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Analysis on Driver's Physiological and Eye Movement Characteristics under Alcohol Effect

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Abstract: Drinking-driving significantly impacts on road traffic safety. Characteristics indicators of driver's physiological and eye movement were screened to conduct driving experimental test, this study comparable analyzed the drivers' variation of skin electricity under different alcohol intake, also uncovered the heart rate change law over drinking different bottles of beer by establishing the Poincare section. Variation of fixation number, average pupil diameter, saccade number, saccade speed peak, blink number, and average blink duration time under different alcohol intake were revealed. According to experimental test and analysis of drivers' physiological and eye movement characteristics indices recovery after drinking, this paper gave the alcohol effect elimination time. Results show that alcohol effect elimination time can be determined by analyzing driver's physiological and eye movement characteristics indices, which is useful for mastering the reasonable driving time after drunk.

Introduction

The phenomenon of drinking driving exists generally in China, which is prohibited gradually by strengthening legal responsibility in recent years. Although it is a fact that drunk driving can cause the serious traffic accidents, whether drinking a small amount of alcohol would influence road traffic accident or not, and how to determine the extent of alcohol impact on safety driving. These problems arouse that lots of experts and scholars have different viewpoints (Holubowycz, 2007). Therefore, it is necessary to conduct the experimental study on the relationship between the alcohol effect and characteristics of drivers' physiological and eye movement, analyze the variation of indices screened from the physiological and eye movement characteristics, uncover the intrinsic reasons for alcohol influence the driver. Which is useful to enhance the consciousness of self awareness, and is great significance of improving road traffic safety.

Experiment Design

(1) Experimental Equipment

Experimental car: Santana 2000 era superman series. Clean appearance, good condition, and good engine performance.

Multi channel physiological instrument: Nexus-10 Multi channel physiological instrument, which mainly consists of laptop computer, sensors, wireless Bluetooth, and software BioTrace +.

Helmet type eye tracker: I View X HED, storage analysis of image data, real-time calculation of time, displacement, speed and pupil diameter, gaze position of eyes movement.

(2) Test Sample

According to the experimental project, considering driving safety after drunken, sample representativeness, time, economic and other factors, three drivers are chosen to be the test sample.

(3) Test Location

Considering the legal requirements and driving safety, driving test location is selected in a new built road without opening, which its traffic signs and markings are clear, can meet the test requirements.

(3) Indices Screening

Owing to test purpose, test condition, and indices characteristics, skin electric and heart rate are chosen to be the physiological characteristics indices; gaze, saccade, and blink are chosen to be the eye movement characteristics indices.

(4) Test Plan

In the process of actual driving, multichannel physiological instrument and helmet type eye movement apparatus are applied for testing drunk drivers' physiological and eye movement characteristics indices. The experiment was divided into the following two stages.

The first stage: Physiological and eye movement characteristics indices of three drivers without drinking are static tested. During the process of experiment, physiological characteristics indices are tested 5 minutes, and eye movement characteristics indices are tested 3 minutes.

The second stage: Physiological and eye movement characteristics indices of three drunk drivers are dynamic tested. Firstly, the driver should be familiar with road environment, and adjust the driving state of mind during the period of 20 minutes driving. Secondly, physiological and eye movement characteristics indices of driver without drinking are tested in the process of 20 minutes driving. Lastly, physiological and eye movement characteristics indices of driver, after who drinks the first bottle of 500ml and 11 degrees bottled Harbin beer (cumulative alcohol consumption 500ml), the second bottle of beer (cumulative alcohol consumption 1000ml), the third bottle of beer (cumulative alcohol consumption 1500ml), the fourth bottle of beer (cumulative alcohol consumption 2000ml), are tested respectively in the process of 20 minutes driving. When the driver finishes one experiment, he will rest 10 minutes, then conduct another experiment.

Analysis of Driver's Physiological Characteristics under Alcohol Effect

Skin Electric

Multi-channel physiological instrument records skin electrical values for the electrical resistance of the skin, its unit is k ohm. Skin electrical values are related to the drivers' mood change when they are driving after drinking. Under the following two different drinking states, driver skin electrical indexes are the specific analyzed. As it can be seen from the result, in normal driving state, the skin electrical values are relatively high, and skin electrical fluctuations are also obviously over time changing. Driving after drinking, the skin electrical values have significantly declined, skin electrical fluctuations over time has become relatively flat, with increased alcohol consumption, skin electrical values begin to gradually decline, down to the rate of relatively stable, skin electrical fluctuations over time are comparable small. Both driver 1 and driver 2 after drinking 2000ml, their skin electrical curve remains a straight line over time changing. Indicating that driving after drinking the mood of people is affected, secretion of sweat and skin conductivity ascends with alcohol consumption increasing.

Heart Rate

Poincare section is an effective means of heart rate analysis, it puts all the adjacent heart rate data markers in a Cartesian coordinate system (Song, 2007), the formation of regular scatter plots. Poincare section can not only reflect the overall characteristics of heart rate, but also show intuitively the beat-to-beat changes in the moment, so it can reveal the heart rate variability with nonlinear characteristics. On the various drinking condition, heart rate data of driver are statistical analyzed, drawing on Poincare section, as shown in Figure 1.

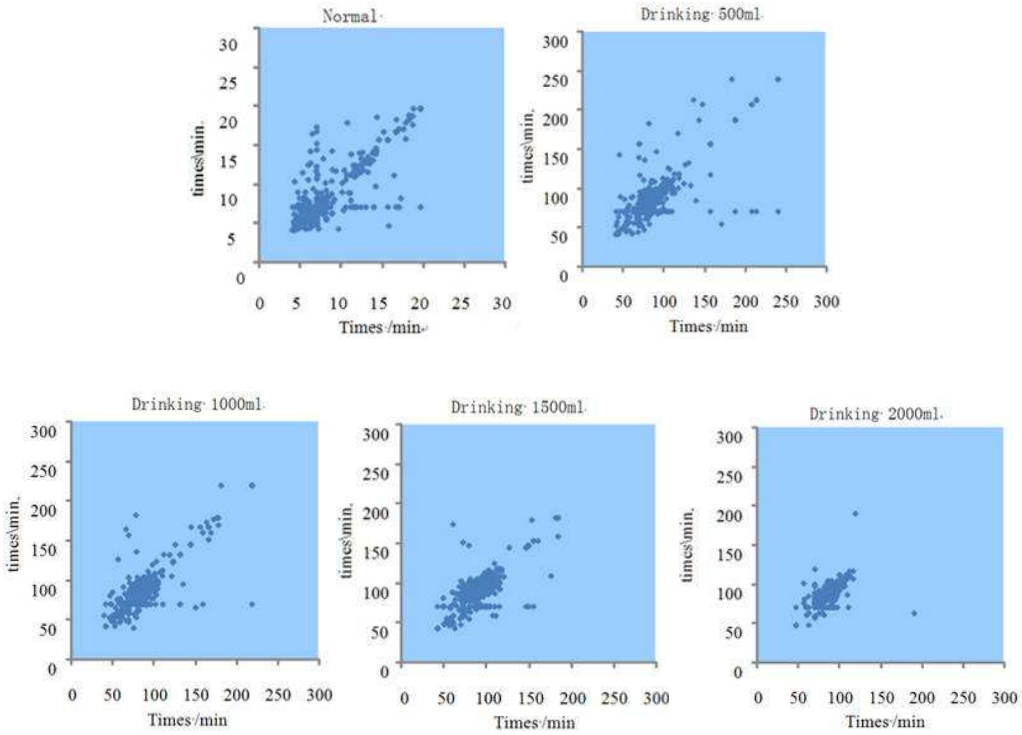

Fig.1 The driver's heart rate on Poincare section

As can be seen from the graph, in normal driving state, most of the scatter is concentrated in the angle of 45 degrees which is close to a straight line, but there are also many scattered distribution from the angle of 45 degrees with straight sides. It shows a kind of sinus arrhythmia phenomenon, and the heart rate the degree of symmetry, changes in heart rate speed. After drinking 500ml, scatter in the direction of 45 DEG distribution distance is longer than that of the normal state, and heart rate changes degree becomes large. After continuous drinking, heart rate variation is small, suggesting that started drinking, alcohol causes central nervous excited, accentuates the burden on the heart, but as the alcohol content increasing, central nervous is restrained; with alcohol consumption increasing, scatter in the direction of 45 DEG distribution distance becomes short, description of heart rate variation amplitude decreases, scatter more and more closely, the heart rate still remain the same level.

Analysis on Driver's Eye Movement Characteristics under Alcohol Effect

Fixation

With the view point number, the information handled, and regions of interest increasing, the fixation point number will also increase (Guo, et al., 2006). It can be seen that the number of fixation decreased with the alcohol consumption increasing, which is shown in Figure 2. The mean

pupil diameter is defined over a period of time the driver all pupil diameter average, can reflect the driver drive in the process of the degree of tension. Figure 3 shows that the average pupil diameter increases gradually after drinking different alcohol.

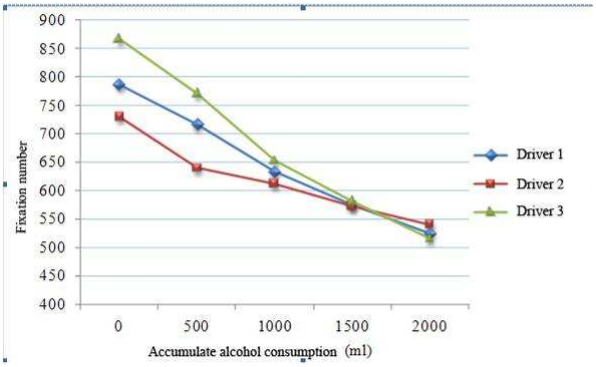

Fig.2 Fixation point number changes under the condition of different alcohol consumption

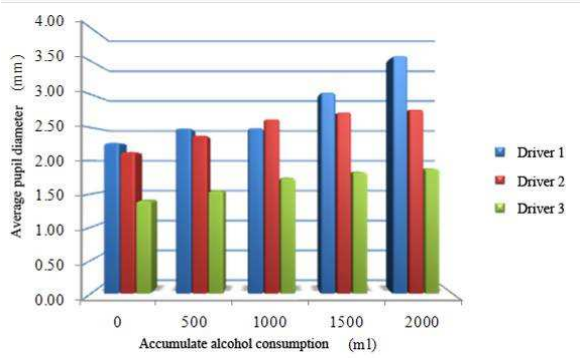

Fig.3 Average pupil diameter under the condition of different alcohol consumption

Saccade

The number of saccade can reflects the driver drive in the process of concentration. Figure 4 shows that the saccade frequency decreases with the alcohol consumption increasing. Saccade eye movement is a variable of motion and saccadic speed peak value is defined in a successive saccades during saccadic speed maximum, can reflect the driver to obtain information on speed. Figure 5 shows that saccade velocity peak value decreases with the alcohol consumption increasing.

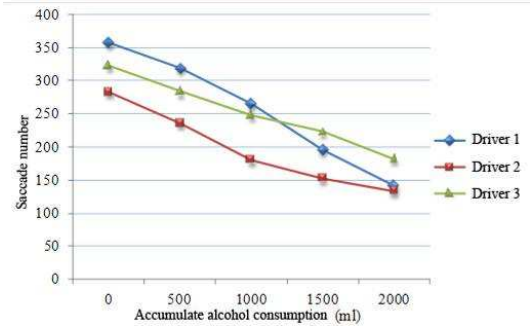

Fig.4 Saccade frequency changes under the condition of different alcohol consumption

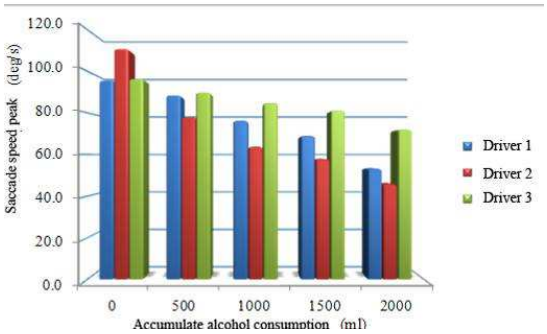

Fig.5 Saccade speed peak changes under the condition of different alcohol consumption

Blink

Under normal circumstances, when the tension of blink frequency will have more concentrate one's attention on blink, number of blink will decrease (Yuan, 2008). With the alcohol consumption increasing, the number of blink dramatically reduces, which is shown in figure 6. Average blink duration refers to a period of time the driver all blink time average, can reflect the driver's fatigue degree. Figure 7 shows that the average blink duration time increases gradually, with the alcohol consumption increasing.

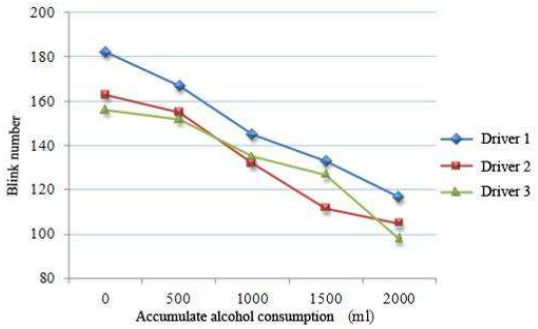

Fig.6 Number of blink changes under the condition of different alcohol consumption

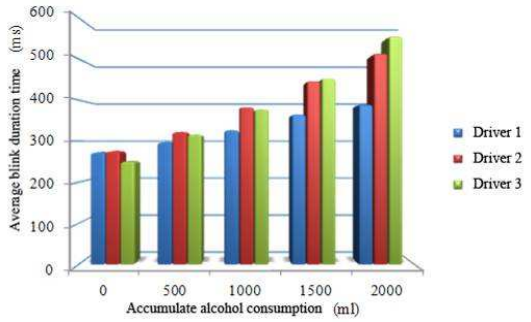

Fig.7 Average blink duration time changes under the condition of different alcohol consumption

Alcohol Effect Elimination Time Analysis

With time going, alcohol effect will be eliminated gradually, and the driver's physiological and eye movement characteristics will also gradually recover. Taken 500ml alcohol for an example, based on the physiological characteristics, alcohol effect elimination time is analyzed.

After each driver drinking 500ml beer, in the 1h, 2h, 3h, 4h, 5h and 6h 6 stages, the physiological characteristics indices are tested separately, the results are shown in Table 1.

Table 1 Recovery test results of driver's physiological indices after drinking 500ml alcohol

Time after drinking	Skin electrical (kΩ)	Heart rate(number/min)
1h	3.624	104.17
2h	4.254	102.35
3h	5.583	100.98
4h	6.631	98.47
5h	7.236	96.26
6h	7.690	95.33
Normal($\bar{x}\pm s$)	7.500±0.500	95.00±5.00

In order to analyze the variation of driver's physiological indices over time going after drinking 500ml alcohol, the relationship model between alcohol effect elimination time and skin electric indicator can be expressed as follows by regression analysis.

$$f_1 = -0.0674t^2 + 1.3384t + 2.1746 \quad (R^2=0.9864) \tag{1}$$

where, f_1 is driver's skin electrical, kΩ; t denotes alcohol effect elimination time, h. The relationship model between alcohol effect elimination time and heart rate indicator is expressed.

$$f_2 = -1.8566t + 106.09 \quad (R^2=0.9886) \tag{2}$$

where, f_2 is driver's heart rate, kΩ; t denotes effect of alcohol elimination time, h.

In formula (1), when F1 = 7, reasonable solution is selected to meet the requirements, t > 4.73. Hence, when it amounts to 4.73h after drinking, driver's skin electrical can return to normal. In the formula (2), when F2 = 100, then t =3.28. Likewise, when it amounts to 3.28h after drinking, driver's heart rate can return to normal. The maximum of above two physiological indicators recovery respectively time is recognized as the alcohol effect elimination time. For instance, if the driver drinks 500ml alcohol, and alcohol effect elimination time is 4.73h.

According to the above method, under alcohol consumption of 500ml, 1000ml, 1500ml and 2000ml, alcohol effect elimination time based on physiological characteristics and eye movement indexes can also be calculated, as shown in Table 2.

Table 2 Alcohol effect elimination time based on physiological and eye movement indexes

Alcohol consumption (ml)	500	1000	1500	2000
Physiological indicators	4.73	7.96	12.13	14.45
Eye movement indexes	4.51	8.27	10.73	12.32

Conclusion

Under the influence of alcohol, the driver's physiological and eye movement characteristics indices are analyzed in this paper. Skin electric and heart rate are chosen to be driver's physiological characteristics indices, and fixation, saccade, and blink are chosen to be the driver's eye movement characteristics indices for studying under different alcohol consumption condition. Research shows that in the process of driving after drinking, alcohol results in that driver's galvanic skin decreases, heart rate climbs, number of fixation goes down, the average fixation duration increases, the average pupil diameter becomes larger, saccade frequency reduces, the average saccade amplitude declines, saccadic speed peak and blink number drops, average blink duration time ascends. In addition, a small amount of alcohol can make drivers nervous excited, and may improve parasympathetic nervous system function of some motorists. In the light of recovery time calculation of driver's physiological and eye movement indices, alcohol effect elimination time can be determined, which is the guiding meaningful for driver grasping driving time after drunk.

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