Eye Movement Analysis on Driving Behavior for Urban Road Environment

Ziyi Qin(✉)

College of Physics and Engineering, Qufu Normal University, Shandong, China
QNUqinziyi@163.com

Abstract. Under real driving environment, drivers are easily distracted by the external factors, such as vehicles or pedestrians. Overtaking, irritating or even attacking behaviors more often than not occur during driving. Driving behavior is the external manifestation of a driver's psychological and physiological changes. Based on real road driving testing to analyze the driving safety, the paper gets the driving behavior information under real driving environment, and systematically describes the relationship between a driver's eye movement changes and road environment. Research results are capable of providing the basis for the analysis of traffic accidents.

Keywords: Driving behavior · Eye movement analysis · Urban road environment

1 Introduction

In traditional driving environment, a driver mainly gets traffic information from eyes. Driver's visual changes vary from road condition to road condition. In urban areas, traffic accidents are more often than not occurred near intersections of large traffic volume. A driver's perception on the road hazard directly affects driving safety, while the driver's perception and reaction are reflected by changes in eye movement. Therefore, it is very important to design eye change movement tests under different road conditions, to collect the driver's eye movement data, to analyze the relationship between the driver's eye movement change and different road environment, to identify changes of eye movements during driving. Research results provide a theoretical basis for road safety evaluation.

The paper collects transcutaneous electrical eye movement data under actual traffic conditions, such as turning, traffic lights, changing lanes, and avoiding vehicles. Moreover, the paper records specific line condition, analyzes the actual traffic situation in the driver changes, and studies the driver's reactions to actual road traffic information. Driving behavior is often a driver's external manifestation of psychological and physiological changes. Real-time monitoring and analysis supports early detection of operational errors, to avoid accidents.

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2 Related Work

Researches on the driver's visual characteristic have been widely studied in Europe, the United Kingdom, France, and the United States. In 2002, David Crundall, Geoffrey Underwood and Peter Chapman [1] conduct researches on driving test by videoing real traffic scenes. They analyze search features of unskilled and skilled drivers in laboratory within a particular road operator, and design a visual search driver training scheme. The results indicate that training can shorten the driver's gaze duration and enlarge the searching range.

Mark Brackstone and Ben Waterson [2] conduct researches on the driver's eye movement in high speed environment, and analyze the relationship between vehicle speed and the driver's visual characteristics. Results show that as vehicle speed increases, the driver's field of vision becomes narrowed.

In 2010, Mitsubishi's safety car ASV2 is designed with the installed steering wheel mounting cameras to detect eye movements and the driver's fatigue. By using text and voice warning, drivers are informed of driving safety [3].

In 2010, Yong-Fang Li [4] researches the distribution of driver dynamic fixation point. The results show that at the same driving speed, with smaller size of words, the driver's gaze point is not fixed. It takes longer time for the driver to determine flag information. For larger words, driver's visual fixations are relatively concentrated.

Currently, researches mainly focus on generalized driving test on actual roads but fewer researches on microscopic dynamic vision issue or the eye movement parameters specifically. This paper is based on the actual road driving test to research blink frequency, blink duration, visual fixation during the driver's driving process.

3 Field Test Methods

In the real driving test, galvanic skin response testing is conducted for each driver in order to ensure traffic safety. During the experimentation, we collect eye movement data and use Biolab, a behavioral synchronization device to monitor drivers' behaviors. On the computer screen, we can directly observe driver's galvanic skin response curve and the corresponding time stamp.

Galvanic Skin Response

If electric potential on skin exceeds 0.05 V during driving, drivers are in excited state, thus they should not continue driving. If electric potential on skin continuously reduces during driving, drivers' sympathetic activity decreases, thus drivers need to stop and have a rest. Therefore, the paper uses Biolab to get behavior curves and identify whether driving behavior is normal or not. Moreover, this can be used as a driving safety indicator in the monitoring process of the actual road driving.

Test Scheme Design

Drivers are chosen for obtaining eye movement data in field test prior to driving on road. In galvanic skin response test, we test the driver's galvanic skin response values in their calm states. The design process of real driving test scheme is shown in Fig. 1.

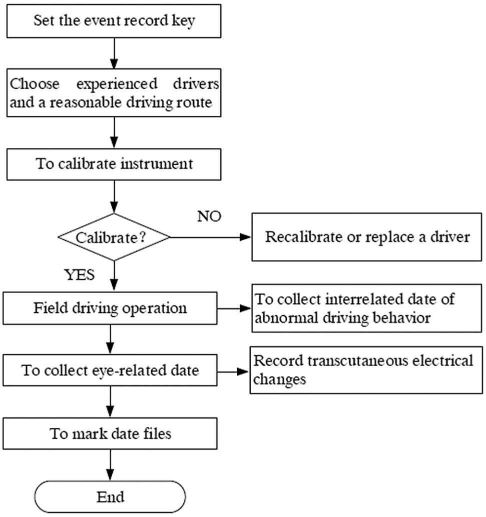


Fig. 1. Design process of driving test

4 Analysis on Visual Characteristic Parameter

4.1 Data Collection

Facelab5.0 eye tracker is installed between the steering wheel and driver's windscreen. Eye tracker should be well fixed to avoid shaking, tracking inaccuracy, and eye movement data deviation during driving. In the process of actual road driving, Facelab5.0 eye tracker fixed in the car.

4.2 Data Analysis

Data collected is put into SPSS software to do variables import analysis [5], and the correlation test, which assumes that the probability of a certain traffic and corresponding eye movement changes at the same time is P. The meaning P in the driving test is as shown in Table 1.

Table 1. The statistical significance of correlation between road conditions and data changes

Correlation P Value	Probability of happen	The connection between the road and data changes	Statistical significance
$P > 0.05$	The probability of happened to occur is more than 5%	The changes between the two groups have no inevitable connection	Changes in the two groups have no significant correlation
$P < 0.05$	The probability of happened to occur is less than 5%	The changes between the two groups have connection	Changes in the two groups have significant correlation
$P < 0.01$	Probability of happened to occur is less than 1%	The changes between the two groups have inevitable connection	Changes in the two groups have very significant correlation

5 Simulation Results

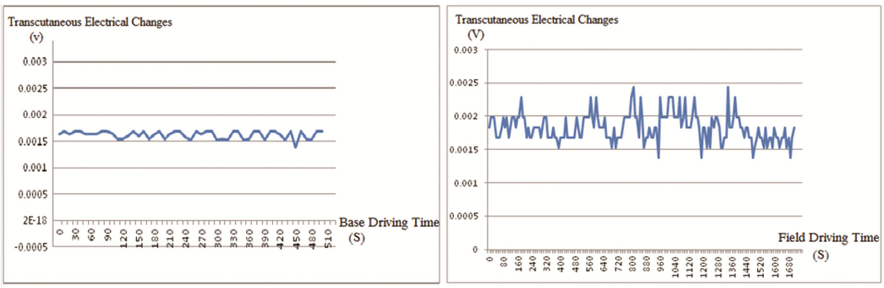
In order to obtain data from real driving process, the paper choose real traffic network of campus in China. Drivers start from and return back to the school gate. During the driving process, drivers will experience different road conditions. When a vehicle starts leaving school gate, it is the deceleration-stop phase. When a driver drives on roads outside the school, we classify roads with low traffic volume and no traffic lights as general roads, and classify roads with with large traffic volume and traffic lights as complicated ones.

The entire driving process takes 28 min and 15 s (1695 s). From starting a vehicle to approaching the school gate, it takes 125 s. From returning to the school gate, it take a total of 1453 s. When a vehicle slows down to a stop, it takes 117 s.

5.1 Galvanic Skin Response

In the entire driving process, the driver's galvanic skin response is maintained at a low value. It indicates that the driver has a driving strong capacity for safe operation in the whole process, and the driver does not have emotional changes, such as tension, anxiety and others.

At the end of the driving process, we collect galvanic skin response data. During data processing, the data is averaged per second to get galvanic skin response values per second. We also plot data curve about galvanic skin response and compare galvanic skin response changes between the time when a driver is in calm state and drives in actual road environment. We also conduct an analysis of the variation range of driver's galvanic skin response. Data curve about galvanic skin response is shown in Fig. 2.



(a) Driver's transcutaneous electrical change curve in a calm state (b) Driver's transcutaneous electrical change curve in field driving

Fig. 2. Driver's galvanic skin response

When a drive is in calm state, galvanic skin changes of drivers only fluctuate within a narrow range over 0.0015 V. When entering the driving phase where road conditions appear more complicated, galvanic skin changes are between 0.0015 and 0.0025 V. The fluctuation is obviously stronger than that in calm state. In actual driving environment, drivers have a high level of alert due to external stimulation. Psychological changes often result in galvanic skin changes of drivers.

5.2 Driver's Blink Duration

When driving on roads, a driver's blink duration is related to the complexity of the traffic conditions. The paper tests the blink duration when driver drives on base and actual road and analyzes changes of the blink duration.

The paper takes blink duration of base driving as the benchmark, and plots a data curve, and conducts comparative analysis on blink duration changes when driving on roads. Blink duration curve of base driving is shown in Fig. 3.

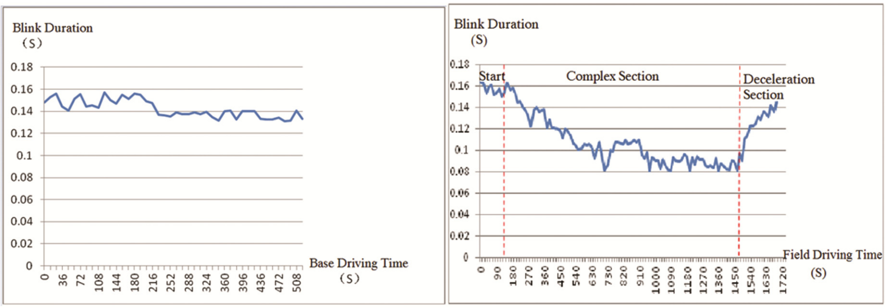


Fig. 3. Driver's blink duration

In the experiment, driver's blink duration has a change range of less than 0.02 s when driver drives in base, and 0.08 s when driver drives in actual road. At the beginning of actual road driving, blink duration is long. When driving outside the school, blink duration is shorter. Blink duration is below 0. 1 s from 917 to 1552 s time. Blink duration increased from the time when entering the gate to the time when decelerating to stop smoothly.

6 Conclusion

This paper designs and conducts a test of driver's eye movement characteristics when driving on roads. In summary, we can get the following conclusions.

Firstly, during the actual driving test, when drivers are in the driving process, galvanic skin change is larger than that in calm state.

Secondly, during actual driving test, the driver's eye movement change is wider than the base eye movement variations. When drivers are in the base driving test, the blinking frequency and duration curve is steady; when drivers are driving on the actual road, the driver's eye movement change is wider.

Thirdly, driver's blink duration is associated with blinking frequency. With the increasing frequency driver blink, blink duration becomes shorter.

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