The Research on Driver's Attention Recovery Based on Various Driving Conditions

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Abstract. To study the effect of subliminal vibration to recover young drivers' attention, fifteen subjects were selected to carry out simulated driving experiments. Focusing on driving (single driving), distracted driving, dominant vibration warning driving and subliminal vibration warning driving were carried out respectively. ECG signal and driving performance of subjects were recorded under these four kinds of driving conditions. ECG signal was analyzed using MATLAB. The results indicate that compared with ECG data of single driving the increasing amplitude of subliminal vibration warning is lower than those of the other warming methods, and the driving performance of subliminal vibration warning is better than those of other warning methods. Therefore, subliminal vibration warning can effectively recover the driver's attention. It also provides a reference for the future research on the road traffic safety system.

Introduction

Because of mobile devices and the increase of the number and complexity of traffic information which the drivers receive, drivers can’t concentrate on driving tasks very well, resulting in a potential risk of driving. Related studies have shown that the frequency of driver distraction and the probability of traffic accident has the very high correlation coefficients (0.72), compared with the normal circumstances, when the driver appear the phenomenon of distraction (for example: making a telephone call), the probability of accident will increase three times [1]. Therefore, the methods that can recover the driver's attention from distraction task to the road has become an important research direction of the safety driving.

Currently, the research methods of drivers' attention restoration mainly focus on three aspects: tactile, visual and auditory warnings [2,3,4]. However, many kinds of warning methods which are put forward and studied now are mostly dominant stimulation. When drivers are stimulated by these methods, they will spread some attention to analyze the signal, which may increase the driver's cognitive load and affect the stability of driver's operation.

In order to avoid this phenomenon, we need a new warning method. This method not only allows the driver to know the potential dangerous situation, but also don’t increase the driver's cognitive load. So the subliminal vibration warning has become a more feasible method. External stimulation must reach a certain extent in order to be realized. And this "certain extent" is the threshold. The vibration that is Below the threshold is the Subliminal warning.

Wang Jing has explored the effectiveness of subliminal information dissemination and mechanism of action which provides a valuable reference for the application of the research of subliminal vibration warning [5]. In addition, Riener has used this stimulation method to carry out an experiment study on changing the driving habits, and this experiment has demonstrated subliminal stimulation can affect driving behavior [6].

An important research aspect of the automotive safety is to evaluate the driver's cognitive load. No matter what kinds of warning methods, they all have a more or less impact on the driver's cognitive load. There are many ways to evaluate cognitive load, including performance-based measurement, self-report, behavior observation, and by physiological measurement [7,8]. In dynamically changing
conditions such as driving an automobile, performance and physiological measures offer the advantage of being both objective and relatively continuous in nature. And ECG responds to the driver's cognitive load effectively[9,10].

In order to explore the effectiveness of subliminal vibration stimulation on driving behavior intervention and take the convenience and objectivity of data measurement into account, this paper uses ECG signal and task performance as the evaluation index. The feasibility of this method to recover the driver's attention is proved by collecting the ECG signals and measuring the corresponding driving performance under different conditions.

**Experiment**

**Participants**
Fifteen drivers between the ages 22 and 28(M=24.8, SD=1.8) participated in the study. They all have a legally valid driver's license and good health. Participants aren’t allowed to carry out intense sports to ensure that there is no fatigue driving phenomenon. And participate are asked to practice to establish a connection between attention and subliminal vibration.

**Apparatus**
This experiment is carried out in the HW-2009 car driving simulator. And the scene uses the computer real-time generated images which can simulate real traffic road. Physiological data is collected by RM6280C multi-channel physiological signal acquisition and management system. The 12-lead way is used to arrange the electrode arrangement to record ECG signal. In the course of the experiment the sampling frequency was 1kHz and the scanning speed was 250ms/div. The vibration device consists of a micro vibration motor and a governor to provide the required vibration signal during the experiment.

**Procedure**
The driver must be strictly in accordance with traffic laws and regulations to drive on the simulated driving device and as far as possible to keep the speed of about 50km/h. Models selected cars, the scene chose the city, the weather selected the fine day, and the number of self-parking vehicles was medium to simulate a general road conditions, the above these were conditions of this experiment simulation.

Before the experiment, subjects were asked to sit quietly on the driver's seat to connect the ECG sensor for ECG records. Subjects drove for 10 minutes as an introductory training so that subjects became familiar with and adopt to driving the car while also being attached to the physiological monitoring sensors.

<table>
<thead>
<tr>
<th>Step</th>
<th>Experiment task</th>
<th>Time(min)</th>
<th>Experiment purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The driving exercises</td>
<td>10</td>
<td>Be familiar with the simulation scene, adapted to the physiological test device</td>
</tr>
<tr>
<td>2</td>
<td>The focusing on driving task</td>
<td>3</td>
<td>The driving performance and physiological parameters as the baseline data</td>
</tr>
<tr>
<td>3</td>
<td>The distracted driving task</td>
<td>3</td>
<td>The driving performance and physiological parameters</td>
</tr>
<tr>
<td>4</td>
<td>The dominant vibration driving task</td>
<td>3</td>
<td>The driving performance and physiological parameters</td>
</tr>
<tr>
<td>5</td>
<td>The subliminal vibration warning driving task</td>
<td>3</td>
<td>The driving performance and physiological parameters</td>
</tr>
</tbody>
</table>

The experiment was divided into four experimental test stages: the focusing on driving task, the distracted driving task, the dominant vibration driving task and subliminal vibration warning driving task. The distracted driving task was to give the driver random interference that allowed the driver to
remember the random number[11]. Ten digital images were randomly presented to the driver, and the driver was required not to repeat the current number and respond to the number before it. The dominant vibration driving task and subliminal vibration warning driving task were to give the driver warning when the driver was distracted.

After each test period was completed, the subject was asked to sit on the simulator for three minutes. The three minutes as the rest time allowed the subject to further restore or adapt to the study conditions. And then the subject continued to the next stage of driving control. Four test simulation conditions were consistent. Driving performance and physiological parameters of the focusing on driving task were the experiment baseline. The experiment sequence was in the order of Table 1.

**Experiment Data**

ECG signals were processed by MATLAB. All the original signals were the same time period. The time domain of the original signal was analyzed to get peak-to-peak and variance. And the Peak-to-peak value refers to the difference between the maximum and minimum of the signal. The variance characterizes the fluctuation of the data. The data under different conditions is shown in Table 2.

<table>
<thead>
<tr>
<th>The driving task</th>
<th>Peak-to-peak</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>The focusing on driving</td>
<td>1.590</td>
<td>1.182</td>
</tr>
<tr>
<td>The distracted driving</td>
<td>1.680</td>
<td>1.227</td>
</tr>
<tr>
<td>The dominant vibration driving</td>
<td>1.646</td>
<td>1.197</td>
</tr>
<tr>
<td>The subliminal vibration warning driving</td>
<td>1.591</td>
<td>1.191</td>
</tr>
</tbody>
</table>

The frequency domain of ECG signal is analyzed by MATLAB. The power spectrum of the ECG signal is obtained by fast Fourier transform and periodic graph method. Figure 1 (a)(b)(c)(d) show the power spectrum under different driving tasks.

(a) The power spectrum under the condition of concentration  
(b) The power spectrum under the condition of distraction  
(c) The power spectrum under the condition of the dominant vibration driving  
(d) The power spectrum under the condition of the subliminal vibration warning driving

![Figure 1. The power spectrum under different driving tasks.](image)

The increase in cognitive load directly affects the driver's manipulation. Table 3 shows the performance of the driver under different driving tasks.
Table 2. Driving performance.

<table>
<thead>
<tr>
<th>The driving task</th>
<th>Red light</th>
<th>Collision</th>
<th>Over-speed</th>
<th>Pressing line</th>
<th>Flame-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>The focusing on driving</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>The distracted driving</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>The dominant vibration driving</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>The subliminal vibration warning driving</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Data Analysis

Figure 2. The increase rate of peak-to-peak. Figure 3. The increase rate of variance.

Figure 2 shows the increase rate of peak-to-peak. And Figure 3 shows the increase rate of variance. When the driver is concentrated, ECG data is lower than other conditions, and there is no significant fluctuations in the power spectrum of ECG. And there is only one flameout, which has a good driving condition. When the driver is disturbed by the outside factors, the variance of ECG data increases by 3.087%, the power spectrum image in Figure 1(b) have obvious fluctuation. The driver's cognitive load increases and the driving situation becomes worse. This is because the attention resource is limited. While dealing with interference and maintaining the stability of driving control at the same time, the subjects' cognitive load increase. With the implementation of some interventions, the driving situation improved obviously.

Figure 4. The comparison of driving performance among the focusing on driving, the dominant vibration driving and the subliminal vibration warning driving.

Through the comparison between the dominant vibration and the subliminal vibration, The study has found that the driver's cognitive load and driving performance under the subliminal vibration are superior to the dominant vibration. When drivers receive the subliminal vibration warning, the variance of the ECG data only increases by 0.761%. And the waveform of the power spectrum is relatively stable which is close to the power spectrum under the condition of concentration, which is
found in the figure 1. This indicates that the subliminal vibration warning has less effect on the driver's cognitive burden.

Comparing with the dominant vibration warning, drivers have a better driving performance. From the figure 4, there are only the phenomenon of flame-out. But running the red light and over-speed appear under the condition of the dominant vibration, which dangerous behavior for the driver. When drivers receive the dominant vibration warning, the drivers have to spend some attention resources to analyze the vibration signal, and this situation increases the drivers’ cognitive load. Therefore, The peak-to-peak and variance of the drivers’ ECG increase significantly, the power spectrum fluctuates more violently, and the driving performance becomes worse. In a word, in terms of driving warning, the subliminal vibration is better than the dominant.

Summary
The ECG signal analysis shows that, compared to the dominant vibration warning, the subliminal vibration has a lower increment, and it is similar to the results of ECG signal under the conditions of concentration. The subliminal vibration and the the dominant can give the driver an early warning message, but the former effect is better. Taking the ECG data indicators and driving performance into account, it is considered that the subliminal vibration warnings can allow the driver to know the potential dangerous situation without increasing the driver's cognitive load.

Due to the impact of the number of samples, the method whether is applicable to other age groups need further study.

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References
