times based on a driving simulator, which represents a well-established method used to assess the reliability and applicability of the results [2, 18].

Critical reaction operation refers to the first emergency operation taken by the driver in case of danger. The emergency reaction time refers to the driver's response time between the occurrence of a risk and the adoption of an emergency operation. Nevertheless, few studies have analyzed the emergency reaction times in different highways landscapes until this point. Most highways in the Yunnan Province are located in mountainous areas because of the unique nature of its geographic location. Compared to other roads, the view of mountain road landscapes has a significant influence on the safety of driving. Chen et al. [19] found that unsafe driving behavior (e.g., careless/reckless driving) would increase injury severity in mountain highways than nonmountainous highways. Therefore, this study attempts to explore the factors influencing drivers' eye movement behavior and emergency reaction times in different mountain highway landscapes and alignments based on a simulation experiment. The rest of this paper is as follows. In Section 2, we introduced the methods of data collection and driving simulation experiment. Section 3 provides the results of descriptive statistics and liner regression model. Lastly, Section 4 discusses the results and concludes the paper.

2. Methods

2.1. Participants. Twenty-four experienced drivers were selected as simulation experiment subjects, consisting of 18 males (75%) and 6 females (25%), and age range was from 29 to 54 years old (mean = 40.2; s.d. = 5.6) in this study. All the subjects held license and had 5 to 23 years of driving experience (mean = 12.2; s.d. = 5.2) who drove at least 6,000 kilometers each year. All the subjects were trained in driving simulator for at least 30 minutes before participating in a preexperiment similar to the formal experimental scenario. All the subjects were asked to drive according to their own experience and try to keep the speed at approximately 80 km/h. The subject who successfully completed the preexperiment can participate in the formal experiment. The purpose of the preexperiment is to familiarize the subjects with the operation methods of the driving simulator, at the same time, to test whether the driver is simulator-sick or not. In this research experiment one participant was found to have simulator-sickness at preexperiment, so he did not participate in the formal experiment. All the subjects who participated in the normal had passed preexperiment and had normal or corrected-to-normal visual acuity.

2.2. Apparatus. This study is based on a simulation laboratory of Faculty of Transportation in Kunming University of Science and Technology including a driving simulator and an eye tracker.

2.2.1. Driving Simulator. The experiment was performed using the full-size interactive driving simulator (KMRTDS) with a fixed base (Figure 1) [20]. The driving simulator setup includes a fully equipped cabin of real car, which includes all normal display and controls (steering, braking, and accelerating). The cabin was placed in front of a curved screen subtending 150° horizontally. Three projectors with the frequency of 50 Hz project the virtual environment on the curved screen at the resolution of 1024×768 pixels. The simulator presents a dynamic image of the driving scene according to the input of drivers. The software Virtual Scene Design (VS-Design) is applied to design the three-dimensional virtual landscape scenarios similar to the real landscape obtained by the vehicle-based acquisition system [21]. This system can provide realistic road and dynamic traffic flow in the right speed, intensity, and direction. This study performed a comparison between real world and driving simulator data to ensure the validity of the test.

2.2.2. Eye Tracker. Eye movement is closely related to attention and internal information processing mechanism [22]. It is a very important source of sensory information in the process of visual cognition. By analyzing eye movement data, we can explore the relationship between eye movement and psychology. Eye movement data includes fixation points, gaze time, and eye movement distance [23]. This study uses the iView HED4 eye tracker to obtain drivers' eye movement data. The iView HED4 eye tracker is a headband and helmet with a camera (Figure 2) [24]. The subject is free to move

Figure 1: The KMRTDS driving simulator.

Figure 2: The iView HED4 eye tracker.

during the test and the eye tracker can detect fixation points in the three-dimensional space. These features make the iView HED4 suitable for our driving simulator.

2.3. Experimental Design

2.3.1. Landscape Classification. The highway landscape information was collected on the highway of Yunnan province in China using a vehicle-based acquisition system of the Road Traffic Driving Simulation Laboratory at the KMUST. Highway landscapes can be classified into different types according to the enclosure degree of the space. Landscape space will show different degrees of enclosure, that is, enclosure degree, expressed by D/H, where D is the lateral distance from the viewpoint to the roadside landscape interface and H is the height of the roadside landscape interface. According to the enclosure degree, landscape was classified into four kinds of type as shown in Table 1. So in this study the landscapes are categorized into open space, semiopen space, semiclosed space, and enclosed space landscapes, from the viewpoints of the drivers (see Figure 3).

2.3.2. Virtual Landscapes. It is important to design relatively realistic landscape scenarios for improving the accuracy of the simulated results. Landscape design software, VS-Design, was used to design the three-dimensional virtual landscapes, which have the same types as those collected by the vehicle-based acquisition system. According to the different landscapes, four landscape roads were designed (Figure 4). The length and road line type of these four landscape roads are the same and accord with the Highway Engineering Technical Standards 2013 in China. These four landscape roads are two-way two-lane roads with a length of 6 kilometers and a lane width of 3.5 meters and the speed of the vehicle was required to be approximately 80 km/h. Each scenario took approximately 6 minutes to finish the experiments. The experiment route is shown in Figure 5.

2.3.3. Simulation Experiments. To test the driver's emergency reaction time, each landscape was presented with a box suddenly dropped from the leading vehicle. These created scenarios were used to simulate emergency situations to quantify the drivers' emergency reaction times. In order to make the experimental scenarios more realistic, the moderate traffic flow was added to the experimental scenarios. Different dropping positions of the box in each scenario are used to estimate the driver's prejudgment. In addition, the dynamic traffic set in each scenario is different. In some scenarios, although there is leading vehicle, the boxes do not fall. It enhances the suddenness and reduces the driver's expectations. The driving simulator randomly adjusts the speed of the front car to reduce the distance between the vehicles. The box dropped when the distance is 55 meters.

2.4. Procedure. At the beginning, experimenters would read instructions and the specific operation method of the driving simulation to subjects. From the instructions, subjects were informed that the test consisted of two sessions. In the first session, subjects were required to drive for more than 30 minutes on a specific scenario to become familiar with the driving simulator. Subsequently, they take a pretest. Each subject must pass the pretest to ensure that they are using the simulator correctly. In the second session, subject would take a formal test. Subjects were asked to keep their heads as stable as possible, and when they encountered an emergency, they should take braking measures to ensure the safety of the vehicle. Participants must drive in the prescribed lane and keep the speed at approximately 80 km/h, yet they are required to obey their own habits and driving patterns. It is not allowed to drive into the opposite lane even in an emergency. When each formal test was finished, the subject should fill out a questionnaire to record their basic information (including name, age, gender, driving distance, driving experience, and personality) and their subjective evaluation of the highway landscapes. The data were collected while a subject was participating in the test.

2.5. Data Collection. In this study, we collected data on the driver's driving behavior on each scenario including vehicle speed, braking time, turning time, and others. Drivers' driving behaviors while driving simulation march were recorded by KMRTDS. The emergency reaction time was defined as the time from the time when the obstacle appeared to the time when the driver stepped on the brake pedal.

The iView HED4 eye tracker in KMUST was utilized to conduct the experiments to collect the eye movement data. In this study, due to the strict requirements of the eye tracker, thirteen subjects' eye movement data were collected

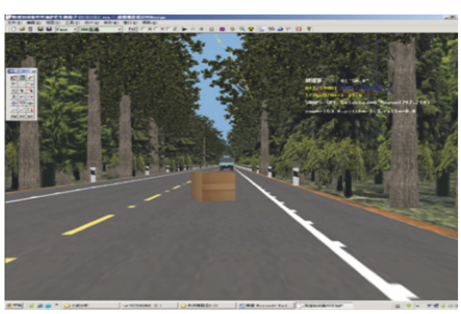
(a) Enclosed space landscape

(b) Semiclosed space landscape

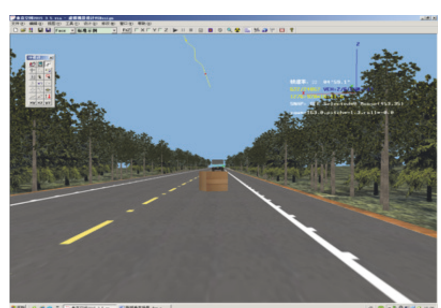
(c) Semiopen space landscape

(d) Open space landscape

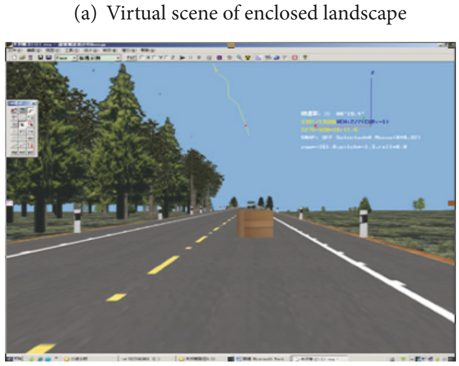
Figure 3: Four types of highway landscapes.



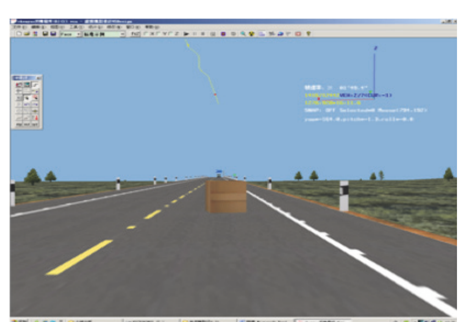
(a) Virtual scene of enclosed landscape



(b) Virtual scene of semiclosed landscape



(c) Virtual scene of semiopen landscape



(d) Virtual scene of open landscape

Figure 4: Four types of virtual landscapes designed using VS-Design.

Table 1: Classification of highway landscapes.

Enclosure degree	Enclosure degree (D/H)	Note
enclosed space landscape	D/H <2	Both sides of the road have a landscape
semi-closed space landscape	2< D/H<4	Both sides of the road have a landscape
Semi-open space landscape	2< D/H<4	One side of the road has a landscape
Open space landscape	D/H >4	No landscape

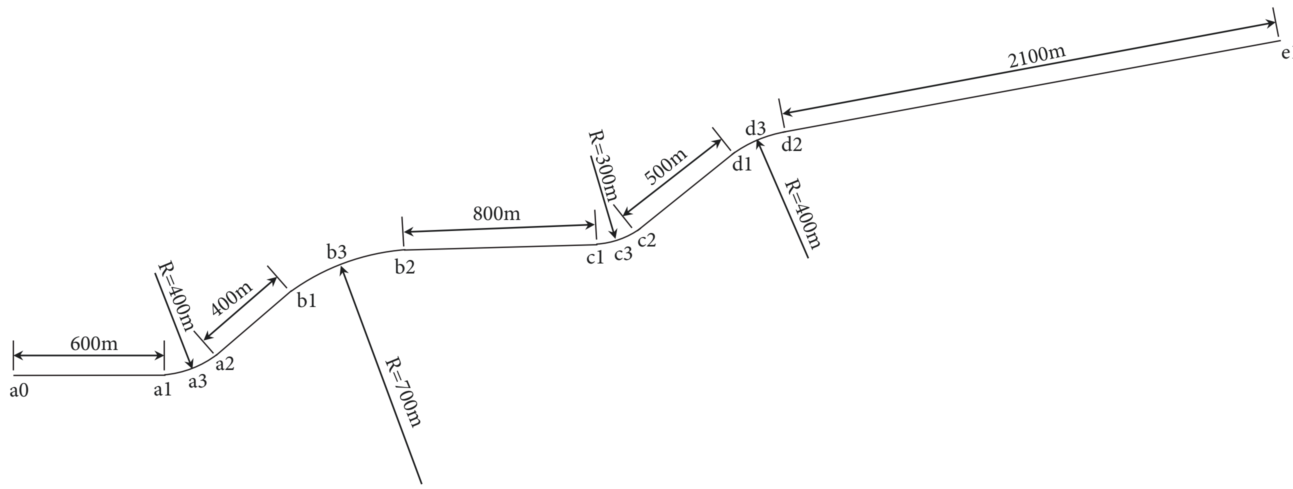


Figure 5: Experimental highway design.

to analyze their visual targets when the obstacle (i.e., dropped box) appeared.

The car speeds in the experiments were controlled to take values approximately 80 km/h. In the experimental results, the average speed in straight highway is 79.7 km/h for open landscape, 78.9 km/h for semiopen landscape, 78.5 km/h for semiclosed landscape, and 77.7 km/h for enclosed landscape. In addition, the average speed in curve highway is 78.7 km/h for open landscape, 78.1 km/h for semiopen landscape, 77.6 km/h for semiclosed landscape, and 77.3 km/h for enclosed landscape in the curves. All of the speed data is full of the experimental requirements.

3. Results

3.1. Drivers' Visual Traces in Different Landscapes. The eye movement data of subjects acquired during the driving processes in different highway landscapes have been analyzed. Since the scatter plots represent the area of fixation, fixate area plots were generated for all the drivers in different landscapes (Figure 6). According to Figure 6, in the enclosed landscape space, drivers' attention was more focused and in a direction that was straight ahead of them. In semiclosed landscapes, the drivers' main fixation ranges are alternately in the far and near of the front, taking into account the center left or right area. In semiopen landscapes, the drivers' fixations are on the right side of the fixation range that is broad, and the main focus is either on the area in front of them, or on the right. In the open landscape, drivers pay attention to all the moving objects and stationary targets; therefore, the eyesight response is more scattered.

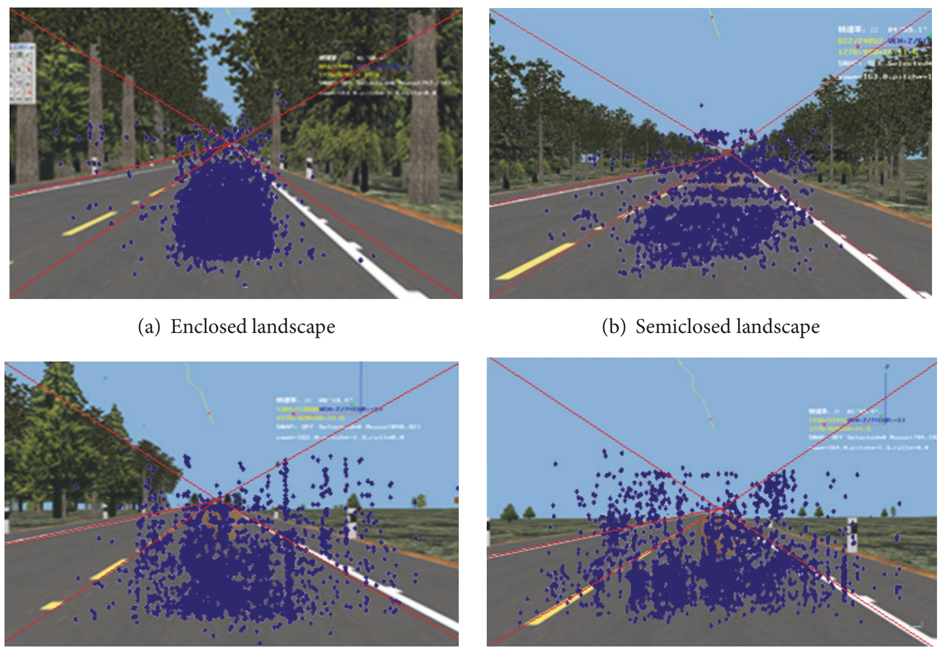
According to the location of the gaze target in the field of vision plane, the fixation area is divided into five regions, respectively, with numbers 1 to 5 (Figure 7). Among them, Region 4 is the center of the main viewing area, Regions 2 and 3 are the left side of the viewing area, Region 5 is the right side, and Region 1 is the faraway area in the front of the viewing. Due to the different types of highway landscapes, the gaze targets in these five regions are also different. The fixation goals and percentage of drivers' visual fixations of each region are listed in Table 2. The dropped box is in Region 4, while the percentage of drivers' visual fixations in Region 4 differs greatly; in the enclosed landscape space, 94.3% of drivers' attentions were focused on this area, and it was declined to 57.5% in the open one. Furthermore, the percentage of drivers' visual fixations of each region at the moment when the box was dropped was statistically calculated; the result was shown in Table 3, and it has the same trend. The result of this visual fixations distribution will lead to a longer emergency reaction time in the open, semiopen, and semiclosed landscapes, especially in open type. In the open landscape, the drivers' attentions are distributed in other regions, and the emergency situation (dropped box) in front of the drive lane cannot be detected in time.

3.2. Questionnaires. Based on the questionnaires regarding the influence of landscape and the terrain along the highway on the behaviors and on the physiological and psychological responses of the drivers, we found that more than 50% of the subjects believe that the landscape would impact their attentions and visions, and approximately 30% of the subjects believe it would impact the driver who in turn alters the

Table 2: Targets in five regions and percentage of drivers' visual fixations in five regions in different highway landscapes.

Fixation regions	Enclosed	Semi-closed	Semi-open	Open
1	A,B(0.4)	B(1.9)	B(0.8)	B(4.6)
2	A,C,D,E(3.1)	A,C,D,E(4.3)	A,C,D,E(1.5)	A,B,C,D,E, M,N(11.2)
3	F,G,H(2.2)	F,G,H(3.6)	F,G,H(1.3)	F,G,H(10.8)
4	I,J,K(93.9)	I,J,K(85.7)	I,J,K(75.2)	I,J,K(57.5)
5	A,C,D,L(0.5)	A,C,D,L(4.5)	A,B,C,D,L,M,N(21.2)	A,B,C,D,L,M,N(15.9)

Note: in the table, 19 capital letters represent 19 targets, A: Trees, B: Sky, C: Traffic Signs, D: Shrubs, E: mileage piles, F: Opposite lane, G: Opposite Cars, H: Left shoulder, I: Driving lane, J: Front car, K: Dropped box, L: Right shoulder, M: Mountains, and N: Grass.



(a) Enclosed landscape

(b) Semiclosed landscape

(c) Semiopen landscape

(d) Open landscape

Figure 6: Drivers' fixation scatter plots in different landscapes.

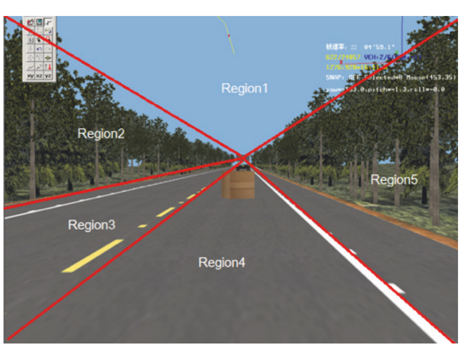


Figure 7: The fixation regions.

vehicular speed. Some subjects believe that it would influence their moods, and only 4% (one subject) believe that it would not influence anything. Based on the initial investigation of subjective feelings of the psychological, physiological, and behavior responses of drivers in different landscapes and the subsequent comparison of the results with the objective measured data, we see that the results are the same; that is, the landscape would have a considerable impact on vision and attention.

3.3. Emergency Reaction Times. In emergency situations, subjects will take different operations, including braking, steering, or braking and steering at the same time. In order to accurately determine drivers' behaviour at the first reaction time in sudden situations, we counted the operation of brake pedals and steering wheels by drivers and found that 17 of the 24 subjects took braking measures after the box appeared, 7 subjects braked and steered at the same time, and there are no drivers who simply steer without braking. So in this study the emergency reaction time refers to emergency braking reaction time. The emergency reaction time of 180 samples ranges from 0.36 to 2.55 seconds (mean = 1.175; s.d. = 0.255). The current literature shows that the reaction time of drivers ranges between 0.3 and 2.5 seconds, and the elicited results from this study are almost in full agreement with the published range [25, 26].

Table 3: Statistics on the percentage of drivers' visual fixations of each region at the moment when the box was dropped under different highway landscapes.

Fixation regions	Enclosed	Semi-closed	Semi-open	Open
1	12.5	45.8	4.3	8.7
2	0	4.2	4.3	21.7
3	8.3	12.5	8.7	4.3
4	66.7	37.5	30.4	26.2
5	12.5	0	52.2	39.1

Table 4: T-tests to compare reaction times for adjacent landscapes.

Alignment	Landscape type	Landscape type	Degree-of-freedom	$t_{(0.01)}$	t	p
Straight	Enclosed	Semi-closed	22	2.508	16.87	<0.01
	Semi-closed	Semi-open	22	2.508	7.159	<0.01
	Semi-open	Open	22	2.508	6.99	<0.01
Curve	Enclosed	Semi-closed	22	2.508	9.09	<0.01
	Semi-closed	Semi-open	22	2.508	6.08	<0.01
	Semi-open	Open	22	2.508	7.97	<0.01

This study combines the descriptive statistics analyses to compare the difference of the emergency reaction time in different landscapes. Drivers' average emergency reaction times in the straight roads with different landscapes are 1.921 seconds (s.d. = 0.318) for the open landscape, 1.494 seconds (s.d. = 0.233) for semiopen landscape, 1.211 seconds (s.d. = 0.252) for semiclosed landscape, 0.831 seconds (s.d. = 0.229) for enclosed landscape, and 1.425 seconds (s.d. = 0.294) for open landscape, 1.074 seconds (s.d. = 0.268) for semiopen landscape, 0.862 seconds (s.d. = 0.193) for semiclosed landscape, and 0.595 seconds (s.d. = 0.155) for enclosed landscape in curves; Figure 8 illustrates the emergency reaction times in different landscapes.

To determine the specific differences among landscapes, the paper analyzes the differences of reaction times between two adjacent landscapes using Student's t-test. Table 4 shows that there are significant pair-wise differences ($\alpha = 0.01$) in the emergency reaction times for adjacent landscapes (p<0.01).

The Spearman rank correlation test was performed to explore whether the reaction time was correlated to highway alignment and highway landscape. The result of Spearman rank correlation coefficient shows that there is liner correlation between the reaction times of highway alignment (R = -0.843; P<0.001) and highway landscape (R = -0.793; P<0.001).

3.4. Regression Model for the Reaction Time. The driver's age and driving experience, etc., will affect the reaction time, and this experiment is tested using multivariate ANOVA under different road landscapes; however, the significance of drivers' gender (p = 0.389), age (p = 0.331), driving distance (p = 0.553), driving experience (p = 0.809), and personality (p = 0.261) on the reaction time is greater than 0.05. Thus, these insignificant variables on reactions time were excluded from the model. The relationships between the independent variables and the dependent variables were established by the regression analysis. From the correlation analysis, it is shown that the response time is linearly related to the highway landscape space (p<0.05) and alignment (p<0.05), so multiple linear regression analysis can be made. Therefore, we take the two variables of highway landscape and alignment as independent variables and the driver's reaction time as the dependent variable to establish the model, and Table 5 shows the values of each parameter in the model, where the adjusted R^2 is 0.714.

The model is as follows:

$$y = 1.86 - x - z \tag{1}$$

where y = reaction time (sec), x = highway landscape (the value 0.961 is for enclosed, 0.636 is for semiclosed, 0.388 is for semiopen, and 0 is for open), and z = highway alignment (0.374 is for curve and 0 is for straight roads). Note: this regression model for the reaction time is the speed of 80 km/h.

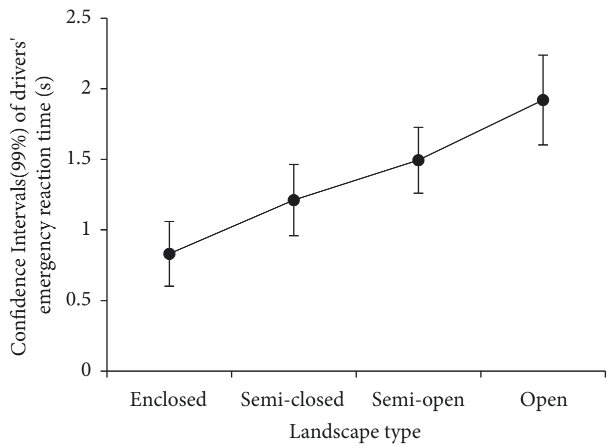
4. Conclusions and Discussion

In order to explore the impacts of the highway landscape on the drivers' eye movement behavior and emergency reaction times, based on driving simulator experiments, the drivers' fixation times, fixation area, emergency reaction times in different landscapes, and questionnaires were analyzed in this study. The key findings are summarized as follows:

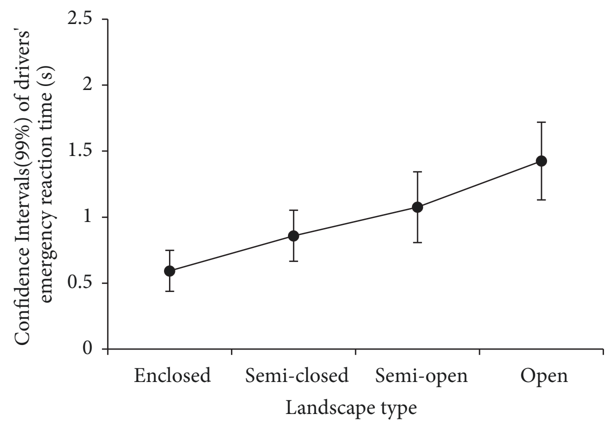
(1) The differences of the drivers' gaze behavior in different landscapes are the main cause of the observed changes of emergency reaction times. In the enclosed landscape spaces, the focus of the drivers was in the front areas of the vehicles, yielding only a small radiation range. In other words, the drivers' attentions were focused. Thus, they could pay attention to emergencies, and thus this resulted in shortened reaction times. In open landscape spaces, the drivers were more likely to pay attention to other moving and stationary targets rather than the road conditions. It led to a larger driver view range and caused considerable

Table 5: Parameter estimation.

Category	Parameters	B	Standard error	t	Sig.	99% confidence interval lower limit	Upper limit
-	Intercept	1.860	0.042	44.266	0.000	1.777	1.943
Landscape	Enclosed	-0.961	0.053	-18.146	0.000	-1.066	-0.857
	Semi-closed	-0.636	0.053	-12.072	0.000	-.0740	-0.532
	Semi-open	-0.388	0.053	-7.329	0.000	-0.493	-0.284
	Open	Reference					
Road alignment	Curve	-0.374	0.037	-10.051	0.000	-0.448	-0.301
	Straight	Reference					
Adjusted R^2		0.714					



(a) Emergency reaction times on straight roads



(b) Emergency reaction times on curves

Figure 8: Confidence intervals of drivers' emergency reaction times for different landscapes.

vehicle trajectory fluctuations that allowed the perception of emergency information in a slower manner.

(2) Significant differences in emergency reaction times in different landscapes were found. The shortest emergency reaction times were observed on curves with enclosed landscapes, while the longest times were found on straight roads with open landscapes. In the same landscape, the emergency reaction time on a curve was smaller than that on a straight road.

(3) The differences between emergency reaction times in different highway landscapes mainly resulted from the influences of landscapes on drivers' attentions. In an enclosed landscape, the drivers' eyesight was focused on the front of the road with few scattered viewpoints, and the attention was more concentrated. In an open landscape, drivers often did not pay attention to the vehicle speed and road conditions, but they were likely to observe other moving objects and stationary targets, and their eyesight was more scattered.

(4) Using the experimental results of drivers' response time of different highway landscapes, we can calculate the stop sight distance at the speed of 80 km/h of highway landscape, thus providing the basis for road alignment design and landscape layout in safety aspect.

(5) Since the reaction time is one of the parameters to effect the stop distance and the stop distance is an important factor affecting traffic safety, the longer reaction time will make the longer stop distance and will increase the probability of accidents.

Despite the abovementioned important findings, this study is not without limitations. In this paper, only the response time at 80 km/h is considered. It would be beneficial to study response time at different speed highway landscapes in the further research. In addition, the contrast of colors has a certain influence on the drivers' response time; in the experiments, the color of the dropped box is brown, and the tree leaves are green. Thus, the box is conspicuous due to the color contrast in the enclosed landscape scenario. It is possible that the result would be different in enclosed and semienclosed landscape if the color of the box or the tree leaves are different. It would be worth analyzing the drivers' response time with diverse color contrasts of the target and background in various highway landscapes. In this study, the emergency reaction time when the box dropped from the leading vehicle was tested and analyzed, but the dropped boxes were designed according to our research needs; in the real world, there are similar situations, such as in the case of living animals crossing the road (e.g., moose); therefore, drivers' behavior in this kind of situations could be a possible follow-up paper topic.

Data Availability

The data will be available to the scientific community by a data article, which will be submitted to an appropriate journal in the near future.

Disclosure

The data used in this study is provided by the Simulation Laboratory of Faculty of Transportation in Kunming University of Science and Technology, Kunming, Yunnan Province, China.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

The work described in this study was funded by Natural Science Foundation of China (No. 71461015). The authors would like to thank their participants for their involvement in the experiments. The experiments were carried out at the Road Traffic Driving Simulation Laboratory at the Kunming University of Science and Technology.

References

[1] H. Antonson, S. Mårdh, M. Wiklund, and G. Blomqvist, "Effect of surrounding landscape on driving behaviour: a driving simulator study," *Journal of Environmental Psychology*, vol. 29, no. 4, pp. 493–502, 2009.

[2] Y. Guo, C. Wang, R. Fu, W. Yuan, and P. Yu, "Driver's reaction time under city road conditions," *Journal of Environmental Psychology*, vol. 26, no. 6, pp. 135–142, 2013.

[3] R. Parsons, L. G. Tassinary, R. S. Ulrich, M. R. Hebl, and M. Grossman-Alexander, "The view from the road: implications for stress recovery and immunization," *Journal of Environmental Psychology*, vol. 18, no. 2, pp. 113–140, 1998.

[4] J.-H. Mok, H. C. Landphair, and J. R. Naderi, "Landscape improvement impacts on roadside safety in Texas," *Landscape and Urban Planning*, vol. 78, no. 3, pp. 263–274, 2006.

[5] H. Chen, A. Fabregas, and P.-S. Lin, "Landscaping of highway medians and roadway safety at unsignalized intersections," *Accident Analysis & Prevention*, vol. 90, pp. 63–72, 2016.

[6] J. Zhang, "Research on drivers' viewpoint distribution characteristics based on eye tracker," *Hunan Communication Science and Technology*, vol. 38, no. 4, pp. 153–155, 2012.

[7] D. K. Tang, *Research on the Relationship between Driver's Driving Physiology, Psychological Reaction and Road Alignment [M.S. thesis]*, Dongnan University, China, 2006.

[8] Q. L. Wang, *Research on Evaluation of Key Parameters of Road Based on Driver's Visual Characteristics [M.S. thesis]*, Changan University, China, 2008.

[9] X. Pan, Q. Fang, and H. Jiang, "Driving visual demand-based safety evaluation of mountainous highway horizontal curve," *Journal of Tongji University (Nature Science)*, vol. 38, no. 12, pp. 1763–1766, 2010.

[10] J. Tian, S. Li, W. Sun, and F. Qiao, "Effects of freeway tunnel on driver's visual characteristics," *Journal of Chang'an University*, vol. 35, pp. 216–221, 2015.

[11] L. Zhang, Y. Yang, M. Qi, and J. Jiang, "Detection of fatigue driving based on facial features," *Journal of Hefei University of Technology*, vol. 36, no. 4, pp. 448–451, 2013.

[12] M. Svetina, "The reaction times of drivers aged 20 to 80 during a divided attention driving," *Traffic Injury Prevention*, vol. 17, no. 8, pp. 810–814, 2016.

[13] Z. L. Yu, *Study on the Driver Critical Reaction Capability upon Simulative Environment [M.S. thesis]*, Universityof Chang Chun, China, 2005.

[14] H. Yuan, G. Shi, X. Huang, and J. Cheng, "Braking model of stopping sight distance," *Journal of Southeast University*, vol. 39, no. 4, pp. 859–862, 2009.

[15] H. Makishita and K. Matsunaga, "Differences of drivers' reaction times according to age and mental workload," *Accident Analysis & Prevention*, vol. 40, no. 2, pp. 567–575, 2008.

[16] L. Warshawsky-Livne and D. Shinar, "Effects of uncertainty, transmission type, driver age and gender on brake reaction and movement time," *Journal of Safety Research*, vol. 33, no. 1, pp. 117–128, 2002.

[17] F. Chen, *The Impact of Road Visual Environment on Traffic Safety [M.S. thesis]*, Chongqing Jiaotong University, China, 2009.

[18] P. A. Hancock, M. Lesch, and L. Simmons, "The distraction effects of phone use during a crucial driving maneuver," *Accident Analysis & Prevention*, vol. 35, no. 4, pp. 501–514, 2003.

[19] F. Chen, S. Chen, and X. Ma, "Analysis of hourly crash likelihood using unbalanced panel data mixed logit model and real-time driving environmental big data," *Journal of Safety Research*, vol. 65, pp. 153–159, 2018.

[20] Z. Liu, J. Xiong, and F. Guo, "Analysis on speed validation of the driving simulator based on different plane alignment," *Journal of East China Jiaotong University*, vol. 29, no. 4, pp. 69–72, 2012.

[21] L. Chen, J. Xiong, and F. Guo, "Validation study of driving simulation system based on vehicle speeds on curves," *Traffic Information and Security*, vol. 28, no. 2, pp. 107–109, 2010.

[22] D. Zhu, "Theories, techniques and applied researches about eye-movement psychology," *Journal of Nanjing Normal University*, vol. 1, pp. 92–97, 2005.

[23] A. Borowsky, D. Shinar, and T. Oron-Gilad, "Age, skill, and hazard perception in driving," *Accident Analysis & Prevention*, vol. 42, no. 4, pp. 1240–1249, 2010.

[24] L. Chen, J. Xiong, F. Guo, and H. Wan, "Image calibration method of driving simulator based on vision and cognition," *China Journal of Highway and Transport*, vol. 30, no. 1, pp. 129–135, 2017.

[25] X. Zhi, H. Guan, X. Yang et al., "An exploration of driver perception reaction times under emergency evacuation situations," in *Proceedings of the Transportation Research Board 89th Annual Meeting*, 2010.

[26] T. J. Triggs, "Driver brake reaction times: unobtrusive measurement on public roads," *Public Health Reviews*, vol. 15, no. 4, pp. 275–290, 1987.