

Retraction

Retracted: Study on Driver Gaze Characteristics in Sight Distance Limited Section of Mountain Highway Based on Visual Information

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

In addition, our investigation has also shown that one or more of the following human-subject reporting requirements has not been met in this article: ethical approval by an Institutional Review Board (IRB) committee or equivalent, patient/participant consent to participate, and/or agreement to publish patient/participant details (where relevant).

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] Y. Tang, X. Peng, S. Xu, M. Bai, L. Lin, and H. Sun, "Study on Driver Gaze Characteristics in Sight Distance Limited Section of Mountain Highway Based on Visual Information," *Journal of Mathematics*, vol. 2022, Article ID 9482875, 8 pages, 2022.

Research Article

Study on Driver Gaze Characteristics in Sight Distance Limited Section of Mountain Highway Based on Visual Information

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In order to study the gaze behavior characteristics of drivers in mountainous road sections with limited sight distance, the real vehicle test is carried out by using Smart Eye Pro 5.7 noninvasive eye tracker. Combined with the sight distance change rate theory, 6 typical test representative mountainous sections are selected to study the gaze distribution law and gaze duration of drivers in different mountainous sections. The research shows that when the driver drives on the test section with the most unfavorable sight distance of 44 m, 50 m, and 56 m, the fixation characteristics of “from far to near” are significant, and the long fixation duration accounts for a large proportion of the driver. When the driver drives on the section with the most unfavorable sight distance of more than 70 m, i.e., the sight distance change rate of less than 1.33, the fixation characteristics of “from far to near” disappear. The driver’s fixation stability increases, the fixation freedom increases, and the proportion of medium and long fixation duration decreases. The data analysis provides a theoretical basis for drivers to pass safely in mountainous sections.

1. Introduction

Sight distance is a necessary basis to ensure driving safety. In mountainous areas, due to poor linear balance and vegetation influence, the incidence of sight distance limited sections is high. Insufficient sight distance can easily lead to insufficient depth of driver’s field of vision, a sharp rise in driving tension, and then, it is easy to take abnormal driving behaviors such as sharp turning and sharp deceleration, making the road section with limited sight distance a high-risk road section. Potts et al. [1] analyzed the impact of sight distance on road traffic safety and concluded that sight distance is an important index affecting road traffic accident rate. At present, the problems related to sight distance have received the attention of scholars at home and abroad.

First, scholars at home and abroad have carried out more research on highway driving sight distance. Based on people’s research on kinematics theory, Yuan et al. [2] have developed a new calculation method of parking sight distance. Du and Fang [3] have proposed a new method of

calculating sight distance by segmented h -order parabola. The original sight distance calculation method has been improved. Based on the road environment perception technology, Li et al. [4] established the ranging model of driving sight distance by extracting effective feature points and using the small hole imaging model. Bassani et al. [5] analyzed the longitudinal behavior of drivers on rural roads with limited sight distance and obtained the relevant impact of sight distance on driving behavior. Yang et al. [6] and others obtained the nonlinear relationship between spatial sight distance and expected velocity by using the method of regression analysis and experiment. Li [7] modelled and analyzed the driver gaze behavior on the basis of drivers while crossing urban roads. Qiao et al. [8] investigated the movement of drivers’ eyes while crossing roads. Wu and Yan [9] studied the distribution characteristics of viewpoint of a driver on the crosswalks. Wuhong et al. [14] studied transportation systems that are smart and connected.

In terms of the impact of horizontal curve design elements on highway traffic safety, Jia and Wang [10] put forward the corresponding improvement scheme of safety

guarantee technology through the evaluation of intersection angle, road conditions, traffic safety facilities, and other factors and combined with the research on its safety influencing factors. Robertson [11] analyzed the impact of geometric design indexes such as curvature radius, truck sight distance, turning radius, and longitudinal slope on truck operation safety. Ibrahim et al. [12] found that the occurrence of adverse combination of alignment will greatly improve the incidence of traffic accidents, among which the adverse combination of horizontal and vertical curves with small radius has the greatest impact;

At present, the research status at home and abroad mainly focuses on the calculation method of highway sight distance and the impact of horizontal curve design elements on highway safety in mountainous areas. The research on drivers' eye movement characteristics mainly focuses on intersections, urban sections, and urban roads. There is less research on drivers' gaze characteristics with limited sight distance in mountainous roads, Therefore, this study intends to carry out real vehicle eye movement test on the road section with limited sight distance in mountainous areas and study the driver's gaze characteristics in the road section, so as to provide theoretical reference for the road element design and the setting of traffic safety facilities in the road section with limited sight distance in mountainous areas.

In the following sections, Section 2 presents the scheme of the test. The fixation distribution characteristics are discussed in Section 3. Further, the analysis of fixation distribution characteristics is given in Section 4. Section 5 ends the study with a conclusion.

2. Test Scheme

2.1. Test Section. This time, g319 Chongqing Bishan Tongliang section is selected as the test section. This section is a class II mountain highway with a design speed of 40 km/h. It has good technical conditions, complex topographic conditions along the line, many small radius flat curve line sections, and prominent problems of limited sight distance.

Relevant research shows that the greater the sight distance change rate, the worse the driving safety of the road section [13]. Take the sight distance change rate as the basis for the selection of sight distance limited sections, and calculate the entry sight distance value, the most unfavorable sight distance value, and sight distance change rate of each curve section, respectively, as shown in the following equation:

$$I_S = \frac{(S_1 - S_2)}{L}, \quad (1)$$

where I_S is the sight distance change rate (%), indicating the turning sight distance value of the road section; S_1 and S_2 are the most unfavorable sight distance values; and L is the length of sight distance transition section.

Seven typical test sections are selected for the real vehicle test, and the alignment parameters are given in Table 1:

The selected road section is shown in Figure 1.

TABLE 1: Selection of alignment parameters of experimental sections.

No.	R (m)	S_1 (m)	S_2 (m)	L (m)	Rate of change, I_S
1	62	65	44	10	2.1
2	80	75	50	15	1.67
3	100	70	56	10	1.4
4	162	90	70	18	1.33
5	260	102	90	11	1.09
6	360	120	106	14	1.00

2.2. Test Personnel. Five drivers with more than 3 years of driving experience are selected, with an average age of 35 years and driving ages of 10, 6, 15, 5, and 6 years, respectively. It is required to have normal physical function, good driving habits, and no previous driving experience on the test section.

2.3. Test Process. Install eye tracker and other test instruments for the test driver, drive the test vehicle to the starting point of the test section, stop, adjust the most comfortable driving position, turn on the host, and try to turn on each instrument synchronously on the premise of ensuring that each test instrument can operate normally, and let the camera record the accurate time of turning on the instrument, and start the test from the starting point of the test section, as shown in Figure 2:

3. Analysis of Fixation Distribution Characteristics

3.1. Characteristic Analysis during Driving. Select the driver's gaze point coordinate data of the two sections with great difference in the severity of sight distance restriction and analyze the difference in the distribution characteristics of the driver's gaze point from entering to leaving the corner.

Figure 3 shows the driver's gaze characteristics during driving in the section with a sight distance of 44 m; when the driver is about to drive into the section with limited sight distance from the general section, the driver's gaze is mainly focused on the landscape at the end of the far field of vision on the right side of the front and the roadside guardrail. At this time, due to the limited sight distance, drivers need to constantly pay attention to the changing road information in the blind area of the right field of vision to adjust their driving behavior.

When the vehicle has just entered the road section with limited sight distance and has not yet passed the midpoint of the curve, because the driving sight distance is seriously limited at this time, the distribution law of fixation points begins to show the characteristics of "from far to near." At this time, the driver mainly focuses on the obstacles near the right side, and the distance between the vehicle and the obstacles needs to be controlled on the one side. On the other hand, the steering wheel needs to be adjusted through the collected visual information, and the visual load will increase to a certain extent.

When the driver passes the midpoint of the curve, with the gradual improvement of sight distance, the driver's gaze



FIGURE 1: Test section.

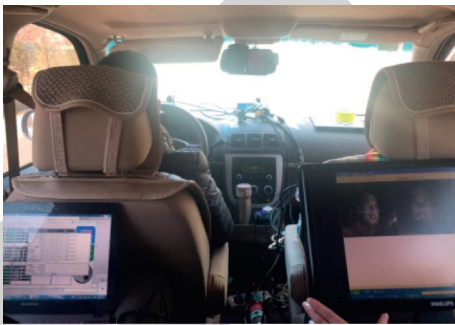


FIGURE 2: Data acquisition during test.

area shifts from the near obstacles on the right to the road, landscape, and guardrail far away on the right. At this time, the driver's attention to the far road landscape increases and the attention to the near obstacles decreases.

Figure 4 shows the driver's gaze characteristics during driving in the road section with a sight distance of 106 m; compared with the gaze characteristics of the road section with a sight distance of 44 m, the driver's gaze points are basically concentrated in the far area from the incoming road section to the midpoint of the curve, and the gaze characteristics of "from far to near" disappear. After passing the midpoint of the curve, due to the further improvement of

the sight distance, the driver looked at the increased degree of freedom and began to pay attention to the vehicle driving on the left. It shows that the driver's gaze stability is higher in the section with small sight distance change.

3.2. Driver's Gaze Distribution under Different Sight Distance Conditions. The fixation point coordinate data of eye movement data are selected to study the distribution law of drivers' fixation points in the road section with limited sight distance under different sight distance conditions.

According to the actual vehicle test (Figure 5), the driver's eye movement data on the road section with sight distance of 44 m are screened and analyzed. It can be seen that when the driver is driving on this road section, the fixation points are mainly focused on the far ahead (right), far right, and near right, and the fixation frequencies are 65%, 20%, and 5%, respectively. At this time, in addition to focusing on the far ahead (right) to adjust the driving direction, due to the limited sight distance on the right side, the driver also needs to pay attention to the obstacles on the right side to ensure that there is sufficient safety distance between the vehicle and the obstacles. During the whole process from entering the curve to driving out of the curve, the driver's gaze characteristics show the characteristics of "from far to near."



FIGURE 3: Distribution of drivers' injection points from entering to leaving the corner in the road section with the most unfavorable sight distance of 44 m.



FIGURE 4: Distribution of drivers' injection points from entering to leaving the corner in the road section with the most unfavorable sight distance of 106 m.

According to the actual vehicle test (Figure 6), the driver's eye movement data on the road section with a sight distance of 50 m are screened and analyzed. It can be seen that when the driver is driving on this road section, the fixation points are mainly focused on the far ahead (right), far right, and near right, and the fixation frequencies are 71%, 10%, and 8%, respectively. Compared with the road section with a sight distance of 44 m, although the driver's fixation frequency on the near right is reduced at this time, the distribution of gaze in the whole curve driving process still shows the characteristics of "from far to near."

According to the actual vehicle test, the driver's eye movement data on the road section with sight distance of

56 m are screened and analyzed (Figure 7). It can be seen that when the driver is driving on this road section, the fixation point position does not change greatly due to the small increase of sight distance. At this time, the driver's fixation points are also concentrated in the far ahead (right), far right, and near right, and the fixation frequencies are 73%, 18%, and 4%, respectively. The fixation characteristics of "from far to near" are still significant.

According to the actual vehicle test, the eye movement data of the driver on the road section with the sight distance of 70 m are screened and analyzed (Figure 8). It can be seen that when the driver is driving on this road section, the distribution of fixation points has changed to a certain extent

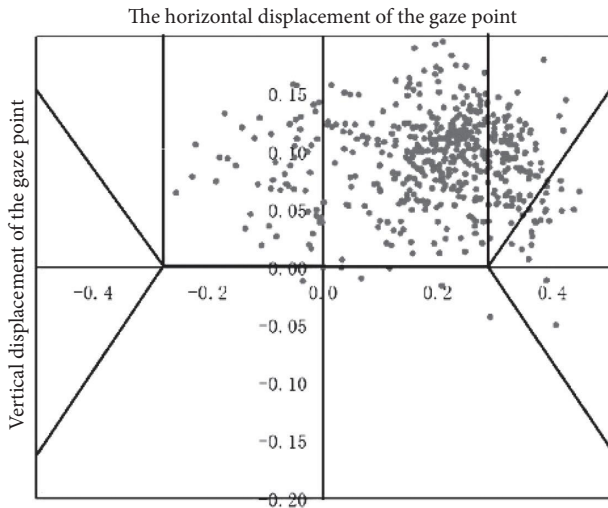


FIGURE 5: Distribution of driver's fixation points in 44 m sight distance section.

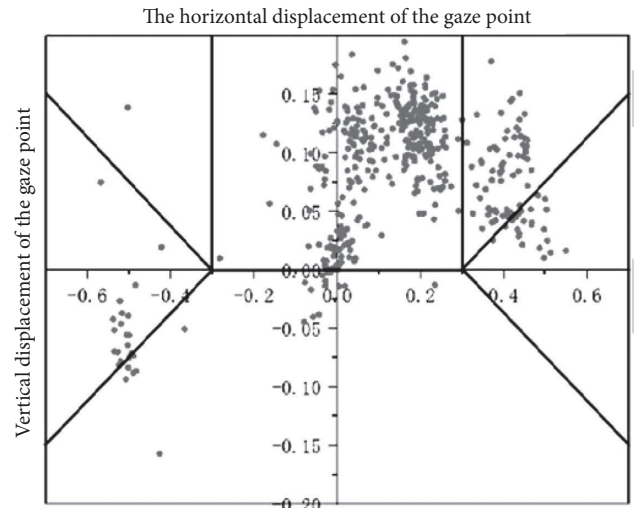


FIGURE 7: Distribution of driver's fixation points in 56 m sight distance section.

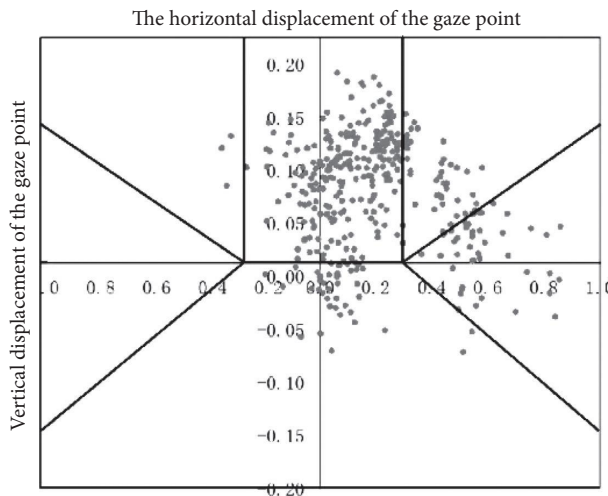


FIGURE 6: Distribution of driver's fixation points in the road section with sight distance of 50 M.

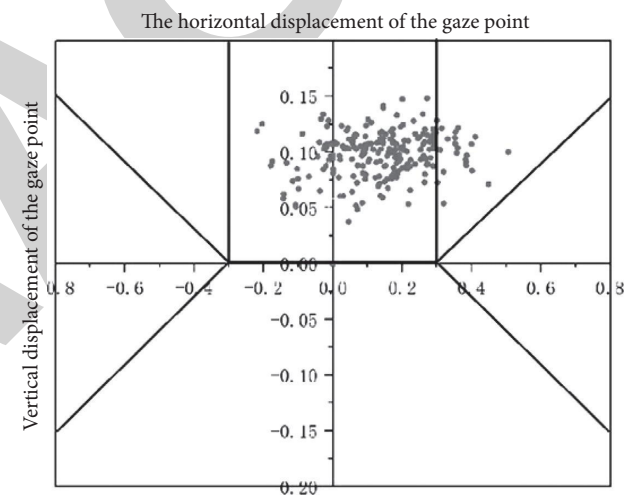


FIGURE 8: Distribution of driver's fixation points in the road section with sight distance of 70 m.

with the increase of sight distance. The fixation points are mainly concentrated in the far ahead and the far right, and the video injection rates are 84% and 16%, respectively; the driver basically focused on the distant landscape, roads, and obstacles. Due to the improvement of sight distance, the lack of depth of vision caused by insufficient sight distance has been improved, and the "from far to near" gaze characteristics have disappeared.

For the test section with a sight distance of 90 m (Figure 9), the driver's main focus area is still far ahead. Compared with the section with a sight distance of 70 m, the driver's frequency of paying attention to the far ahead (left side) increases, indicating that in the right turn section with a wide sight distance, the driver has a greater degree of freedom to pay attention to the road traffic information not on the right side.

When the sight distance value of the test section reaches 106 m (Figure 10), due to the continuous improvement of sight distance, the driver has a higher degree

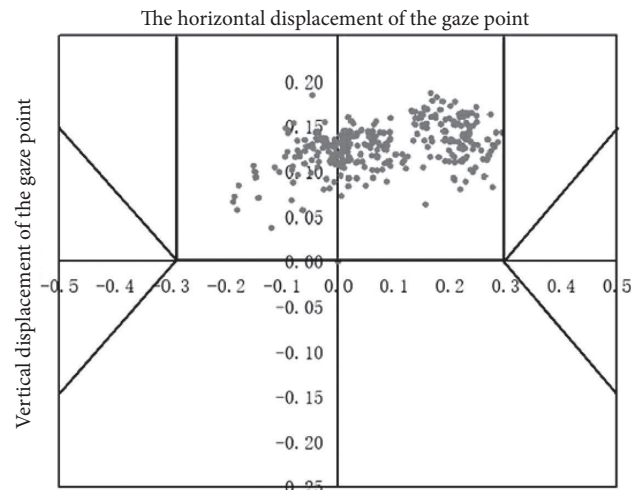


FIGURE 9: Distribution of driver's fixation points in 90 m sight distance section.

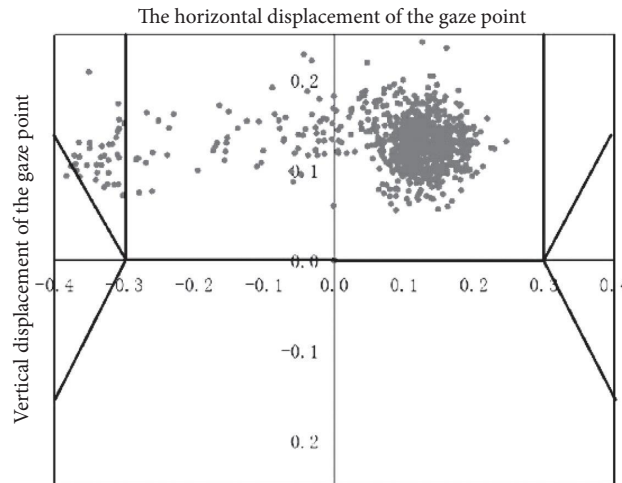


FIGURE 10: Distribution of driver's fixation points in 106 m sight distance section.

of freedom to pay attention to the road traffic information in other directions, and the attention to the road landscape and traffic information in the distance is much higher than that in the near.

When the driver is driving on the road with limited sight distance, the gaze characteristics change with the gradual increase of sight distance. When the sight distance restriction is serious, the gaze characteristics of "from far to near" are significant (Tables 2 and 3). Although the main gaze area is far ahead (right side), due to the serious sight distance restriction, it is necessary to focus part of his energy on nearby things such as roadside obstacles, compared with the general road section with good sight distance, the visual load will accumulate, and the psychophysiological intensity load of long-term driving and driving on this road section will accumulate, which is not conducive to the driving safety of the road section. When the sight distance value reaches 70 m and the sight distance change rate is close to 1.33, the driver's attention to the road landscape and traffic information in the distance is much greater than that in the near, the "from far to near" gaze characteristics disappear, and the gaze stability increases. With the further increase of sight distance value and the further decrease of sight distance change rate, the driver's gaze freedom increases.

4. Fixation Duration Analysis

In the process of driving, different objects carry different amounts of information, which also leads to differences in the difficulty of drivers in identifying different objects. The difficulty of drivers in identifying objects can be measured by gaze duration. The shorter the gaze duration, the less difficult it is to process traffic information, and the easier it is for drivers to identify objects. When the driver's gaze time is too long, it is considered that it is difficult for the driver to process the traffic information, or the driver is interested in the area. In this section, the relevant data of the driver's gaze duration under the sight distance of 44 m, 50 m, 56 m, and 106 m are selected for analysis, as given in Table 4.

It can be seen from Table 4 that in sections with limited sight distance, the driver's gaze duration is mostly less than 50 ms. With the gradual increase of sight distance, the driver's gaze duration will focus more on short gaze, and the longer gaze will gradually decrease. It shows that with the continuous improvement of sight distance, the difficulty for drivers to obtain the road information in front is gradually reduced, and there is no need to look for a long time to obtain the driving information.

- (i) In the right turn section with a distance of 44 m, the driver's gaze duration is mostly concentrated within 100 ms. However, due to the serious restriction of sight distance in the section, the driver needs to pay constant attention to the information such as obstacles near the right side and roadside dangerous objects to ensure his driving safety. Therefore, the proportion of driving gaze duration exceeding 100 ms exceeds 30%. It reflects that the driver needs to constantly pay attention to the changing road traffic information when driving under the sight distance condition. Compared with the road section with better sight distance condition, it is easier to accumulate visual load.
- (ii) In the right turn section with a distance of 50 m, the proportion of drivers' gaze duration exceeding 100 ms is still high, reaching about 25%
- (iii) In the right turn section with sight distance value of 56 m, the proportion of drivers with gaze duration less than 100 ms reaches 78.14%, and the proportion of drivers with gaze duration less than 50 ms reaches 52.79%. Compared with the first two sections, such short note video rate increases, but the proportion of gaze duration more than 150 ms still exceeds 10%.
- (iv) When driving on a right turn section with a plane sight distance of 70 m, the proportion of drivers' gaze duration less than 100 ms has reached 85%, the proportion of longer gaze duration has been greatly reduced, and the proportion of gaze duration greater than 300 ms has changed to 0%, indicating

TABLE 2: Proportion of fixation distribution 1.

Proportion of fixation point distribution under different sight distance conditions	44 m	50 m	56 m
Far ahead	65%	71%	73%
Near the front	0	0	0
Far right	25%	10%	18%
Near the right	5%	8%	4%
Far left	0	0	0
Near the left	0	0	0

TABLE 3: Proportion statistics of fixation point distribution 2.

Proportion of fixation point distribution under different sight distance conditions	70 m	90 m	106 m
Far ahead	84%	100%	86%
Near the front	0	0	0
Far right	16%	0%	0
Near the right	0%	0%	0
Far left	0	0	13%
Near the left	0	0	1%

TABLE 4: Analysis of driver gaze duration in different sight distance limited sections.

Fixation duration t (ms)	Percentage of corresponding fixation time under different sight distances (%)					
	44 m	50 m	56 m	70 m	90 m	106 m
$0 < t < 50$	47.37	52.84	57.79	70	71.24	77.14
$50 \leq t < 100$	20	23.07	20.35	15	21.43	14.29
$100 \leq t < 150$	11.16	10.53	11.16	7.5	4.15	2.86
$150 \leq t < 200$	5.26	3.85	2.38	0	0	1.43
$200 \leq t < 250$	5.26	2.52	3.22	0	1.72	1.43
$250 \leq t < 300$	7.9	5.39	3.1	7.5	0	0
$t \geq 300$	3.05	1.89	2	0	1.28	2.86

that when the sight distance is increased to 70 m, the driving field of vision increases, and the proportion of short gaze duration increases. The proportion of longer gaze duration is small, the difficulty of obtaining road traffic information is reduced, and the driving visual load is reduced.

- (v) When the plane sight distance reaches 106 m, the proportion of the driver's fixation duration less than 100 ms has exceeded 90%, and the proportion of the driver's fixation duration more than 150 ms has decreased to 3%, indicating that the driver's visual load intensity accumulation speed has decreased to a great extent, and the psychological tension will be reduced accordingly.

5. Conclusion

In this study, we found that the distribution of drivers' fixation points in the road with limited sight distance is affected by the sight distance change rate. In the case of larger change rate of sight distance, the driver gradually transfers his gaze energy from the far right to the obstacles near the right due to the lack of depth of field of vision, and the gaze characteristic of "from far to near" is significant. On the other hand, when the sight distance change rate is decreased, the fixation characteristics of fixation point "from far to near" gradually weakened, disappeared when the sight distance change rate was close to 1.33, and the fixation freedom increased.

Moreover, in the road section with limited sight distance, the driver's gaze is mainly short gaze. With the gradual increase of sight distance, the proportion of short gaze increases and the proportion of medium and long gaze decreases. In addition, the driver is prone to the visual load accumulation effect in the road section with severe sight distance restriction. Reasonable safety guarantee measures shall be arranged to induce the driver to adopt reasonable running speed to safely pass through the road section with limited sight distance.

Data Availability

The data supporting the findings of this study are included within the article.

Disclosure

The authors confirm that the content of the manuscript has not been published or submitted for publication elsewhere.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors have read the manuscript and approved the study.

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References

- [1] I. B. Potts, D. W. Harwood, D. J. Cook, E. T. Donnell, and B. Hamadeh, *Design Guidelines for Horizontal Sightline Offsets*, No. Project 15-59, 2019.
- [2] H. Yuan, G. Shi, X. Huang, and J. Cheng, "Stopping sight distance braking model," *Journal of Southeast University (Natural Science Edition)*, vol. 39, no. 4, pp. 859–862, 2009.
- [3] B. Du and S. Fang, "Sight distance and design method of segmented cubic parabola," *Highway traffic science and technology*, vol. 05, pp. 45–47, 2002.
- [4] T. Li, Y. Lai, T. Fang, Y. Tianyu, and L. Yongtao, "Research on vehicle sight distance detection algorithm based on feature point extraction technology," *Journal of Chongqing University of Technology (Natural Science)*, vol. 33, no. 7, pp. 37–43, 2019.
- [5] M. Bassani, L. Catani, A. Salussolia, and C. Y. D. Yang, "A driving simulation study to examine the impact of available sight distance on driver behavior along rural highways," *Accident Analysis and Prevention*, vol. 131, 2019.
- [6] Z. Yang, Z. Guo, and X. Du, "Prediction model of expressway running speed based on visual information," *Journal of Tongji University (Natural Science Edition)*, vol. 35, no. 7, pp. 929–934, 2007.
- [7] Z. Li, "Modeling and analysis of driver gaze behavior based on real vehicle eye movement experiment," *Science Technology and Engineering*, vol. 18, no. 11, pp. 312–317, 2018.
- [8] J. Qiao, R. Guo, and W. Li, "Analysis of eye movement characteristics of drivers crossing urban roads," *Chinese Journal of safety science*, vol. 30, no. 7, pp. 13–18, 2020.
- [9] L. Wu and G. Yan, "Study on the distribution characteristics of driver's viewpoint on the crosswalk," *Traffic science, Technology and Economy*, vol. 22, no. 3, pp. 1–4, 2020.
- [10] M. Jia and L. Wang, "Research on safety of abnormal highway intersection," *Science and Technology Innovation*, vol. 35, pp. 91–92, 2017.
- [11] S. Robertson and L. A. Hall, "Incorporating truck crash modeling into a methodology for evaluating the relative need for truck route improvements," 2001.
- [12] S. E. Ibrahim, T. Sayed, and K. Ismail, "Methodology for safety optimization of highway cross-sections for horizontal curves with restricted sight distance," *Accident Analysis & Prevention*, vol. 49, pp. 476–485, 2012.
- [13] J. Gao, H. You, and G. Wu, "Alignment safety evaluation of mountainous expressway based on preview sight distance," *Highways*, vol. 22, no. 5, pp. 451–712, 2008.
- [14] W. Wuhong, B. Martin, and J. Xiaobei, *Green, Smart and Connected Transportation Systems*, <https://link.springer.com/book/10.1007%2F978-981-15-0644-4>, 2007.