Experimental Study on Visual Recovery Time of Drivers after Super Glare

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Abstract. With the rapid growth of vehicle ownership in China, more and more roads are equipped with road monitoring fill lights to regulate the driving behavior of drivers and ensure the accuracy and efficiency of public security law enforcement. According to the statistics of relevant departments, in recent years, the number of traffic accidents caused by the flicker interference of high brightness road monitoring fill light affecting the driver's vision, has increased by 12% annually in recent years. During driving, the difference between the high brightness of the fill light and the low brightness of the normal driving environment is too large after the driver is illuminated by the fill light during driving, resulting in the driver's visual disability. The vision of driver can be divided into two stages from being stimulated to returning to normal, which are light adaptation stage and dark adaptation stage. In the restoration process, the time of dark adaptation was significantly longer than that of light adaptation. Based on the study of various factors such as brightness of fill light, illumination time of fill light and background brightness of road that affect the driver's vision in the process of dark adaptation, this paper concludes that, firstly, in the process of driver's pupil area recovering from the minimum pupil area after stimulation to the normal environment before stimulation, the pupil area changes regularly and rapidly when the minimum pupil area recovers to 80% of the normal, while the subsequent 20% pupil area fluctuates greatly and takes a long time to recover. Secondly, with the increase of the illumination time of the fill light, the visual recovery time of the driver increases first and then decreases. Thirdly, the change of the brightness of the fill light has great impact on the longest visual recovery time of the driver. This experiment aims to provide the relevant theoretical basis for the design and the improvement of the bad effect of the road fill light on the driver's vision.

Glare and Human Eyes

Glare and Harm

Glare is a visual phenomenon in which the presence of an overly bright object in the field of view or extremely high brightness contrast causes discomfort and reduces the ability to see objects and details. According to different evaluation methods, glare can be divided into incapacitating glare and uncomfortable glare. Uncomfortable glare is caused by the scattering of light into the eye, which does not affect the vision and vision. Incapacitated glare is caused by the overlapping of the images of the retina due to scattered light, resulting in a decrease in contrast, which reduces the visual efficiency and sharpness. In the process of driving, the information acquired by the driver through vision accounts for 80% to 90% of all the information. Therefore, glare will have a direct impact on drivers' observation of the surrounding environment and timely protective measures, which is related to the personal safety of drivers and pedestrians.

Adaptation Process of Glare to Stimulate the Eyes of Later Generations

The eye can see things clearly because the light emitted or reflected by the object being observed enters the eye and eventually forms an image on the retina. The amount of light entering the eye is controlled by the size of the pupil area. When the amount of light entering the pupil is too large or too small for the eye to see objects or the surrounding environment, the pupil will adjust its size to
increase or decrease the amount of light entering the pupil to meet the visual needs of clearly observing objects or environment. The process of eye adjustment is an adaptive process. Bright adaptation refers to the process of adaptation from dark environment to light environment, and dark adaptation from light environment to dark environment.

However, when the driver is disturbed by strong glare in the process of driving, he/she first needs to undergo bright adaptation to adapt to the strong light, and then needs to undergo dark adaptation to restore the visual function after the strong light disappears. In the whole process, the vehicle is still driving, and the time of light adaptation is short, but the process of dark adaptation is quite long. Therefore, it is very important to study the process of dark adaptation and improve the adverse effects caused by dark adaptation to improve the safety of drivers and pedestrians.

**Experimental Methods**

**Experimental Conditions**

The experimental site of this experiment is a space with an area of $4.5M \times 6.5M \times 15M$, and the space interface is all black, so the reflection is low. 1:2 ratio was used to simulate the scene of road flash lamp. The light source was located at one end of the experimental site, 3.3M away from the ground. The background light source is at the same height as the glare light source and is 12M away from the glare light source. The experimenter was tested directly below the background light. (see Fig. 1)

![Figure 1. Ection diagram of the experimental site.](image)

**Experimental Device**

1. RADIANT VISION SYSTEMS i-plus brightness imager, which can measure various pavement parameters, as shown in figure 2.
2. Dikeablis Pro eyeglass eye tracker: real-time video light function of eye camera collecting pupil size, blink times, pupil and visual field. The data collection is 60 times per second, which can clearly reflect the changes of pupil data, and can accurately calculate the changes of pupil area before and after flashing and the time length between the changes of pupil area, as shown in figure 2.
3. Dazzle light source: self-made adjustable power dazzle light source, the power of the light source is 20W, the light color 10000K is CREE chip, the power range of the light source is 1W-20w, and it is set at a position 3.3M high from the ground.
4. Background brightness light source: LED projection light, voltage 220V, power 100W, 150W, 200W, 300W color temperature 3500K, set at a height of 3.3M from the ground, 12M from the horizontal distance of glare light source.
5. Circuit control module: a. a single set of output closed power supply is used to convert 220V voltage into 24V safe voltage b. 220V time relay to control the irradiation time of the dazzled light source and the precision of the instrument is 0.1s. c. adjustable step-down power module further modulates the 24V voltage to the rated voltage range of LED lamps.
Figure 2. The left side is the eye tracker and working interface, and the right side is the brightness imager and working interface.

**Experimental Procedures**

(1) Measure the brightness and evenness of the road surface with the brightness imager, and make the road surface brightness 1.5nt, 2nt, 3nt, 4nt and 5nt respectively through the combination of different power background light sources.

(2) The power of glare light source is 5W, 10W, 15W and 20W, with a total of four levels. The vertical illumination of human eyes at different power positions was measured as 90lx, 130lx, 150lx and 170lx.

(3) Duration of dazzle light source is controlled by time relay. In the experiment, the duration modulation of dazzle light source is 0.5s, 1.0s, 1.5s, 2.0s and 3.0s, including five groups.

(4) The experimenter wear eye movement instrument from the dazzling light source position of 12 m test, pupil highly unified control at the height of 80 cm, visual focus to look at the road ahead, and then adjust the eye movement parameters make the experimenter pupil capture normal area, at the same time to proofread the experimenter visual focus of the focus of the instrument in the screen with the experimenter's visual focus.

(5) First, the brightness of road surface was adjusted to 1.5nt, and the brightness of glare light source was adjusted to 5W. Then, the experimenter was stimulated with different glare exposure times, and the data was recorded. After the experiment, the brightness of glare light source was changed. After measuring the brightness of all glare light sources, change the background brightness and repeat the above experiment steps. Between each group of experiments, subjects were required to rest for 1-5 minutes in a non-glare environment according to the duration of exposure to restore visual disability and trance after strong light exposure.

**Data Analysis and Conclusion**

This experiment is to verify the effect of glare intensity, glare exposure time and background brightness on the dark adaptation time of human eyes after being stimulated by strong light.
Because of the main study on the visual impact of road fill light on drivers, the background brightness was set within the range of possible background brightness of the road surface, and the road surface brightness was controlled at 1.5nt - 5.0nt, divided into 5 levels. The power range of the light source is 5w-20w, divided into 5 grades. Glare duration ranges from 0.5s to 3.0s, and there are 6 grades. Then, pupil response data of glare sources with different intensity and duration of glare were sorted out.

**Changes in Pupil Area during Eye Recovery**

In this paper, the initial time of dark adaptation is defined as the moment when the stimulus light source is closed, and the end time is when the pupil of the experimenter returns to the area before the stimulus and is in a relatively stable state. Starting from the driver's visual stimulation to the driver's visual changes in a visual recovery process is the most intuitive performance change of pupil area, the experiment with the driver under different conditions by analyzing and processing the pupil area changes of the human eye in the visual recovery process can be divided into three phases, the first stage for the pupil area is dramatic changes and regularity of stage, the stage of starting point to stimulate the light source is closed instantly, the finish for the pupil area change the first inflection point; The second stage is the stage where pupil area changes sharply and regularly. The starting point of this stage is the end point of the first stage, and the end point is the second inflection point of pupil area change. By the end of the second stage, the pupil area had recovered to about 80% of the pupil area of the driver when stimulated. The third stage is the stage where pupil area changes slowly and fluctuates a lot. The starting point of this stage is the end point of the second stage. Due to the large and irregular pupil area change, the duration cannot be accurately determined. See figure 3. At the same time, it can be concluded that in the first two stages of eye recovery, although the time is short, the pupil area changes greatly in this process, so the first two stages can be regarded as the driver's vision has been basically restored.

**Figure 3. Diagram of pupil recovery stage.**

**Relationship between Eye Recovery Time and Glare Intensity**

Through experiments, it is concluded that the main research scope of human visual recovery is from the pupil area of the experimenter at the moment when the stimulus light ends to the pupil area of the experimenter when the pupil area of the experimenter returns to 80% of the pupil area when the stimulus light is not stimulated. This interval includes the first and second phases. It was concluded that the duration of the first stage did not change significantly with the increase in the brightness of the stimulus light source, as shown in table 1. The duration of the second stage first increases and then decreases as the brightness of the stimulus light source increases, as shown in table 2. However, the total time for the pupil to recover to 80% of the unstimulated pupil area showed a pattern of first increasing and then decreasing.
Table 1. Duration of the first stage when the background brightness is 1.5nt [Unit: second].

|       | 0.5s | 1.0s | 1.5s | 2.0s | 3.0s |
|-------|------|------|------|------|------|
| 5W    | 0.976| 0.978| 1.154| 1.194| 0.967|
| 10W   | 0.839| 0.942| 1.518| 1.226| 0.952|
| 15W   | 1.069| 0.976| 1.118| 1.301| 0.961|
| 20W   | 0.959| 1.222| 1.079| 1.088| 0.972|

Table 2. Duration of the second stage when the background brightness is 3.0nt [Unit: second].

|       | 0.5s | 1.0s | 1.5s | 2.0s | 3.0s |
|-------|------|------|------|------|------|
| 5W    | 0.804| 0.466| 1.000| 0.884| 0.317|
| 10W   | 0.984| 1.267| 1.817| 0.817| 0.950|
| 15W   | 1.467| 2.667| 2.317| 1.087| 1.234|
| 20W   | 0.933| 1.843| 1.200| 1.467| 0.933|

Relationship between Human Eye Recovery Time and Stimulus Time

The experiment concluded that when the brightness of the background and the brightness of the stimulus source remained unchanged and the length of the stimulus time changed, the duration of the first stage of visual recovery of the experimenter generally increased first and then decreased with the increase of the stimulus time. In this process, the difference between the maximum length and the minimum length was not large, as shown in table 3. The duration of the second stage generally increases first and then decreases as the stimulus time increases, but there is a large gap between the maximum duration and the minimum duration in this process, as shown in table 4.

Table 3. Duration of the first stage when the background brightness is 5.0nt [Unit: second].

|       | 0.5s | 1.0s | 1.5s | 2.0s | 3.0s |
|-------|------|------|------|------|------|
| 5W    | 0.819| 0.717| 1.371| 0.744| 0.845|
| 10W   | 0.910| 0.918| 0.747| 0.647| 0.794|
| 15W   | 0.699| 0.686| 0.870| 0.657| 0.784|
| 20W   | 0.887| 0.779| 1.134| 0.868| 0.601|

Table 4. Duration of the second stage when the background brightness is 5.0nt [Unit: second].

|       | 0.5s | 1.0s | 1.5s | 2.0s | 3.0s |
|-------|------|------|------|------|------|
| 5W    | 0.766| 1.834| 1.433| 0.683| 0.517|
| 10W   | 0.600| 0.667| 0.700| 0.790| 0.567|
| 15W   | 0.733| 0.717| 0.367| 0.533| 2.400|
| 20W   | 0.616| 0.850| 1.000| 1.334| 0.754|

Relationship between Human Eye Recovery Time and Background Brightness

According to the experiment, when the intensity of the stimulus light source and the stimulus time remain unchanged and the background brightness changes, the duration of the first stage of visual recovery of the experimenter generally increases first and then decreases with the increase of the background brightness. At the same time, no matter how the brightness of the stimulus light source changes, when the stimulus time is between 1.5s and 2.0s, the difference between the maximum and minimum length in the first stage is large, about 0.5s. When the stimulus time is 0.5s and 3.0s, there is a small difference between the maximum and minimum length of the first stage, about 0.2s. However, the duration of the second stage has no obvious rule with the change of background brightness. As for the recovery time to 80% of the pupil area before stimulation, the recovery time decreases gradually with the increase of background brightness, and the recovery time with high background brightness is shorter than that with low background brightness, as shown in table 5 and table 6.
| Time (s) | 1.5nt  | 3.0nt  | 5.0nt  |
|---------|--------|--------|--------|
| 0.5s    | 1.069  | 0.984  | 0.699  |
| 1.0s    | 0.976  | 1.162  | 0.686  |
| 1.5s    | 1.118  | 1.343  | 0.870  |
| 2.0s    | 1.301  | 0.820  | 0.657  |
| 3.0s    | 0.961  | 1.231  | 0.784  |

| Time (s) | 1.5nt  | 3.0nt  | 5.0nt  |
|---------|--------|--------|--------|
| 0.5s    | 1.217  | 1.467  | 0.733  |
| 1.0s    | 1.267  | 2.667  | 0.717  |
| 1.5s    | 1.184  | 2.317  | 0.367  |
| 2.0s    | 1.066  | 1.184  | 0.533  |
| 3.0s    | 0.450  | 1.234  | 2.400  |

**Experimental Application and Significance**

In this experiment, by simulating the influence of the strong glare generated by the road supplementary light on the driver, the process of the driver's recovery after being stimulated is divided into three stages, among which the first and second stages have a greater impact on the time of visual recovery. According to the conclusion of this experiment, the following points can be proposed for the research on how to alleviate the impact of super dazzle light on driver's vision and the key stage of the research.

(1) It is known from the experiment that during the recovery of human vision, the pupil area changes greatly and rapidly when it is restored to 80% of the area before stimulation. In the recovery process of the latter 20% area, the pupil area changes less, and the change is relatively unstable. Therefore, in the later study on how to improve the effect of super-glare on driver's vision, the recovery process of 80% pupil area should be the focus of the study.

(2) It is known from the experiment that the stimulation time has a great influence on the visual recovery time, and the shortest or longest stimulation time is the shortest time when the pupil recovers to 80% of the unstimulated pupil area. Although the visual recovery time of the stimulus time was relatively short for the medium light stimulus time, the human vision was still in the state of incapacitation during the stimulus light source's existence, so the total incapacitation time of the pupil increased rather than decreased. Therefore, when setting the exposure time of the road supplementary light, the exposure time of the supplementary light should be as short as possible on the condition that the required information can be clearly photographed.

(3) According to the experiment, it is known that the change in the brightness of the stimulus light source has relatively little impact on the driver's visual recovery time. Therefore, combined with the second point, the brightness of the road supplementary light can be appropriately increased to meet the brightness requirements of the camera for clear shooting of the object in a short time, and the exposure time of the road supplementary light can be further reduced.

(4) It is known from the experiment that the time required for the pupil area to recover to 80% of the pupil area when the light source is stimulated is gradually decreased with the increase of the background brightness. Therefore, when designing the road lighting in the relief area of supplementary light, the road brightness can be appropriately increased to reduce the driver's visual recovery time.
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