Study on the Law of Drivers' Eye Movement Index in Different Landscape Environment

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Abstract To study the law of drivers' eye movement indices, indoor simulation driving experiment method was adopted, two-lane second-class grassland highway was designed to simulate real road conditions. 48 subjects were selected for the experiment, groups were divided according to different driving ages, three eye movement sensitive indexes including fixation duration, pupil diameter and scan range were extracted, the variation rule of eye movement index of drivers with different experience under different landscape environment was quantified. It was found that the relationship between the landscape environments and eye movement index was U-shaped, the changes of eye movement indexes of drivers at different driving ages were different. The results showed that 4 /km was the optimal threshold number of combined elements. In this environment, the change rate of driver eye movement index was the largest, extraction information was the most; When the number of elements was greater than or less than 4 /km, the change rate of driver eye movement index would decrease. The results could provide reference for improving and optimizing the design of grassland highway landscape environment.

1. Introduction
The main landscape type in Inner Mongolia Autonomous Region was grassland, where there was little traffic volume and low population density. Most of the highway lines were long straight lines or large radius curves, and landscape environment was single and vegetation coverage was low. The traffic engineering facilities was single and the quantity was insufficient; the road surface was mostly gray black asphalt pavement; the monotonous landscape environment was easy to reduce drivers' driving operation ability and their perception, judgment and decision-making ability of traffic information, thus seriously endangering drivers' physical and mental health and driving safety.

Thiffault et al. believed that the long, straight and monotonous road environment could easily make drivers produce negative emotions, affect driving behavior, induce driving fatigue and increase accident incidence, while the changing road landscape environment could effectively alleviate driver fatigue and reduce safety risks[1]. Dick DE Waard et al. believed that if landscape elements were added in the monotonous environment, the effort level of drivers would be correspondingly reduced and the level of safe driving would be improved[2]. Wu Hui et al. believed that different landscape elements had different physiological and psychological effects on human body[3]. Mao Kejun thought that too much...
or too little information could not form a good effect on drivers, and the information amount of visual stimulation should have a reasonable range[4]. Zhang Guiman believed that the combined signs of linear induction and warning were relatively suitable for the stimulation of drivers and could play an effective prompt role[5]. Shao Qi et al. believed that colored roads could effectively impact drivers' vision, improve their attention and alert the changes of road conditions[6]. Zhuo Xi believed that yellow and red road surface was better in improving visual inductivity research, gray and black road surface was worse[7].

In conclusion, the research on landscape monoton y mainly focused on the single or coupled elements of the same landscape type, while the research on the coupling of multiple landscape elements of different landscape types was less. This paper adopted the indoor driving simulation experiment method, designed a two-lane secondary prairie road, selected 48 different experience drivers, researched the change law of the driver's eye movement indices in the different landscape environments, established the model of between the landscape environment and driver's eye movement index, confirmed the importance of highway landscape environment for driver's eye movement indices. This study has great theoretical and practical significance for improving and optimizing the monotonous landscape environment of grassland highway, such as single landscape and insufficient information, and improving the driving safety level of drivers.

2. Experimental Scheme Design

2.1. Section profile and element selection

Secondary grassland highways in Inner Mongolia Autonomous Region account for 56.97%, reaching 14,600 km. This study takes S309 grassland secondary road as an example, after investigation, the above 80% for long straight line sections, the longest line of 16.35km, and taking 100km of this section for investigation and statistics, it is found that road traffic engineering facilities were not perfect and the quantity was seriously insufficient. Based on the actual situation and research needs, the author selected the landscape types for two kinds of traffic engineering facilities and the humanities landscape elements, including ban signs, warning signs, directional signs, indication signs, tourism signs, speed hump, orange-red road, orange road, bushes, sculpture, billboards 11 landscape elements to build different landscape environment, studied its effect on the driver's eye movement index.

2.2. Simulation experiment scene design

In order to effectively control the experimental environment and avoid interference from other external environmental factors, the experiment adopted interactive controllable, safe and economical simulated driving environment. The simulation experiment section scene data adopted the real road condition and environment data of grassland secondary highway, with two lanes and speed of 80km/h. Based on previous studies, the simulation scene was set as long straight highway, with clear weather, free driving within 80km/h, and no traffic flow. There was no other element information except the setting element. Due to the different roles of each landscape element played in the environment and the importance of information transfer, the experimental method combined with expert investigation method and analytic hierarchy process was used to assign weights to each element, as shown in Table 1.

| landscape elements | prohibitory sign | warning sign | directional sign | Orange-red road | Orange road | sculpture |
|--------------------|------------------|--------------|------------------|-----------------|-------------|-----------|
| weight (%)         | 30.23            | 16.42        | 9.39             | 7.56            | 7.54        | 6.52      |

| landscape element  | tourist sign     | indication sign | speed hump | bush | billboard | total |
|--------------------|------------------|-----------------|------------|------|-----------|-------|
| weight (%)         | 6.11             | 5.84            | 4.49       | 3.39 | 2.54      | 100   |

In table1, the traffic engineering facilities elements were the simple signs of the simple information defined in the "Standard", and the cultural landscape elements were all based on individual units of a
certain size. After investigation, the set number of landscape elements was 1 /km unit straight line length in the actual grassland highway. The corresponding weight range was 0-0.1. This landscape was a simple landscape, which was set as a reference section in the simulation scene and represented by D0. Based on this, four kinds of simulation experiment sections were set up according to the trend of increasing landscape elements, which were respectively represented by D1, D2, D3 and D4. The specific setting methods were shown in Table 2. Each simulation experiment section was 15km.

### Table 2  Settings of landscape elements in different landscape environment

| Different landscape environments | elements (a/km) | 15km elements (a) | weight range |
|----------------------------------|----------------|-------------------|-------------|
| D0                               | 1              | 15                | 0-0.1       |
| D1                               | 2              | 30                | 0.1-0.2     |
| D2                               | 3              | 45                | 0.2-0.3     |
| D3                               | 4              | 60                | 0.3-0.4     |
| D4                               | 5              | 75                | 0.4-0.5     |

### 2.3. Subjects and experimental requirements

According to the central limit theorem, 48 subjects, aged 25-55, were selected and divided into 4 groups according to different driving ages, including 0-1 year 12 (0.67±0.51 million km/y), 1-5 years 12 (3.35±14,820 km/y), 5-10 years 12 (7.34±22,450 km/y), and over 10 years 12 (9.76±0.53 million km/y). The age and driving age of the subjects were analyzed significantly, and there were no significant differences between the groups. The day before the experiment, drivers were required to get enough sleep and not to take any drugs or pungent drinks within 24 hours. Before the formal experiment, simulated driving training was conducted for 30 minutes. At the beginning of the formal experiment, the static test was carried out for 5 minutes, and then the experiment was carried out in 5 scenes at a speed of 80km/h. To ensure the validity of the experimental data, the subjects conducted the experiment at the same time every day. During the experiment, kept the car quiet and turned off the electronic devices unrelated to the experiment, pay attention to the landscape information element as much as possible.

### 3. Results

#### 3.1. Fixation duration

To better analyze the impact of landscape environment and driving experience on average gaze duration, K-S test all followed normal distribution (sig.>0.05) and conformed to homogeneity of variance test (Levene=1.252, p=0.248), two-factor analysis of variance was further performed, landscape environment had a significant influence on average fixation duration (p=0.001), driving experience had a significant influence on average gaze duration (p=0.001), interaction between landscape environment and driving experience (p <0.05).

The analysis of the law of average fixation duration of drivers in different landscape environments was shown in Figure.1. It could be seen from Figure.1, the drivers average gaze duration decreased from D0-D4 landscape environment. High driving age drivers had better experience and skills, paying more attention to traffic information, and could effectively extract and processed traffic information. However, it was difficult for drivers with low driving age to extract the content of traffic information, pay more attention to irrelevant traffic information during driving, and the average fixation duration of a single point of information was greater than that of drivers with high driving age. The mean value of each group of drivers reached the minimum value under D3 landscape environment.
Figure 1 Mean fixation duration

3.2. Mean pupil diameter

For the change of the pupil diameter of the driver caused by the change of the external environment, the normal test value of the driver at rest could be used for comparative analysis. K-S test was conducted on the data by statistical analysis method. They all followed normal distribution (sig.>0.05) and met homogeneity of variance test (Levene=0.123, p=0.921). Further two-factor variance analysis showed that different landscape environments had significant influence on average pupil diameter (p=0.001), different driving experiences had significant influence on average pupil diameter (p <0.05), and there were interactions between different landscape environments and driving experiences (p <0.05). The variation rule analysis of drivers' average pupil diameter under different landscape environments was shown in Figure 2.

Figure 2 mean pupil diameter

It can be seen from figure 2 that the average pupil diameter of drivers decreases gradually with the change of landscape environment during driving, and the average pupil diameter was the smallest under static measurement. Low driving age driver experience was insufficient, or nervous or excited, pupil diameter variation fluctuated greatly. Drivers with a high driving age could quickly acquire traffic information and had a low cognitive load of information. However, drivers with a low driving age need to pay more efforts to perceive and judge traffic information due to their lack of experience, so their psychological load was larger and their average pupil diameter was larger. The mean value of each group drivers' indicators reached the minimum value under D3 landscape environment. In the static test state, the drivers were completely relaxed without any mental load, and the average pupil diameter was normal. In the D3 landscape environment, the average pupil diameter of drivers was closest to the mean value of static measurement indicators, with small psychological load, the most relaxed body and mind, and the highest cognitive ability. However, in the D4 landscape environment, excessive landscape elements lead to increased visual load, and increase the average pupil diameter gradually.
3.3. Average scan range

Statistical analysis method was used to quantitatively analyze the variation of drivers average scan range in different landscape environments. K-S test was normally distributed and conformed to the homogeneity test (Levene=0.224, p =0.452). The two-factor variance analysis showed that landscape environment had a significant impact on the average scan range (P=0.014), driving experience had a significant impact on the average scan range (p =0.013), and there was an interaction between landscape environment and driving experience (p<0.05). The variation pattern of drivers average scan amplitude in different landscape environments was shown in Figure.3.

It can be seen from Figure3 that the mean of drivers' scan amplitude increased gradually with the difference of landscape environment. In the environment where landscape elements have multiplied, drivers experienced with high driving age could search for relevant traffic information in a wide range, extracted effective traffic information flexibly and acquire visual information gradually. Drivers with low driving age lacked experience and were greatly affected by the interference information in the process of searching for traffic information targets, less effective traffic information was obtained, and their average scan range was small. Each group of drivers reached the maximum value under D3 landscape environment. In the environment with the greatest complexity of D4, the average scan range decreased gradually, indicating that landscape elements exceeded the driver's ability to process information, and the information acquired by the driver at a single glance decreased.

![Figure 3  Mean scan range](image)

3.4. Relationship model between landscape complexity and eye movement index

Furthermore, the relationship between landscape complexity and eye movement indices was calculated to quantify the variation rule of drivers' eye movement indices under different landscape environments. The mean values of three eye movement indices in different landscape environments were selected for analysis and fitting, as shown in Table 3.

| variate        | conic curve fitting equation          | R²      |
|---------------|---------------------------------------|---------|
| fixation duration | y = 3.1977x² - 29.59x + 593.82        | 0.8496  |
| pupil diameter  | y = 0.1559x² - 1.5317x + 75.258        | 0.8261  |
| scan range     | y = -0.0091x² + 0.0891x + 0.9967       | 0.6741  |

It can be seen from Table 3 that landscape environment and eye movement indices showed a significant conic relationship, which conformed to the change rule of U-shaped model[8]. The landscape environment was significantly correlated with the goodness of fit of mean gaze duration and pupil diameter (P <0.05). The goodness fitting of the landscape environment and scan range were slightly lower, and the significance was not significant (p>0.05). Take derivatives of the above fitting equations and set their derivatives as zero, and the critical number of combined landscape elements with better driver's eye movement indices could be obtained as 4 /km, and the weight of such landscape elements was within the range of 0.3-0.4, namely the weight threshold range of D3.
landscape environment (4 /km).

4. Analysis and Discussion
Prairie road long straight line monotonous landscape environment made the driver's operation ability and traffic information perception, judgment and decision-making ability decrease, and brought driving safety hidden trouble. The author believed that reasonable increasing traffic engineering facilities and cultural landscape elements could play an effective role in guiding drivers to drive, and effectively improve drivers' drowsiness, mental fatigue and brain consciousness reduction caused by insufficient information of external environment. There should be a reasonable range of landscape elements in the combination of traffic engineering facilities and cultural landscape elements. This paper introduced the weight levels of combined elements, studied the variation rules of drivers' eye movement indicators under different weight levels, analyzed the relationship between different landscape environments and eye movement indicators, and quantified the weight threshold range of the number of combined elements.

The monotony of grassland highway landscape environment was one of the problems that need to be solved urgently in grassland highway traffic safety. This paper takes S309 grassland highway as the object, aiming at the monotonicity of grassland highway landscape, the simulation experiment analysis method was carried out, the quantitative study of landscape elements was carried out, and the reasonable threshold value of landscape elements was put forward, which could provide reference for the improvement and optimization of the grassland highway monotonous landscape environment and the design of the landscape environment to be built. On the basis of indoor driving simulation experiment research, field confirmatory experiment research would be carried out in the future to further improve the research content.

5. Conclusion
Through the indoor simulation driving experiment, this paper studied the change law of driver’s eye movement index in different landscape environment and drew the following conclusions:

1) The more landscape elements was, the smaller the fixation duration, the pupil diameter, and the larger the scan range. When a certain degree of complexity was reached, the opposite trend changed.

2) The experimental results confirmed that the change law of drivers' eye movement indicators under different landscape environments and could be characterized by the relationship between complexity and eye movement indicators, which presented an obvious quadratic curve relationship.

3) By fitting the quadratic curve, the threshold value of the optimal landscape element quantity was determined to be 4 /km, within the weight range of 0.3-0.4. In this landscape environment, drivers could extract and process traffic information with the highest efficiency, fully grasp the traffic environment and ensure driving safety, but it was not recommended to exceed this threshold.

4) The efficiency of extracting and processing traffic information for drivers with high driving age was higher than that for drivers with low driving age. Drivers with low driving age had insufficient experience in acquiring traffic information elements and were vulnerable to interference from non-traffic information elements.

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