

Fatigue Test Analysis of Freeway Drivers under Different Terrain Conditions

Hu Sheng Neng^{*a}, Han Juan^b, Wu Ya Jun^c

^aSchool of Civil Engineering & Communication, North China University of Water Resources and Electric Power, Zhengzhou, China.

^bUniversity for science & technology zhengzhou ,Zhengzhou, 450007, China.

^cSchool of MBA, Henan University of Economics and Law ,Zhengzhou, China.

hushengneng2006@126.com

To study the effects of different terrain conditions on the driver's fatigue, Chinese Lian-Huo freeway under the condition of different terrain section is selected for the driving test. The heart rate and heart rate variability index were tested by using the heart rate measuring instrument and the reaction time instrument, by the method of qualitative and quantitative analysis, the results show that: the driver in a mountainous area road are more likely to produce fatigue driving compared to the other condition of roads.

1. Introduction

Fatigue can be divided into three stages: perception fatigue; judgment fatigue and operating fatigue different fatigue stages have different influence on driving safety. Europe and the United States of the traffic accident statistical analysis showed that 49% of the responsibility for accidents due to fatigue driving.

Developed countries attach great importance to driving fatigue research, mainly through the study of the relationship between the continuous driving time of motor vehicle and traffic safety, the relationship between the driver's drowsiness and the accident, and the relationship between continuous driving time, different driving conditions, and the relationship between the driving fatigue, etc., has accumulated some experience. Using biochemical indicators (body hormone content), physiological indicators (blood pressure, heart rate), psychological indicators (visual, auditory reaction time, etc.), sound, subjective fatigue evaluation and other indicators, S.Milosevic studied driving fatigue of truck drivers, found that after a long time driving, the diastolic pressure rise, visual and sense of hearing reaction time increases, the heart rate drop as well as the sound intensity has the remarkable change. In the study of the influence of automobile vibration on driving fatigue, Tiankoumenxing used the adrenaline content in urine to evaluate the degree of driving fatigue, and increased with the increase of the degree of driving fatigue, adrenaline containing increased Stephen evaluated the driver's fatigue by the car status, think that with the increase of driver fatigue, the driver driving operation instability will increase, collected motoring condition quantity through installing in sensor on steering wheel and accelerator pedal, compared with analysing its instability, thus judges the weary degree of pilot. Riemersma and so on the research discovered that after long time's night driving, the heart rate of pilot will drop. Chinese scholars have made some achievements in the study of driver fatigue detection technology, From the current collection of information, many of the articles are for driving fatigue factors for qualitative analysis, or put forward some preventive measures to prevent driving fatigue, such as the car to maintain adequate sleep, driving time is not too long, etc.. Some researchers have carried out a detailed and in-depth study on the influence factors of driving fatigue through experiments. Some scholars start to utilize human body information technology research driving to be weary and burden.

According to the research, the serious and heavy traffic accidents have a great relationship with the road terrain conditions and the driver. Different road geological conditions and hydrological conditions, the operation of the pilot frequency and mental tension have very big different, the driving fatigue difference is very big also. Therefore, according to different terrain conditions, using the experimental psychology test method, to study the influence of driver's perception, judgment and operation fatigue evaluation index under

different road conditions, analysis of the changes of fatigue evaluation index, provide reference for traffic safety design and management of mountainous freeway, and have important social and economic value.

2. Experiment

2.1 Selection of test road

The experimental section is Lian-Huo freeway, located in the territory of Henan Province in China, Sanmen-xia to Kai-feng section, the full length is 309km, two-way 8 lane, and design speed is 120 km. Among them, san men-xia to gong-yi section, 175 km, belong to the mountains high domain, complex terrain, tunnels, Bridges and large slope protection engineering, has the characteristics of the typical mountainous area freeway. Gong-yi to Kai-feng section is 134km, flat, roadbed high speed generally in 4 meters above, the road plane alignment with linear and large radius curve, belong to plain area freeway. The vehicle driving vehicle is basically in a state of free flow, it can reduce the influence of the external environment on the index; and choose good weather experiment, provide good observation conditions for test.

2.2 Test driver requirements

According to the main factors of experimental study and research, the random stratified sampling method was used to select 20 drivers, the drivers were healthy and had no traffic accidents, and it was considered that the physiological indexes of the heart were unchanged in one day. Male 16, female four; the average age of 37; driving time is 1 ~ 28 years, average driving time for 18 years.

2.3 Experimental procedure

Require the driver to ensure adequate sleep 1 days before the test, to ban alcohol consumption within 24 hours of the trial, 3 hours to prohibit tea, coffee. In order to guarantee the comparability of the test data, test assurance at the same time every day, single need 3 h to the finish, and at noon in Gong-yi city rest some time. Starting the afternoon before the driver for response detection, the data with the morning before departure is almost the same, indicating that the driver's psychological and physiological function at this time has returned to normal, to avoid the accumulation of fatigue. During the testing period, the driver will be required to control the speed of the following design speed, and the specific time of the special traffic conditions, such as overtaking, etc. were asked to record. Before the experiment, the static physiological data of 10min driver was measured by using the biological feedback instrument.

2.4 Experimental equipment

Test equipment including: domestic car, Micro printer, PE-Sport2000 heart rate measuring instrument, mainly composed of four parts, heart rate watch, heart rate emission band, computer converter and with 25 pin connector of the cable, as shown in figure 1. The heart rate is used to transmit the heart rate, the heart is close and comfortable to wear in the driver's chest; heart rate watch is used to receive the heart rate, the driver should wear the wrist, real-time collection of the driver's heart rate; the experiment can be used to transfer the heart rate data into the computer. BD- -510A type reaction time measuring instrument produced by Chinese company, which to determine the driver's choice reaction time and simple reaction time, test the driver's reaction speed.



Figure 1: PE-Sport2000 heart rate measuring instrument

In addition, in order to avoid error produced by the pilot on the degree of familiar with instrument, the driver has been able to skilfully use before starting the experiment instrument, when driving in the car include two cameras, a shooting the driver's operation, another to shoot, two cameras synchronization. Before the experiment, the static physiological data of 10min driver was measured by using the biological feedback instrument.

2.5 Index selection

Heart rate variability data were collected by using the biological feedback instrument, and driver's ECG signal data were collected in a continuous time. The frequency domain indexes of heart rate, time domain and heart rate variability were analysed by the data processing module. Heart rate variability is the phenomenon that the RR interval of a successive heartbeat, the performance of the heart rate or heart rate changes. This article selects the ECG index as freeway driver's physiological evaluation index, the index testability is strong, and the data processing method is relatively mature [8]. The common index of heart rate (HR) and heart rate variability (HRV). The change of the external environment will affect the heart rate, if meet the external environment changes, stress, or emotional changes in heart rate will accelerate; Under a state of rest or sleep when the heart rate slows down. In the experiment, the effects of different terrain conditions on driver fatigue are studied, and the characteristics of the driver's individual differences (such as age, physical condition, etc.) and the characteristics of freeway driving tests are studied. In order to better reflect the fluctuation of the heart rate, can use the actual heart rate value $H(t)$ minus the static heart rate average, get the heart rate fluctuations in value $h(t)$ at the moment [9], namely

$$h(t) = H(t) - \bar{h}(t = 1,2,3 \dots) \quad (1)$$

Type: $h(t)$ indicates fluctuating quantity of heart rate at a certain time, times/min; $H(t)$ subjects heart rate in a certain time period, times/min; \bar{h} indicates the average heart rate of the subjects in the static test, times/min. Studies show that [10]: the rate of heart rate increase over 20% of the normal heart rate, the driver will be nervous; more than 40% of the normal heart rate, the driver will be frightened. The heart rate data analysis of this paper is to measure the driver's psychological and physiological burden of 20% or 40% of the heart rate change, and the driving operation and reaction time to analyse the driving fatigue characteristics.

3. Results and analysis

3.1 Analysis of heart rate fluctuation and driving operation

Combined with the terrain condition compared with morning and afternoon driver's heart rate increase rate in different road section, and the change of the heart rate of 20% or 40% as a measure of the driver's psychological and physiological burden index, and analyze the influence of different road section on the driver's fatigue level. Before the experiment, measured heart rate of the driver calm state was 73 times/min. Drivers in gong-yi to kai-feng road sections and san men-xia to gong-yi road sections heart rate increase rate variation as shown in figure 2 and figure 3.

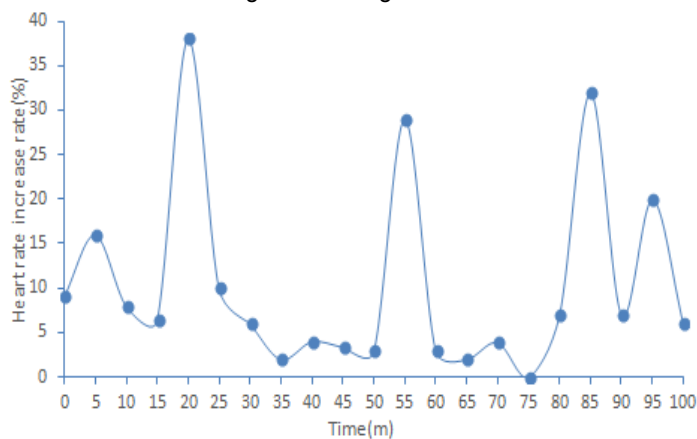


Figure 2: San men-xia to Gong-yi road sections heart rate increase rate variation

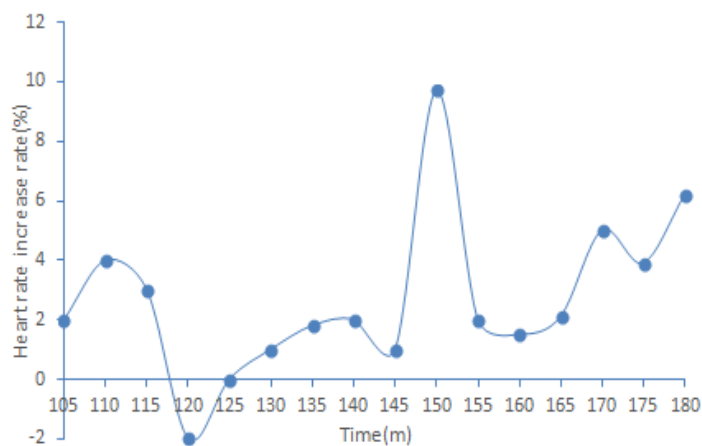


Figure 3: Gong-yi to Kai-feng road sections heart rate increase rate variation

From Figure 1 and Figure 2 can be drawn: the driver's heart rate increase rate curve of San men-xia to Gong-yi road sections volatile, and part of the heart rate increase rate more than 20%, with individual data of more than 30%; while the driver's heart rate increase rate curve of gong-yi to kai-feng road sections not very much, the heart rate is relatively stable, changes are basically 10%. According to the observation of driving operation: the driver's driving steering frequency shifting frequency, braking frequency in gong-yi to kai-feng road section respectively 0.9 times / min, 0.02 times / min, 0.05 times / min, and the driving operation is very small. While the driver's driving steering frequency shifting frequency, braking frequency in San men-xia to Gong-yi road section respectively 3.9 times / min, 0.82 times / min, 0.75 times / min, and the driver has repeatedly continued to shift and long-time brake.

Combined with the roadside environment analysis: gong-yi to kai-feng road section is flat, eye shot is open, the freeway geometry alignment is straight and short, plane and vertical alignment index is high, driver shift frequency is small, driving not nervous, psychological and physical pressure is not, heart rate fluctuation is small, only occasionally in beyond the car, the in the mind a little bit nervous. San men-xia to Gong-yi road section on both sides of the terrain change is big, along with a large number of tunnels, bridges and large slope retaining wall. Because according to the mountain route layout, road alignment quality is not high. Flat curve is more, the radius of flat curve is generally small, and the longitudinal section is larger, and the slope length is large. Therefore, the driver driving on this road will feel dangerous, mental tension and even feel scared, and frequent operation greatly, prone to mental and physical fatigue, resulting in driver psychological and physiological function and driving performance decline, vulnerable to accidents.

3.2 Reaction time analysis

When the reaction time is determined, measures two groups each time, each group red and yellow, green light demonstrates 10 respectively times, light colour is random combination, reaction instrument will display each lamp under the colour of the driver's reaction time, the average response time for each light colour and accumulative errors. When simple reaction time determination, only use the green display lamp, each group showed 10 times, reaction apparatus shows each of reaction time, reaction time and error times on average. The experimental results can be printed out by the micro printer to print the response time, the average value and the number of errors and so on.

The driver is not under driving condition of choice reaction time and simple reaction time as shown in table 1 (error number: 1, reaction time: s).

Table 1: No driving condition of reaction time

Light colour	Choice reaction time	Dispersion degree	Simple reaction time	Dispersion degree
Red	0.53	0.15		
Yellow	0.62	0.19		
Green	0.5	0.14	0.27	0.07

On the test day ,the choice reaction time and simple reaction time data on the San men-xia to Gong-yi road section and gong-yi to kai-feng road section as shown in Table.2 (error number 2 times, reaction time unit: s) and Table.3 (error number 2 times, reaction time unit: s)

Table 2: Reaction time after San men-xia to Gong-yi road section

Light colour	Choice reaction time	Dispersion degree	Simple reaction time	Dispersion degree
Red	0.57	0.18		
Yellow	0.61	0.19		
Green	0.48	0.11	0.31	0.07

Table 3: Reaction time after gong-yi to kai-feng road section

Light colour	Choice reaction time	Dispersion degree	Simple reaction time	Dispersion degree
Red	0.54	0.09		
Yellow	0.63	0.14		
Green	0.39	0.09	0.28	0.05

From table 1, table 2, table 3 can be seen: the driver's choice reaction and simple reaction time of plain area have no difference under the non-driving state, the overall table 2 of the data is slightly larger than the table 1, except when very individual response; But in mountain area, the driver's choice reaction time and simple reaction are much bigger than the data in the non-driving state, although the two section of the road test is the same as the same, but the mountain is more than the plain area data. Simple reaction time is particularly evident, in order to increase the test sequence, the average simple reaction which is through the mountain is 0.31 seconds, more than 0.302 seconds, the study shows that When simple reaction time over 0.302 second, driver has traffic accident's probability to be very big. This suggests that after the same driving tasks, the driver fatigue in the mountainous area is bigger than in the plains, the mountain road sections are more likely to make the driver fatigue.

4. Conclusions

Through the experiment, the analysis of three indexes of driver's heart rate, driving operation and reaction time can be obtained. Compared with other terrain conditions, mountainous area freeway are more likely to lead to fatigue driving, and the main influencing factors are driving environment and road conditions. Mountain terrain is complex, the continuity and equilibrium of the road plane alignment is not high, longitudinal slope and slope length is larger, plane and vertical section combination is inappropriate, will cause the driver's frequent operation, at the same time, because the mountain road, bridge, tunnel and large retaining wall is larger, affects the driving vision, resulting in driving speed is discontinuous, the driver brakes frequently. Therefore, in a mountainous area, drivers are often in excessive tension, physiological burden on the heart, lead to fatigue driving.

Therefore, in order to avoid driving fatigue in mountain roads, the driver should be careful, slow down, driving a certain period of time (preferably not more than 2 hours) to stop and rest. In addition, can also from linear transformation, transport facilities renovation and construction of a district in the external aspects, try to eliminate the driver's tension, reduce the burden of cardiac physiology, specific advice is as follows:

- (1) Alignment should be consistent, and the linear technology parameters of adjacent sections are not big, so as to ensure the consistency of the speed of the driver.
- (2) The elements of plane and vertical section design should be coordinated, should meet the visual and psychological aspects of continuous, comfortable, in harmony with the surrounding environment, and avoid adverse combination of three dimensional space.
- (3) Road facilities should provide good sight induction function, the driver on the road ahead anticipation is consistent with the actual conditions, and it is strictly prohibited.
- (4) At the junction between the roads and Bridges and other structures, should have the speed change of transition section, at the same time, it is forbidden to cross-sectional mutations.
- (5) Set the rest area at a certain interval.

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