Research on the Impact of Road Landscape Color on the Driving Fatigue of Drivers

Xueping Yao, Bingkui Ji*, Mingda Li, Yuzhuo Men and Xin Jin
Changchun Institute of Technology, Changchun, Jilin, China

*Corresponding author e-mail: jd_jbk@ccit.edu.cn

Abstract. In the closed-loop system of human-vehicle-road-environment, the environment has a very important impact on drivers. The long-term monotonous environment will lead to the visual fatigue of drivers, thus affecting the driving safety; while a good road landscape environment will give drivers a comfortable visual experience, which can relieve the visual fatigue of drivers to some extent. This paper takes the Impact of landscape color on the driving fatigue of drivers as the view of research and reflects the impact of landscape color on driving safety. This paper analyzes the basic attributes of color and analyzes the color fatigue characteristics of drivers using the spectral sensitivity (spectral luminous efficiency) function. Due to the uncertainty of the color attribute value of roadside landscape environment, the eye tracker is used to record the characteristics of the eye movement of drivers in the experiment. Also, based on the example of the landscape color of Qinghai-Tibet Highway, this paper selects the blinking frequency of drivers as the analysis index to quantitatively measure the driving fatigue of drivers, which can indirectly reflect the relationship between landscape color and driving safety.

1. Introduction
The human-vehicle-environment system consists of drivers, vehicles, roads and landscape environment, in which each sub-factor interacts with each other. The landscaped environment has an important impact on the driving behavior of drivers, affecting the vision of drivers and easily giving rise to driving fatigue for drivers in monotonous environment.

According to relevant researches, more than 80% of information is obtained by vision. Based on relevant color experiments, when observing an object under normal conditions, the first thing that leads to visual reflection is color. When initially observing an object, the attention to color is about 80%, while the attention to the form is only 20% [1]. Therefore, the landscape color attribute value is used in this paper to describe the landscape environment to study the impact of color on the fatigue of drivers, thus reflecting the relationship between landscape environment and driver fatigue. As color attribute value will change with the variation of landscape ecology, it is difficult to accurately measure the attribute value of the landscape color. Therefore, the mathematical model of color and driver fatigue cannot be established directly. Excluding the interference of other factors other than landscape color, this paper takes the eye movement characteristics recorded by eye tracker as the measurement index of the driving fatigue of drivers and quantitatively analyzes the impact of landscape environment color on the driving fatigue of drivers.
Zheng Jiancheng [2] mainly studied and analyzed the anti-driving fatigue highway landscape in mountainous areas and it was discovered that the overall landscape design of the highway exerted a direct impact on the driving fatigue of drivers. Wei Zhonghua and Wang Shan [3] elaborated on the psychological effect of color, including coldness and warmth, expansion and contraction, advance and retreat, liveliness and fatigue, and introduced the application examples of color in highway landscape design.

Foreign researches based on color effect in the transportation field mainly focus on the impact of the color of traffic signs and signals on drivers. Michael J. Flannagan et al. [4] used the experimental method to study the impact of signal color on the vision of drivers; Jeong-Hun Mok et al. [5] compared the number of collision accidents before and after the improvement of landscape environment (mainly the improvement of green vegetation) to study the impact of the landscape environment on the driving behavior of drivers.

Scholars at home and abroad have realized the significance of color to traffic safety, mainly from the perspective of traffic psychology. They analyze the visual perception or psychological feeling caused by color on drivers and applies it to road landscape design.

Based on the color vision, this paper uses the eye tracker to collect the blinking characteristics of drivers, analyzes the impact of color on driver fatigue and studies the relationship between landscape environment color and driving safety, which is of great practical significance for improving the road landscape design, optimizing the road landscape environment, relieving the tension and fatigue of drivers, promoting the coordination between people and road landscape environment, enhancing the comfort and safety during driving, and reducing the traffic accident rate. In addition, the study is conducive to the revision and improvement of current relevant highway technical standards and specifications in China.

2. Mechanism Analysis of the Impact of Color on Driver Fatigue

2.1. Basic Attributes of Color
Hue, lightness, and saturation are the three basic attributes of color. Hue is the primary feature of color and the measurement terminology of color, which is the most accurate standard for distinguishing different colors. Hue is a visual response caused by the stimulus of light at different wavelengths. Lightness is the reflection of the brightness of color in human visual and it can represent the stereoscopic spatial relationship and subtle change in the hierarchy of color pictures. For pictures with the variation in lightness, people will feel lively and the three-dimensional effect. Saturation, which in fact refers to the purity of color. The higher the purity, the more vivid it will be; the lower the purity, the less vivid it will be.

2.2. Color Fatigue Characteristics of Drivers
Considering the color characteristics and color attributes of roadside landscape environment, this paper takes hue as the main research attribute of color, and studies the impact of color on driver fatigue from the impact of hue on the vision of drivers.

The difference in hue is caused by the difference in light wavelength, which means that different wavelengths give people different color perceptions. According to the descending sequence of wavelength, the spectrum is: red, orange, yellow, green, cyan, blue, and purple. Color is the vision of eyes for different wavelengths of light. People distinguish different things according to different colors and obtain information about these objects, such as shape and position. The perception of human eyes for different colors can be characterized by a spectral light efficiency function [6]:

$$v(\lambda) = 1/E_\lambda$$

In this equation: $v(\lambda)$ is the function value of spectral light efficiency; $E_\lambda$ is monochromatic light energy.
Spectral light efficiency is also known as spectral sensitivity (spectral luminous efficiency), which reflects the response sensitivity of human eyes corresponding to different wavelengths of radiation. In a brighter environment, human vision is most sensitive to Greenlight with a wavelength of around 555 nm, which means that in this environment, the human perception time is shorter, and the time needed for causing visual fatigue is relatively longer. That is to say, when driving in the green-based road landscape environment, drivers are less likely to feel fatigue.

3. Proposal of Experimental Schemes

3.1. Selection of experimental location
Highways with large traffic volume should be avoided to reduce the impact of non-road environmental factors such as traffic flow on drivers. This experiment selects the Qinghai-Tibet Highway as the research object and avoids the road section of complex-linear situation so as to reduce the impact of linear factors on drivers. The landscape environment characteristics of two road sections are as follows:

(1) Road section 1: the whole road section is not covered by grassland and meadow

(2) Road section 2: part of the road section is covered by grassland meadows

3.2. Experimental time
The experiment is conducted in good weather condition from 9 am and 11 am to minimize the driver fatigue caused by weather, physique and other factors.

In the survey report [9] of “How long will you feel fatigue when driving”, 43% of netizens indicate that they will feel fatigue when driving for 1 to 2 hours (44% between the age of 15 and 25, 41% between the age of 26 to 35 and 15% with the age of above 36), 39% of netizens indicate that they will feel fatigue when driving for 2 to 4 hours (44% between the age of 15 and 25, 41% between the age of 26 to 35 and 15% with the age of above 36) and 18% of netizens indicate that they will feel fatigue when driving for more than 5 hours. The questionnaire is shown in the table below:

| Option          | Subtotal | Proportion |
|-----------------|----------|------------|
| 1-2 hours       | 212 votes| 71%        |
| 2-4 hours       | 72 votes | 24%        |
| More than 5 hours| 16 votes | 5%         |
According to the data analysis in the questionnaire, the continuous driving time of drivers in this experiment is controlled between 1 and 2 hours and cannot exceed 2 hours.

(3) Selection of experimental drivers
Two drivers are selected for this experiment. Drivers are required in good physical condition, rich driving experience, no record of traffic accidents, and naked vision of 0.8 or above.

(4) Collection of eye movement data
The eye tracker is used in the experiment to collect the characteristics of eye movement. The structure of the eye tracker generally includes four systems, namely the optical system, pupil center coordinate extraction system, superposition system of vision and pupil coordinates, and recording and analysis system of images and data. The experiment mainly collects the following data: direction, average velocity, time and amplitude, the average number of blinking, time of eye closure, etc.

4. Example Analysis
This paper conducts uses the blinking frequency collected on the Qinghai-Tibet Highway for statistical analysis.

Figure 1 is a landscape view of the Qinghai-Tibet Highway. On this highway, there are few types and small coverage of vegetation. Also, there are few inhabitants on both sides and rarely can we see residential constructions. The natural landscapes of Qinghai-Tibet Highway mainly include: plateau meadows, perennial snow cover, mountainous and hills (Green grass coverage; sandstone, no vegetation coverage), etc. The landscape color is mainly Yellow plateau, white snow, Green plateau meadow. This paper analyzes the impact of plateau meadow on driver fatigue.

4.1. Trend analysis of the average blinking frequency of drivers
(1) The trend of average blinking of drivers on-road section without grassland and meadow coverage is shown in the following Figure:

![Figure 2. Curve of the number of blinks of drivers 1, 2 in the no-grass meadow covered road section.](image)

(2) The trend of average blinking of drivers on-road section where some parts are covered by grassland and meadow is shown in the following Figure:
Figure 3. Curve of the number of blinks of drivers 1, 2 in some grassland meadow covered road sections.

It can be seen from Figure 2 and 3 that due to the individual differences of drivers in physiology, age, driving age, etc., the trend curve of the blinking frequency of different drivers is different. However, there is both a downward or upward trend in each trend curve.

**Analysis of different drivers on the same road section:**

It can be seen from Figure 2 that on-road section 1, where the whole area is not covered by the plateau meadow, there is a rising trend of the blinking frequency of drivers. After 60 minutes of driving, the blink frequency is almost more than 20/min, indicating that drivers are prone to visual fatigue after driving on the highway of single landscape color for a long time.

It can be seen from Figure 3 that on the road section 2, where part of the area is covered by plateau meadow, the fluctuation of the blinking frequency of drivers is significant, rising in the initial stage and falling in the later stage. The blinking frequency of driver 1 is high when driving for 34 to 56 minutes while the blinking frequency of driver is high when driving for 34 to 50 minutes, indicating that drivers feel the fatigue after a long time of driving. Then, the blinking frequency begins to decrease, which is almost equal to that before the experiment. It can be seen from the corresponding time that this road section is covered by plateau meadow, indicating that the plateau meadow attracts the attention of drivers, reduces the blinking frequency, and relieves the driving fatigue.

**Analysis of different road sections of the same driver:**

The average blinking frequency of driver 1 on-road section 1 is 17.96/min, and that on-road section 2 is 15.69/min; the average blinking frequency of driver 2 on-road section 1 is 17.5/min, and that on-road section 2 is 15.97/min.

The average blinking frequency driver 1 on-road section 2 (53 to 72 minutes), where part of the area is covered by plateau meadow is 15.85/min. In the corresponding time, the average blinking frequency on-road section 1 is 21.8/min. The average blinking frequency driver 2 on-road section 2 (46 to 62 minutes), where part of the area is covered by plateau meadow is 16.94/min. In the corresponding time, the average blinking frequency on-road section 1 is 22.41/min.

It can be seen from the comparison the blinking frequency of the same driver on different road sections that the average blinking frequency on-road section 2 is lower than that on-road section 1; in the time period corresponding to the plateau meadow, the blinking frequency of driver 1 and 2 on road section 2 is lower than that on-road section 1, which indicates that drivers are more prone to fatigue on-road section 1 compared with road section 2. Also, the blinking frequency of drivers decreases significantly on the road section covered by plateau meadow.

4.2. **Analysis of the increasing rate of average blinking frequency of drivers on-road section where some parts are covered by plateau meadow**

The increasing rate of average blinking frequency of drivers first increases and the decreases with the increase of driving time. It indicates that the blinking frequency of drivers begins to increase over time, indicating that drivers begin to feel the driving fatigue. When driving on the road section covered by plateau meadow, the increasing rate of blinking frequency decreases, indicating that the plateau meadow environment provides drivers with good visual perception, which can alleviate the driving fatigue.
5. Conclusion
(1) It can be seen from the research results that when driving on the road section without plateau meadow, drivers will have higher blinking frequency and are more prone to fatigue compared with the road section covered with plateau meadow, resulting in a higher possibility of accidents. When planning roadside landscape environment, the area of Green vegetation should be expanded, and emphasis should be attached to the choice and matching of vegetation color to effectively improve the driving environment, providing a pleasant visual experience to drivers, reducing visual fatigue, lowering the probability of traffic accidents and ensuring the driving safety.

(2) This paper selects blinking frequency as the analysis index of eye movement characteristics. In future researches, multiple eye movement characteristics indexes can be used for comprehensive statistical analysis. In addition, this paper takes the daytime under normal weather condition as the experimental time and only studies the impact of landscape color on driving safety under the condition of photopic vision, while further research is needed for special weather conditions and scotopic vision. The distribution law of the driver's fixation points is closely related to the driving direction control.

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