Study on the Influence of Tunnel Environmental Noise on Driving Fatigue

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Abstract. Almost all tunnel traffic accident investigation point out that fatigue driving is one of the important causes of accidents. In the long tunnel driving process, due to the acoustic characteristics of the tunnel, drivers are in a high noise environment for a long time. By recording the electroencephalogram (EEG) of drivers under tunnel noise conditions, the EEG characteristics of driving fatigue are described by using specific EEG power spectrum, moreover, attention level is measured by spectrum of SMR. The correlation model between different noise and driver's attention and fatigue degree is obtained, and the influence of tunnel noise on driving safety is analysed. The analysis results have great practical significance to improve the driving safety of drivers.

Keywords: Tunnel noise, EEG power spectrum, attention, fatigue degree.

1. Introduction
The traffic flow in the long tunnel of expressway is usually very large, and once an accident occurs, it will be difficult to deal with because of the limitation of the inner space of the tunnel, so the direct and indirect losses are particularly serious. In 2017, the May 23 accident in Futuyu No.5 Tunnel of Zhangshi Expressway in Hebei Province caused 13 deaths and the scene of the accident was tragic. The "August 10" serious road traffic accident occurred in Qinling mountain tunnel group, and there were 80 tunnels in the accident section. Almost all tunnel traffic accident investigation point out that fatigue driving is one of the important causes of accidents. In the process of driving in a long tunnel, due to the acoustic characteristics of the tunnel, the noise sound pressure level distribution, decay and reverberation characteristics are different from those of the road section with open space outside the tunnel. When the driver is in the high decibel noise environment for a long time, he will feel pressure and fear to accelerate the generation of fatigue and inattention, and greatly increase the probability of traffic accidents, which seriously affects the safety of driving[1]. It is proved that noise has a significant impact on people's safety attention. When the noise value of the working environment is greater than 60 dB, the level of people's safety attention will obviously decline [2]. The environmental noise of long tunnels is generally higher than 90dB, even the peak value is more than 130dB, which is far higher than that of general expressway [3].

At present, a large number of studies focus on the sound propagation model and tunnel noise reduction in long tunnels [4,5]. The existing research on the subjective impact of vehicle interior noise on people mainly focuses on the sound quality model [6]. In recent years, with the deepening of research, Huang

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et al. established the prediction model of vehicle interior noise quality based on belief network [7]. Li and Huang proposed a noise discomfort model for micro commercial vehicles suitable for various road conditions [8]. Based on the subjective evaluation test results and fuzzy comprehensive algorithm, Wang et al. established a fuzzy comprehensive evaluation model of comprehensive irritability [9]. Fang et al. researched the psychoacoustic subjective and objective evaluation model of noise quality of electric vehicles [10]. Gao et al. established the calculation model of objective psychoacoustic parameters loudness of interior sound quality [11].

The research on driver attention and driving fatigue is also deepening [12-15], but the research on the insecurity of noise to human driving is less. Ding et al. pinpointed that the tunnel acoustic environment has a negative impact on drivers [16]. However, there is a lack of in-depth research on the impact of noise on driving safety in the special environment of long tunnel. This paper records the EEG of drivers with different driving time under the condition of tunnel noise. The specific EEG power spectrum ratio is shown to describe the EEG characteristics of driving fatigue, and the SMR amplitude value is illustrated as an index to measure the level of attention to get the long tunnel based on the correlation model of noise, driver's attention and fatigue, the influence of tunnel noise on driving safety.

2. Test Method

2.1. Subjects
The five subjects, aged between 28 and 45, were drivers with more than five years of driving experience and voluntarily participated in the test. The subjects were in good mental condition with normal vision or correction. The subjects were asked not to drink alcohol or caffeinated drinks within 24 hours before the experiment.

2.2. EEG Signal Acquisition Equipment
This experiment uses Emotiv EPOC, a head mounted device released by Emotiv company. The device has 14 salt solution electrodes, which are placed according to the widely used international 10-20 electrode position standard system: af3, AF4, F3, F4, FC5, FC6, F7, F8, T7, T8, P7, P8, O1, O2, as shown in Figure 1. Emotiv EPOC can provide the original data to researchers for further analysis, and is widely used in EEG research [17].

![Figure 1. Channel locations.](image)

2.3. Test Process
The test started at 9 am, driving for 30 minutes on the city road, and then driving back and forth two times in Nanjing Dinghuaimen tunnel. All subjects wore Emotiv EPOC according to the best signal acquisition state of Emotiv EPOC (100 displayed by Emotiv software) and recorded the EEG signals of the subjects in the whole process. Meanwhile, Aihua awa5680 sound level meter was used to record the sound pressure level around the subjects in the whole process.
3. Data Acquisition and Processing

3.1. EEG Acquisition and Preprocessing of EEG Signal
The EEG raw data collected by Emotiv EPOC contains a large number of artifacts, of which the high-frequency components are mainly composed of atmospheric thermal noise and power frequency noise, while the low-frequency artifacts are mainly caused by human physiological activities, including eye movement, head movement, breathing and heartbeat. Their characteristic is that the amplitude is in the range of millivolt and the frequency band is 0-16 Hz, while the amplitude of real EEG signal is in the range of microvolt and the frequency band is mainly distributed between 1-30 Hz [18]. Therefore, to process the EEG signal containing these noises, it is necessary to first pass a band-pass filter whose upper and lower cut-off frequency are 40 Hz and 0.1 Hz respectively, and then rebuild the reference baseline to all the data with the mean value of all 14 electrodes. Finally, ICA of EEGLAB in Matlab toolbox is used for independent component analysis to screen and eliminate physiological noise signals such as eye movement and eye drift.

3.2. Fatigue Related EEG Signal Processing
According to frequency, EEG can be divided into five different rhythms in Table 1. Wang and other researchers pointed out that with the deepening of driving fatigue, the rhythm of \( \alpha \) and \( \beta \) will gradually weaken [19]. SMR wave refers to the low \( \beta \) wave in the range of 12-15Hz, which is generally used to reflect the state of people's attention. When the SMR wave is reduced, the attention is often reduced [20].

| Rhythm  | Frequency (Hz) | Typical physiological characteristics                  |
|---------|----------------|--------------------------------------------------------|
| delta(\( \delta \)) | 1 ~ 4         | Sleep state                                           |
| theta(\( \theta \))  | 4 ~ 8         | Be down in spirits                                    |
| alpha(\( \alpha \)) | 8 ~ 12        | Relax and wake up when you close your eyes             |
| beta(\( \beta \))  | 14 ~ 30       | Inner activity or excitement                          |
| gamma(\( \gamma \)) | > 30          | Perceptual combination of different neurons            |
| SMR     | 12 ~ 15       | Attention state                                        |

4. Analysis of Test Results
In the urban road test, the average value of noise near the driver is 68.2dB, the average value of all electrodes of group average \( \alpha \) power spectrum of all subjects is 0.7367, and the average value of \( \beta \) is 0.6076. The average value of tunnel noise is 79.2db. After driving back and forth in the tunnel for 30 minutes, the average value of all electrodes of group average \( \alpha \) power spectrum of all subjects is 0.5558 and \( \beta \) is 0.4863. After leaving the tunnel, the average value of all electrodes of group average \( \alpha \) power spectrum of all subjects is 0.7734 and \( \beta \) is 0.5139. There was significant difference in power spectrum between the two groups (\( P < 0.05 \)). It can be seen that after entering the tunnel for a period of time, the average values of all electrodes of the group average \( \alpha \) and \( \beta \) power spectrum of all subjects have decreased, and after leaving the tunnel, they have increased, which indicates that the tunnel noise brings driving fatigue to all subjects, and the fatigue is relieved after leaving the noise environment. The SMR values of the above three cases were 0.7454, 0.6461 and 0.6224, respectively. It can be seen that the tunnel noise brought about the decrease of attention of all subjects. After leaving the tunnel, due to the influence of long-term noise, the decrease of attention could not be alleviated immediately. Therefore, it can be seen that tunnel noise will bring fatigue to drivers and reduce their attention. Tunnel noise will have a negative impact on driving safety.

5. Conclusion
To sum up, the test shows that it is a feasible way to study the influence of tunnel noise on driving safety by recording the EEG signals of drivers under the condition of tunnel noise. The method of describing driving fatigue state based on EEG power characteristics is reasonable and feasible. The test results
show that tunnel noise will bring fatigue influence to drivers and reduce their attention. Due to the limitation of experimental conditions, the number of subjects selected by the author is small, and only after leaving the tunnel, although it has statistical significance, future research should expand the number of subjects to study the impact in a longer time.

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