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# Optimal setting of traffic prohibition and warning signs on four-lane highway in plain terrain based on driver's EEG signal

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**Abstract**: In order to investigate the impact of various highway traffic prohibition and warning signs on four-lane highways in flat regions, electroencephalography (EEG) data from drivers were collected through field experiments. A comprehensive analysis was conducted on EEG potential, time-frequency characteristics, topography, power, and derived indicators. The study aimed to objectively evaluate the effects of different traffic signs on driver behavior by examining the EEG characteristics exhibited by drivers when observing various types of traffic prohibition and warning signs. The result shows that (1) The alterations in frontal lobe potential and EEG power are significantly more pronounced than those observed in a resting state when drivers encounter traffic prohibition and warning signs, suggesting a heightened activation level in the relevant brain regions. This implies that the presence of traffic prohibition and warning signs in this context effectively alerts drivers. (2) Notable differences were identified in the EEG relative power of the $\beta$ wave and the $\theta/\beta$ power indicator across six categories of traffic prohibition and warning signs, which include crossroads, weight limit, roundabout, T-junction, speed limit, and removal speed limit signs. Specifically, the relative power of the $\beta$ wave was found to be higher, while the $\theta/\beta$ power indicator was lower for speed limit and removal speed limit signs, indicating that these types of traffic signs are more effective in capturing drivers' attention. (3) Conversely, the relative power of the $\beta$ wave was lower and the $\theta/\beta$ power indicator was higher for weight limit, crossroads, and T-junction signs, suggesting that these signs are less effective in attracting sufficient attention from drivers. This diminished effectiveness may be attributed to factors such as drivers' habitual behaviors and the surrounding road environment. Consequently, it is recommended that greater emphasis be placed on optimizing weight limit, crossroads, and T-junction signs when enhancing the traffic prohibition and warning signs along this segment of the highway. The results of this study may serve as a valuable reference for the optimization of traffic prohibition and warning signs on similar highways.

**Keywords**: traffic engineering; optimal setting; EEG Signal; traffic sign; EEG power; brain topography

## 1 Introduction

As an important part of the driving environment, traffic prohibition signs and warning signs can provide driving information such as prohibition, restriction and warning. These signs directly affect the driver's driving cognition and driving behavior, and play a significant role in regulating driving behavior and reducing motor vehicle traffic accidents[1]. Setting unreasonable traffic prohibition signs and warning signs cannot attract sufficient attention from drivers, or it requires more cognitive time for drivers to process relevant information, which is likely to have a negative impact on their driving behavior and lead to traffic accidents. Therefore, it has important practical significance to objectively evaluate the setting effect of various traffic prohibition signs and warning sign[2].

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In order to fully utilize the function of road traffic signs, domestic and foreign scholars have conducted relevant research and obtained valuable research results. In previous studies on the effect of traffic signs, scholars used methods such as questionnaires and negotiations to collect data. In recent years, some scholars have explored the use of experiments to study traffic signs. In these studies, common experimental methods include EEG monitoring, eye movement recording, verbal report, driving response, traffic sign recall, etc[3]. Zhu[4] used EEG signals to conduct quantitative analysis of the information content of grassland traffic signs, and explored the optimal range of grassland highway traffic sign information content by comparing the changes in the driver's EEG signals under different information content conditions. Lu[5] used EEG and event-related potential (ERP) to analyze drivers' semantic cognition and emotional processing process of traffic signs. Zhang[6] applied EEG time-frequency analysis methods to study the impact of traffic signs on drivers' physiological state during curve driving. Wascher[7] used virtual driving technology to analyze the impact of controllability of driving environment on EEG signals. Yang[8] analyzed the impact of the number of place names in traffic signs on driving safety through eye movement indicators and EEG. Johansson[9] evaluated the information transmission effect of traffic signs by drivers' review of traffic signs passing through the road section. In these studies on the effectiveness of traffic sign settings, scholars commonly used research methods including EEG analysis (EEG power, ERP, EEG sample entropy, etc.), eye movement analysis (physiological characteristics such as vision, visual field, and vision), behavior analysis (motor acceleration, heart rate, heart rate variability, skin conductance, etc.), as well as questionnaires, interviews, and other methods. Common methods for processing data include line charts, box plots, correlation analysis, linear and nonlinear regression analysis, one-factor and multi-factor variance analysis, factor analysis, etc.

In the process of driving, driver needs to constantly perceive and judge the traffic condition, and operate the vehicle reasonably. Therefore, the brain needs to process a large amount of relevant information. EEG monitoring can objectively and truly reflect the changes in the driver's level of concentration and alertness during driving, and it has the characteristic of high temporal resolution[10], which has certain advantages in related research. During driving, various information received by the driver, including visual information and auditory information. It will be reflected in the changes of the driver's EEG signals, and the changes of various physiological indicators of the driver are also closely related to the fluctuations of EEG signals. Among the many physiological indicators that monitor the driving state of the driver, EEG signal can reflect the current level of concentration and alertness of the driver in real time and objectively, with high temporal sensitivity and not easily affected by the subjective intention of the driver. It has been widely applied in evaluating driver fatigue. In this study, EEG signals are selected as the main indicator to monitor the state of the driver, and box plot, non-parametric test and other methods are used to objectively display the changes of EEG signals when the driver observes different traffic signs.

With the widespread application of wearable biometric devices in the field of transportation human factors engineering, research on traffic signs based on driver's biological information has achieved many results. However, most scholars used simulated driving to obtain physiological indicator information of drivers for analysis, which cannot fully reflect the objective reality under real driving conditions. In view of this, this study conducted a field experiment on a four-lane highway in a plain area to collect the physiological index data of drivers during vehicle driving for statistical analysis, in order to draw a more practical conclusion.

Based on the analysis of domestic and foreign research methods, this paper measured the changes in EEG signals induced at relevant electrode locations when drivers observe different traffic prohibition signs and warning signs through field driving experiments, and analyzed the actual information conveying effects of different traffic prohibition signs and warning signs, with a view to making quantitative evaluations of the setting of traffic prohibition signs and warning signs.

## 2 Method

### 2.1 Experiment preparation

The experiment used a 32-channel Enobio wireless EEG device produced by the Spanish company NE to collect EEG data with a sampling rate of 500 Hz, and used the NIC2 software to record the changes in EEG signals during the experiment. The Dikablis Glass 3 eye tracker produced by the German company ERGONEERS and the supporting D-Lab software were used to record and analyze eye movement data to determine the driver's gaze on traffic signs and provide accurate time intervals for EEG data analysis.

Fifteen drivers were recruited in the experiment, and their independent driving time was not less than 2 years. Due to the influence of head movement, sweating, and emotions during the experiment, the data of 3 test drivers were excluded. The 12 test drivers studied in this paper were aged between 25 and 40 years old, in good physical and mental health, with normal vision or corrected vision, and had 2-15 years of driving experience. They did not drink alcohol, smoke, drink tea, or take drugs during the experiment and within 48 h before the experiment. Each test driver performed a live test without being informed of the purpose of the experiment.

The experiment selected a four-lane highway in a plain area, located in Hejian City, Hebei Province. The selected road section is the roundabout section of National Highway G337 in Hejian City, which is a two-way four-lane road with a design speed of 80 km/h. Since its opening to traffic at the end of 2019, this road section has opened up the dead end road between Yingnan Road and Baocang Highway, effectively alleviating the traffic congestion and environmental pollution caused by transit vehicles crossing the urban area, and playing a significant role in improving the layout of the ring road network in Hejian City. All the test drivers have no driving experience on this highway. After communicating with the local transportation authority, they agreed to conduct this experiment. The length of the selected experimental road section is 7.2 km one way, and the total distance for driving back and forth is 14.4 km. The experimental vehicle is a joint venture brand SUV, which is one of the common models in the local area. The entire experiment involves 45 traffic signs, and the types and quantities of traffic signs are shown in Table 1. The research object of this paper is traffic prohibition signs and warning signs, and directional signs are not included in the scope of research. Therefore, the signs studied include 6 categories and 25 traffic signs, of which prohibition signs include three categories: weight limit, speed limit, and removal speed limit, and warning signs include three categories: crossroads, roundabout, and T-Junction.

**Table 1  Type and quantity of traffic signs**

| Type | Directional | Crossroads | Weight limit | Roundabout | T-Junction | Speed limit | Removal speed limit |
|---|---|---|---|---|---|---|---|
| Quantity | 20 | 13 | 2 | 2 | 4 | 2 | 2 |
| Form |  |  |  |  |  |  |  |

## 2.2 Experimental process

Before the experiment, the test driver correctly wore the EEG device and eye tracker, and conducted device debugging and calibration, as shown in Figure 1. At the beginning of the test, the test driver sat quietly in the main driving position. They adjusted and maintained relaxed state, and recorded their 3-minute eye-open resting state EEG data. After indicating the test section to the test driver, the test driver normally drove on the section. During the driving process, the test driver's EEG and eye movement data were recorded. Each test driver completed a complete test that took approximately 25 min.

During the experiment, the driver was simultaneously wearing an EEG device and an eye tracker. The experiment staff used NIC2 software to operate the EEG device and D-Lab software to operate the eye tracker. The time axes of the two software were aligned by entering markers in the computer. After the experiment, the eye tracker data were processed using D-Lab software to statistically analyze the specific moments when the driver's pupil focus aligned with each traffic prohibition sign and warning sign. Then, the characteristics of the EEG signal at the corresponding time were analyzed. The EEG data were processed using Eeglab (version

**Fig. 1 Test driver equipment commissioning and calibration**

2014), and the time previously recorded by the eye tracker was imported into the EEG data to statistically analyze the EEG signals during the experiment when the driver observed traffic prohibition and warning signs.

### 2.3 Preprocessing of EEG data

During the experiment, the EEG data of the test driver will inevitably be affected by vehicle vibration, noise, electromagnetic signals, etc. The muscle electricity caused by the head shaking of the test driver and the signal drift caused by blinking will also affect the EEG data[11]. In order to eliminate the artifacts caused by various noises in the EEG signal, the experimental data were preprocessed using the Eeglab software. The normal EEG frequency mainly distributes below 45 Hz[12]. In the preprocessing, the filtering frequency is set to 0.5 Hz (high-pass filter) to 45 Hz (low-pass filter). In addition, the artifacts in the EEG data were removed through methods such as re-reference, interpolation bad leads, and ICA, etc [13].

## 3 Experimental result

### 3.1 Comparison of brain potential changes

After preprocessing of the EEG data, the resting-state data and task-state data of 12 test drivers were segmented and then averaged separately. The resting state refers to the stable state of the test driver at the beginning of the experiment when he was not driving, and the task state refers to the state when the driver was observing traffic signs while driving. The frontal lobe region of the human brain is closely related to human cognitive functions such as attention, problem solving, and memory[14]. In this paper, we selected three electrodes located in this brain region, F3, Fz, and F4, to explore the potential changes in the frontal lobe region of the brain. We drew an average brain potential map, and the results are shown in Figure 2. It can be seen that the potential oscillations in the frontal lobe region of the driver under task state conditions are more pronounced than those under resting state conditions.

### 3.2 EEG time-frequency comparison results

Time analysis and frequency analysis are two common analysis methods for EEG signal analysis[15]. By plotting the Event-Related Spectral Perturbation (ERSP) diagram of 12 driver subjects' EEG signals, the influence of events on EEG signals at corresponding time and frequency can be analyzed. The ERSP results of the driver in the resting state and task state in this experi-

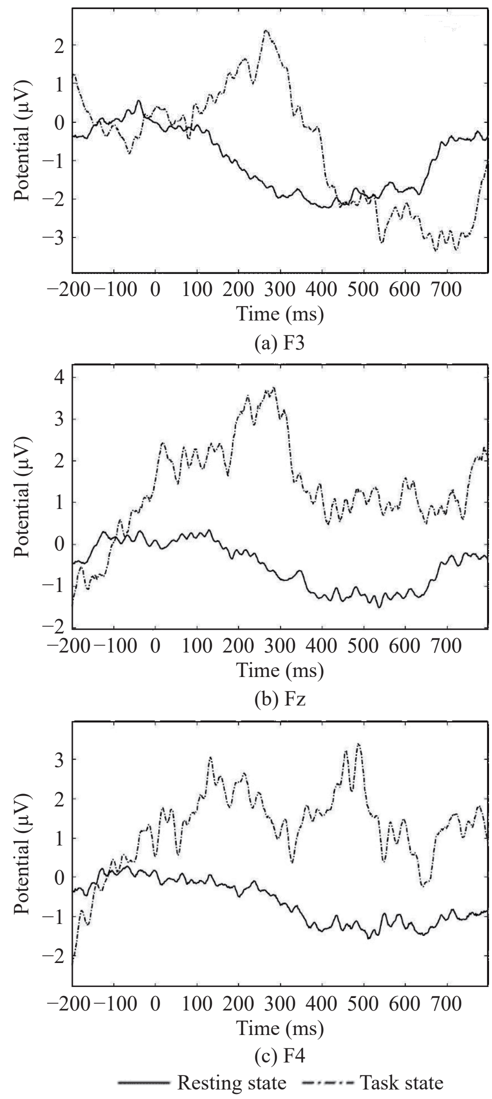


**Fig. 2 Comparison of frontal lobe potentials between drivers' resting and task states**

ment are shown in Figure 3, with the EEG frequency range from 0.5 Hz to 45 Hz, and three electrodes F3, Fz, and F4 are selected for display. The color depth in Figure 3 can be used to judge the EEG power at corresponding time and frequency. The results showed that the frontal lobe EEG power changes more significantly in the task state than in the resting state.

### 3.3 Results of brain topography

In the field of neurophysiology, the $\beta$ wave (14 Hz to 30 Hz) of EEG can be used to reflect the changes in attention of brain regions. The 22 Hz in $\beta$ wave is the most typical frequency, and it is also one of the default frequencies for drawing brain topography in Eeglab, which is often used by scholars for frequency-domain topo-

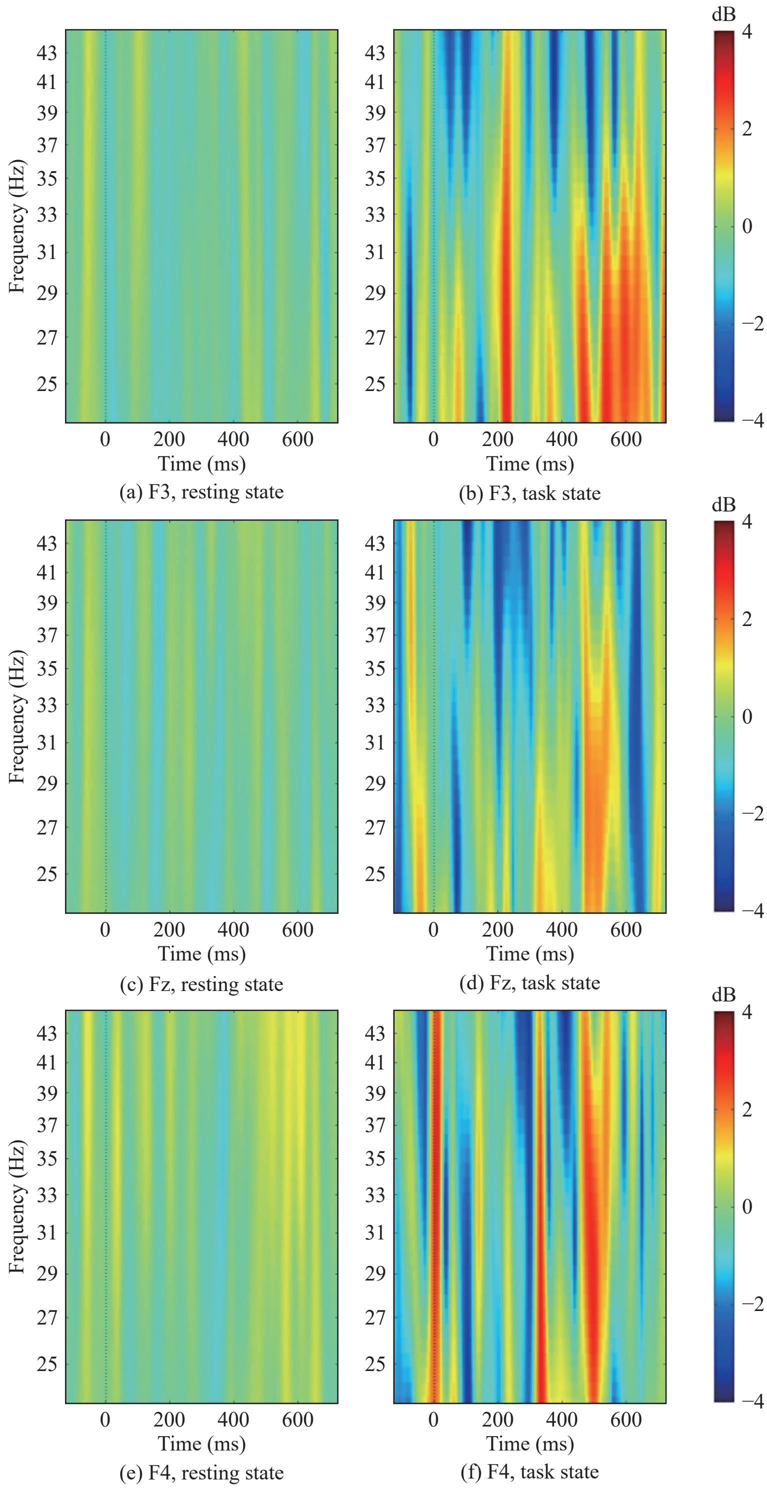


**Fig. 3 Drivers' frontal lobe ERSP in resting and task states**

graphy research related to $\beta$ wave[16]. In this study, $\beta$ wave is taken as the main analysis object, and 22 Hz is taken as an example to draw the frequency-domain topography of the observed traffic prohibition signs and warning signs by the test drivers. The brain activity of 12 test drivers when observing different types of traffic signs has certain consistency. The brain topography of one test driver is shown in Figure 4, where the color depth of different regions reflects the brain power of corresponding brain regions.

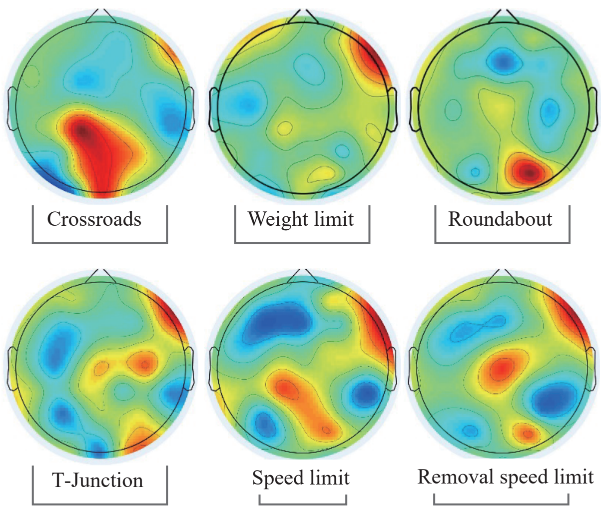


**Fig. 4 Brain topography of test drivers**

### 3.4 Results of EEG power comparison

According to different frequencies, brain waves are divided into different bands: $\delta$ wave, $\theta$ wave, $\alpha$ wave, $\beta$ wave and $\gamma$ wave. The power changes of different brain wave signals can reflect the changes in human neurophysiological state[17]. When using brain wave signals to study road-related facilities, some scholars have selected different brain wave indicators or combinations of indicators such as $\delta$ wave, $\theta$ wave, $\alpha$ wave, $\beta$ wave, $\alpha+\beta$, $\alpha/\beta$, $\theta/\beta$, and $(\theta+\alpha)/\beta$ for analysis[18-21]. According to the purpose of this study, we selected the $\beta$ wave and $\theta/\beta$ power indicator to evaluate the effects of different types of traffic prohibition signs and warning signs on the driver's brain wave signals. The larger the $\beta$ wave power, the more focused the driver's attention; the smaller the $\theta/\beta$ value, the higher the alertness of the driver, and the greater the impact of traffic signs on the driver's brain[22].

Among various methods for calculating EEG power, the Welch method is one of the most commonly used methods[23]. In this study, the Matlab (version 2019b) pwelch function was called to calculate the EEG $\beta$ wave power and $\theta/\beta$ power indicator of each driver under different types of traffic prohibition signs and warning signs during data processing. In order to facilitate statistical analysis of the EEG power data of different driver subjects, the $\beta$ wave power calculated during data processing in this study was relative power, which is the percentage of absolute $\beta$ wave power to the total power of the whole EEG band. The box plot of the experimental data was drawn using Origin (version 2018).The relative power of the $\beta$ wave of 12 driver subjects while observing different types of traffic prohibition signs and warning signs is shown in Figure 5, and the $\theta/\beta$ power indicator is shown in Figure 6.

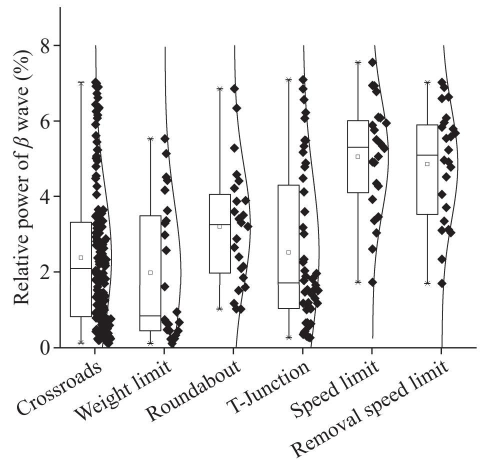


**Fig. 5 Test drivers' relative power of $\beta$ wave**

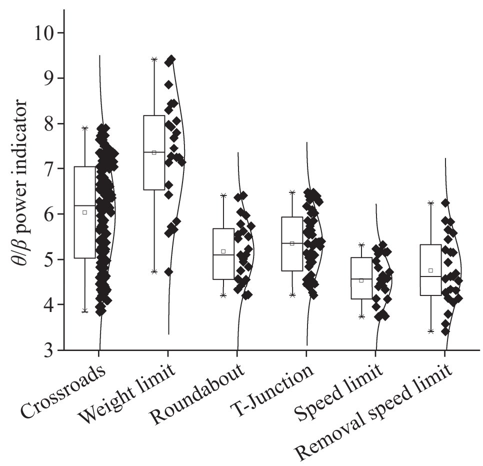


**Fig. 6 Test drivers' $\theta/\beta$ power indicator**

### 3.5 Nonparametric test of EEG power

Based on the trend analysis of Figure 5 and Figure 6, it can be seen that different types of traffic prohibition signs and warning signs have different effects on the EEG power of the test drivers. Whether this difference reaches statistical significance requires further testing. Using SPSS26.0, Shapiro-Wilk tests were conducted on the relative power of $\beta$ waves and $\theta/\beta$ power indicators of 12 test drivers while observing different types of traffic prohibition signs and warning signs, to verify their normality. The results are shown in Table 2.

**Table 2 Results of normality test**

| EEG power indicator | Type of signs | Shapiro-Wilk statistic | $D_f$ | $P$ |
|---|---|---|---|---|
| Relative power of $\beta$ wave | Crossroads | 0.905 | 156 | 0.000** |
| | Weight limit | 0.839 | 24 | 0.001** |
| | Roundabout | 0.953 | 24 | 0.319 |
| | T-Junction | 0.857 | 48 | 0.000** |
| | Speed limit | 0.973 | 24 | 0.735 |
| | Removal speed limit | 0.951 | 24 | 0.288 |
| $\theta/\beta$ power indicator | Crossroads | 0.946 | 156 | 0.000** |
| | Weight limit | 0.970 | 24 | 0.658 |
| | Roundabout | 0.957 | 24 | 0.383 |
| | T-Junction | 0.945 | 48 | 0.025* |
| | Speed limit | 0.936 | 24 | 0.132 |
| | Removal speed limit | 0.976 | 24 | 0.819 |

Note: * indicates a significant level of $P$<0.05; **indicates a significant level of $P$<0.01.

In the normality test results, the crossroads, weight limit, T-Junction in the relative power of β waves, and the crossroads, T-Junction in the $\theta/\beta$ power indicators do not conform to the normal distribution ($P$<0.05). Therefore, the experimental data in this study does not meet the prerequisite conditions for analysis of variance. In order to verify the differences in EEG power when the test drivers observe different types of traffic prohibition signs and warning signs, the experimental data in this study were analyzed using nonparametric tests. The Kruskal-Wallis H test was conducted using SPSS26.0, and the results are shown in Table 3.

**Table 3 Results of nonparametric test**

| EEG power indicator | Sample size | Kruskal-Wallis H test statistic (adjusted) | $D_f$ | $P$ |
|---|---|---|---|---|
| Relative power of $\beta$ wave | 300 | 64.063 | 5 | 0.000** |
| $\theta/\beta$ power indicator | 300 | 90.646 | 5 | 0.000** |

Note: **indicates a significant level of $P$<0.01.

The results of nonparametric tests indicate that the significance of the relative power of $\beta$ waves and the $\theta/\beta$ power indicators are both less than 0.01, indicating that different types of traffic prohibition signs and warning signs have different effects on the brain of drivers. To further analyze the differences between different types of signs, the brain wave data under different types of traffic signs were compared pairwise. The significance of the relative power of $\beta$ waves (after Bonferroni correction) is shown in Table 4, and the significance of the $\theta/\beta$ power indicators (after Bonferroni correction) is shown in Table 5.

From the results in Table 4, it can be seen that there are significant differences in the $\beta$ wave power of the EEG when the test drivers observe traffic signs for crossroads and speed limit, crossroads and removal speed limit, weight limit and speed limit, weight limit and the removal speed limit, T-Junction and speed limit, and T-junction and removal speed limit ($P$<0.01).

The results in Table 5 show that there were significant differences in the EEG $\theta/\beta$ power indicators between the test drivers when observing traffic signs for cross-

**Table 4 The test results of relative power of $\beta$ wave pairwise comparison**

| Type of signs | Crossroads | Weight limit | Roundabout | T-Junction | Speed limit | Removal speed limit |
|---|---|---|---|---|---|---|
| Crossroads | 1.000 | 1.000 | 0.357 | 1.000 | 0.000** | 0.000** |
| Weight limit | 1.000 | 1.000 | 0.136 | 1.000 | 0.000** | 0.000** |
| Roundabout | 0.357 | 0.136 | 1.000 | 0.956 | 0.138 | 0.264 |
| T-Junction | 1.000 | 1.000 | 0.956 | 1.000 | 0.000** | 0.000** |
| Speed limit | 0.000** | 0.000** | 0.138 | 0.000** | 1.000 | 1.000 |
| Removal speed limit | 0.000** | 0.000** | 0.264 | 0.000** | 1.000 | 1.000 |

Note: **indicates a significant level of $P$<0.01.

**Table 5 The test results of $\theta/\beta$ power indicator pairwise comparison**

| Type of signs | Crossroads | Weight limit | Roundabout | T-Junction | Speed limit | Removal speed limit |
|---|---|---|---|---|---|---|
| Crossroads | 1.000 | 0.001** | 0.017* | 0.014* | 0.000** | 0.000** |
| Weight limit | 0.001** | 1.000 | 0.000** | 0.000** | 0.000** | 0.000** |
| Roundabout | 0.017* | 0.000** | 1.000 | 1.000 | 0.691 | 1.000 |
| T-Junction | 0.014* | 0.000** | 1.000 | 1.000 | 0.045* | 0.521 |
| Speed limit | 0.000** | 0.000** | 0.691 | 0.045* | 1.000 | 1.000 |
| Removal speed limit | 0.000** | 0.000** | 1.000 | 0.521 | 1.000 | 1.000 |

Note: * indicates a significant level of $P<0.05$; **indicates a significant level of $P<0.01$.

roads and weight limit, crossroads and speed limit, crossroads and removal speed limit, weight limit and roundabout, weight limit and T-junction, weight limit and speed limit, and weight limit and removal speed limit ($P<0.01$). There were also significant differences in the EEG $\theta/\beta$ power index between the test drivers when observing traffic signs for crossroads and roundabout, crossroads and T-junction, and T-junction and speed limit ($P<0.05$).

## 4 Discuss

### 4.1 Analysis of resting-state and task-state EEG results in drivers

The frontal lobe is the main functional area of the brain responsible for attention, cognition, and other functions. As can be seen in Figure 2, the potential changes in the task state are more significant than those in the resting state at the three electrodes F3, Fz, and F4 in the frontal lobe region. The brain frontal lobe region of the test driver is more active during observation of traffic prohibition signs and warning signs than during the resting state. In Figure 3, the darker the color represents the greater the EEG power at the corresponding time and frequency. At the three electrodes F3, Fz, and F4, the task-state EEG power is significantly higher than the resting-state power. The analysis of the β waves also reached the same conclusion. The level of arousal or concentration of the driver during driving while observing traffic prohibition signs and warning signs is higher than that during the resting state. Based on a comprehensive analysis of the potential maps and ERSP maps of the frontal lobe region of the test driver in the resting state and task state, the driver has certain cognitive and attention responses after observing traffic prohibition signs and warning signs, reflecting that the setting of traffic prohibition signs and warning signs can arouse the driver's alertness.

### 4.2 Analysis of EEG results for six types of traffic prohibition signs and warning signs

The results of Figure 4 show that when the driver observed speed limit traffic signs during the experiment, the color of the front part of the brain topography was darker, and the activation of the frontal lobe region was more significant. This suggests that these traffic signs played a good reminder role for the driver. When observing signs for removal speed limit and roundabout, there was also a certain degree of activation in the frontal lobe region, but when observing signs for weight limit, T-Junction, and crossroads, the activation level in the frontal lobe region was lower, suggesting that there were deficiencies in the design of these signs and room for optimization. In addition, the brain topography results suggest that there was a significant dark color on the upper right edge of the brain topography when the driver observed signs for weight limit, T-Junction, speed limit, and removal speed limit. When observing signs for crossroads, there was also a sign of deepening color in this area. It is speculated that the driver's EEG signal was greatly affected by right-sided eye movements. The analysis suggests that most traffic signs on ordinary arterial highways are located on the right-hand side of the sign post, and when the driver encounters a traffic sign, they need to look up and to the right. Therefore, this right-sided eye movement interference is a common phenomenon during driving. During the experiment, the roundabout signs were all located within the island in the middle of the road, and there was no evidence of right-sided eye movement interference in the corresponding brain topography, which also confirms the above results.

Through the comparison of EEG power indicators, the impact of different types of traffic signs on EEG signals can be analyzed more accurately and quantitatively. Figure 5 represents the changes in relative power of $\beta$ waves under the stimulation of six types of traffic prohibition signs and warning signs, and Figure 6 represents the changes in $\theta/\beta$ power indicators under the stimulation of six types of traffic prohibition signs and warning signs. After comprehensively analyzing Figure 5 and Figure 6, it can be seen that the conclusions drawn from the two indicators are highly consistent, and both indicators suggest that the information warning effect of traffic signs that weight limit is the least significant in the experimental road section, followed by traffic signs that crossroads, while the information warning effect of traffic signs that speed limit and removal speed limit is the best. The analysis conclusions based on $\beta$ waves and $\theta/\beta$ power indicators are basically consistent with those based on brain topography. Based on the results in Table 3, it can be seen that six types of traffic prohibition signs and warning signs display significant differences in relative power of $\beta$ waves and $\theta/\beta$ power indicators. From the results of comparisons between various signs in Table 4 and Table 5, it can be seen that there are significant differences in relative power of $\beta$ waves and $\theta/\beta$ power indicators between five pairs of signs, including crossroads and speed limit, crossroads and removal speed limit, weight limit and speed limit, weight limit and removal speed limit, and T-Junction and speed limit. Combining the distribution of six types of traffic prohibition signs and warning signs in Figure 5 and Figure 6, it can be seen that signs that speed limit and removal speed limit have good setting effects, while signs that crossroads, weight limit and T-Junction have poor setting effects.

By viewing the driving video based on the driver's perspective in the D-LAB software and conducting a survey of the test drivers, a comprehensive analysis of the situation when the driver observes the weight limit signs was conducted. The analysis found that the reasons why the sign could not attract enough attention from the test drivers included: ① The sign was set on the shoulder and was low in height from the ground, making it difficult for the driver to observe. ②When the driver was driving on the inside of the lane and there were vehicles outside the front, or when the driver was following a vehicle, the sign was easily obscured by other vehicles. ③The test drivers usually drive private cars, which lack sensitivity to weight limit traffic signs. The poor setting effect of crossroads and T-Junction traffic signs was mainly due to the similarity between the two types of signs and the high number of low-grade highways intersecting with the experimental road section, resulting in the high number of these two types of traffic signs being set. The driver was tired of these signs, and some sections of the road were under construction, which distracted the driver's attention. Through a survey of the test drivers, it was found that the test drivers generally paid more attention to traffic violation fines and demerit points, which was largely related to the fact that speed limit and removal speed limit traffic signs in this experiment could attract enough attention.

## 5 Conclusion

This paper aims to study the characteristics of EEG signals in drivers under the stimulus of traffic prohibition signs and warning signs on four-lane highways in plain area. In the experimental section, the frontal lobe region of the brain is more activated when drivers observe traffic signs than in the resting state. The setting of traffic prohibition signs and warning signs on this section can arouse the driver's alertness.

Among the six types of traffic prohibition signs and warning signs in the experimental road section, including crossroads, weight limit, roundabout, T-Junction, speed limit, removal speed limit, the signs for weight limit, crossroads, and T-junction have poor effects and cannot attract enough attention from drivers. The signs for speed limit and removal speed limit have good effects and can play good reminder roles. It is recommended that when optimizing the traffic prohibition signs and warning signs in this road section, the signs for weight limit, crossroads, and T-junction should be given priority consideration.

As discussed in the previous chapter, the tested drivers generally lack sensitivity to weight limit traffic signs due to driving habits and other factors. When viewing driving videos using the D-LAB software, it was found that such signs are often obscured by vehicles on the outside due to their placement on the shoulder and low height. It is recommended that weight limit signs be placed on the gantry first when setting up, and when placed on the shoulder, full consideration should be given to the impact of the driver's viewing angle, and the height should be appropriately increased under the premise of meeting regulatory requirements to avoid being easily obscured by vehicles on the outside. If necessary, consider using materials with good reflective properties at a large angle to make such traffic signs, or by adding ground warning signs to coordinate with traffic signs to achieve better prompting effects. The specific impact of weight limit traffic signs on the driver's brain waves requires further experimental analysis by selecting tested drivers with driving habits of driving large trucks. The number of traffic signs on the experimental road sections with crossroads and T-Junction is too large, and the layout of low-grade highways intersecting with the experimental road sections should be optimized to reduce unnecessary intersections and reduce risks.

The experimental road section has been open to traffic for less than two years, and the traffic signs are relatively new compared to most other road sections. The selected experimental vehicle model is a small car, which differs from large cars in terms of vision and other aspects. The selected test drivers usually drive small cars, which limits the generality of the conclusions in this paper. In the future, further research can be conducted on different road conditions, different vehicle models, and different types of drivers.

## Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

## Acknowledgments

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