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Effects of Different Emotional Music on Driving Fatigue and Arousal Experiment

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Abstract: *With the rapid growth of the number of motor vehicles, road traffic accidents are becoming more and more serious. Fatigue driving has become one of the main causes of traffic accidents. It is particularly critical to find effective solutions to fatigue driving. At present, the academic community believes that the phenomenon of fatigue driving can be controlled by means of prevention and intervention. In terms of intervention countermeasures, using sound stimulation as a wake-up method has the advantages of easy implementation and significant effect, which has become the research focus in the driving fatigue mitigation scheme. Through the establishment of a simulation driving platform, driving fatigue detection system and driving fatigue wake-up system in the laboratory, the experimental research is carried out to study the fatigue generation of drivers in different emotional types of music environment and the effectiveness of wake-up countermeasures. Three sound environments were constructed in the experiment, which were driving noise environment, positive emotional music mixed with driving noise environment and negative emotional music mixed with driving noise environment. The subjects were tested in three sound environments in turn. When entering fatigue, they were given no stimulation, positive emotional music stimulation or negative emotional music stimulation according to the experimental design. The experimental results were obtained after considering the subjective evaluation questionnaire and the experimental data analysis based on pupil diameter variation coefficient, average blink rate and other indicators. The experimental results show that when driving for a long time, the driver will enter the fatigue state regardless of whether the driving background has different emotional music. The driver's fatigue depth in the positive emotional music environment is shallower than that in the negative emotional music environment and the music-free environment; there is no significant difference in the degree of fatigue between the driver 's fatigue in the negative emotional music environment and the fatigue in the absence of music environment. In the comparison of music arousal stimuli with different emotions, the introduction of positive emotional music as arousal stimulus has the best effect.*

Keywords: *Fatigue Driving, Sound Stimulation, Fatigue Arousal, Emotional Voice*

1. Introduction

Driving fatigue detection can be divided into subjective detection and objective detection [1]. The early detection of driving fatigue is mainly subjective detection. At present, the methods of detecting driving fatigue by using on-board equipment, physiological characteristics and behavioral characteristics acquisition devices are relatively mature. There are usually two ways: one is direct detection based on driver 's physiological signals and behavioral performance; the other is indirect detection based on the driver 's vehicle control level, such as lane departure control, steering wheel angle control, etc. Zhao et al. considered that sound stimulation is one of the main countermeasures to reduce driving fatigue by studying the influencing factors such as sound intensity, sound frequency and stimulation interval [2]. In the theory of introducing sound to alleviate driving fatigue, the wake-up effect has been proved to be effective by a large number of experiments, but it will also lead to increased driving fatigue in a long-term monotonous sound environment. Usually, the sound environment of the driver during driving is more complicated. Zwaag et al. divided music into positive music and negative music, and found that drivers listening to negative music reduced the breathing rate than not listening to music, and listening to positive music reduced the driving speed than not listening to music [3]. The existing music playing platforms often classify music based on emotional types, so it provides a wide and effective source for the selection of music materials required for the experiment. This paper mainly studies the effects of different emotional music on driving fatigue and wake-up experiment.

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2. Experimental Environment Design

2.1. Experimental subjects

(1) Twelve subjects aged between 20 and 30 were selected.

(2) Hold a motor vehicle driving license C1 and above, with actual road driving experience.

(3) Right-handed, normal hearing, visual acuity or corrected visual acuity 1.0 or above, no color weakness, color blindness and other eye diseases.

(4) One week before the experiment did not take medicine, 24 hours did not observe drinking, coffee, functional drinks, smoking and other acts;

(5) No music was heard within 12 hours before the experiment.

(6) After the relevant training before the experiment, the subjects were able to operate the simulator skillfully.

2.2. Construction of Experimental Environment

From the perspective of safety and research cost, this paper refers to the experimental research methods of other scholars, through the indoor simulation driving method to achieve the purpose of driving fatigue. When the subjects were judged to enter the fatigue driving state, the corresponding wake-up stimuli were introduced. The detection of driving fatigue is mainly achieved by collecting the eye behavior characteristics of the subjects. Focusing on the above purpose, an experimental environment was built in the laboratory. The experimental environment consists of three parts: simulation driving platform, driving fatigue detection system based on human eye behavior characteristics and driving fatigue wake-up system.

2.2.1. Simulation Driving Platform

In this paper, the model JDM-9C simulation driver is used in the experiment, and its design structure and operation are modeled on the design of a real manual car. In front of the simulator are three 21-inch 720p LCD displays for visual simulation during driving. The simulation driver is equipped with simulation driving software, which can simulate driving a variety of cars, trucks, buses or other vehicles, and can simulate different road conditions, such as urban roads, highways, rural roads, as well as night, day, sunny days, rainy days and other road conditions. The simulator has its own sound equipment, which can adjust the volume intensity through the volume adjustment knob. According to the driving state of the vehicle, the simulator can emit engine noise, whistle, wind noise and other road sounds.

2.2.2. Driving Fatigue Detection System

Driving fatigue detection system uses Tobii X2-30 eye tracker to collect eye behavior characteristics, and uses ErgoLab software for preliminary data collation and analysis. The Tobii eye tracker (shown in Figure 1) can capture eye behavior characteristics such as blink times and pupil diameters. During the experiment, the eye tracker was fixed at the edge above the dashboard of the simulated driving device to collect data without interfering with the normal operation of the participants. The Tobii Eye Tracker is also equipped with the ErgoLab software (shown in Figure 2) to perform preliminary processing of eye movement data to calculate blink count, average blink rate, and pupil diameter, greatly improving the efficiency of analyzing data.

Figure 1: Eye tracker of Tobbi.

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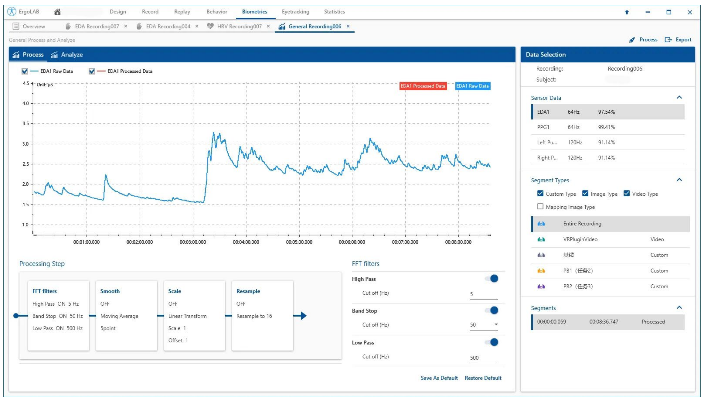

Figure 2: ErgoLab software.

2.2.3. Driving Fatigue Wake-up System

In this paper, a driving fatigue wake-up system is composed of a set of independent computer and audio equipment. When it is determined that the subject is in a state of fatigue, the system plays a pre-set wake-up sound to achieve the wake-up function. In addition, the sound equipment of the simulator and the driving fatigue wake-up system together constitute the construction of the entire simulated driving sound environment. In order to effectively control the volume of the sound, the volume measurement of all environmental sounds and wake-up sounds is completed during the experimental preparation and implementation phase using the decibel meter shown in Figure 3, and the range control is performed. The standard makes detailed provisions on sound level, sound measurement instruments and measurement methods. According to this standard and the actual driving situation of the driver, the cumulative percentage of sound in this paper is set to 75 %. In the experiment, the loudness of motor vehicle driving sound and other non-variable factors are controlled within 65 dB. According to the standard, the loudness level is moderate, and the influence of variables on the experimental results will not be weakened.

Figure 3: Decibel meter.

2.3. Experimental measurement indicators

(1) Pupil Diameter Variation Coefficient

The pupil diameter variation coefficient is the ratio of the standard deviation of pupil diameter to the mean of pupil diameter in the time interval. The calculation formula is:

$$C_V = \frac{\sigma}{\bar{\mu}} \times 100\% \tag{1}$$

C_V——V-pupil diameter variation coefficient;

σ ——standard deviation of pupil diameter;

$\bar{\mu}$ ——Mean pupil diameter (mm).

In order to reduce the impact of data fluctuations on the experimental results, ensure that all indicators can be analyzed and compared in the same time dimension, determine the appropriate analysis time interval. In this paper, 5min is selected as the fixed analysis time interval of each index, and the mean of all time intervals in a certain time period under a certain index is used to represent the level of the interval of the index.

(2) Average blink rate

The Blink Rate Per Second is the ratio of the total number of blinks to the time window. The BR calculation formula for the i-th time window is:

$$BR_i = \frac{BT_{ei} - BT_{si}}{T_{br}}, BT_i \neq 0, i = 1,2,\cdots,n \tag{2}$$

BT_{ei}——The total number of blinks at the end of the i-th time window;

BT_{si}——The total number of blinks at the beginning of the ith time window;

T_{br} ——BR calculation time window size, blink frequency optimal calculation time window is 60 s.

2.4. Experimental Process Design

Check and ensure that all equipment works properly before the experiment starts. The subjects filled in the subjective evaluation questionnaire before the start of the experiment, and then carried out the simulated driving experiment in the set environment. During the single experiment, the subjects continued to drive until the end of the experiment, and the driving fatigue detection equipment continued to work after starting operation. When the participants were judged to be in a state of fatigue driving, a certain type of music was given for fatigue awakening. The awakening process lasted for 1 minute, and the previous sound environment was restored after 1 minute until the end of the experiment. After the experiment, the subjects conducted a subjective evaluation questionnaire survey again, and the subjects confirmed whether the data collection results were complete and accurate. Each participant conducted an experiment at most once a day and completed all experiments in the shortest possible time. The experimental scene is shown in Figure 4.

Figure 4: Experimental scene.

In the course of the experiment, the degree of driving fatigue should be determined immediately, and when the fatigue level is reached, the fatigue wake-up stimulus should be introduced immediately. However, due to the individual differences of each participant and the limitations of the actual operability of the laboratory, it is difficult to independently identify fatigue driving under the existing conditions. In other studies, drivers typically begin to feel tired after 30 minutes of continuous driving [2]. Therefore, in this paper, it is considered that the subjects have reached a certain degree of fatigue when performing more than 40 minutes of simulated driving, and the corresponding fatigue wake-up stimulation is

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introduced.

3. Experiment

3.1. Experiment Content

In order to study the influence of different emotional music on driving fatigue and the effect of introducing wake-up music stimulation on driving fatigue wake-up effect, the sound environment of the driver during driving is classified according to the experimental design, which is divided into two categories: single driving noise environment, driver 's autonomous playing sound and driving noise mixed environment. In the mixed environment, according to the existing music emotion classification method, two emotional types of music and driving noise are selected as the monotonous sound environment in the experiment. The subjects were simulated driving experiments in three monotonous environments. In a monotonous sound environment, when the subjects have driving fatigue, the subjects were given a wake-up stimulus for 1 min. After the stimulation stopped, the sound environment returned to the previous state, and the subjects continued the experiment until the end of this experiment. Through the determination of the data index of eye behavior characteristics, the influence of different emotional music on driving fatigue and the awakening effect are evaluated.

3.2. Sound Environment Setting and Music Material Selection

In the experiment, the driving noise environment alone was used as the control group variable, and the mixed sound environment of different emotional music and driving noise was used as the experimental group variable. Driving noise is determined by comprehensive factors such as vehicle structure, driving speed and driving road conditions. The driving sound in this experiment is emitted by the simulated bridge, and the sound loudness is controlled at 65 dB. The existing music emotion model can be divided into text keyword model and acoustic feature model. The former is to extract some keywords from the lyrics of music according to the weight as music emotion to establish the emotion model, which is represented by Hevner emotion model. The latter is based on the acoustic characteristics of music to express emotions and establish an emotional model, which is represented by the Thayer emotional model [4]. By using acoustic feature extraction and machine learning methods to connect the underlying acoustic features of music and the upper semantic emotion understanding, music can be better classified [5]. Most of the domestic music platforms classify music based on acoustic characteristics and then analyze the semantic and emotional analysis of lyrics. Therefore, this experiment first selects ' happy and emotionally high ' and ' sad and emotionally tense ' from the Netease cloud music song list. Yang elaborated in the study that different rhythms of music have different effects on the rate of driving fatigue [6], so the rhythm of alternative music is controlled at 110bpm (± 5bpm). Then the lyrics of the alternative music are analyzed by semantic emotion, and the ' positive emotion ' and ' negative emotion ' are divided according to the tendency of the text emotion, and the music that does not match the emotional type of the song list is removed (' happy and emotional ' matches with ' positive emotion ', ' sad and emotional ' matches with ' negative emotion '). The remaining music is used as the final music material library, and ' positive emotion ' and ' negative emotion ' are used as the emotional division of music. The total duration of each emotional type of music is not less than 200 minutes. Four songs were randomly selected from the two emotional types of music as fatigue wake-up music materials. The remaining music and driving noise were played at the same time as the background sound of simulated driving, and the background music was played randomly in disorder. Each fatigue wake-up stimulus music intercepted 60 s, out of order random play.

3.3. Experimental Design and Implementation

As mentioned above, 12 subjects were selected to participate in the experiment. Each subject was trained in equipment operation the day before the experiment. The experiment was conducted at 13: 00-18: 00 every day when people were prone to sleepiness [7]. Each subject needs to carry out 5 experiments, each experiment lasts about 60 minutes. Experiment 1 is a control group experiment with driving noise, no background music and blank sound stimulation. Experiment 2 ~ 5 is an experimental group experiment with driving noise, background music and fatigue wake-up stimulation. Before each experiment, the subjects filled in the ' subjective evaluation questionnaire before the experiment ', as shown in Table 1, and then breathed evenly for 5 minutes to stabilize the mood, and simulated the driving adaptation operation for 5 minutes to ensure that the eye movement equipment data collection work was

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normal.

Table 1: Pre-experimental subjective evaluation questionnaire.

Experiment number：							
1. Attention can not be concentrated	nil	0	1	2	3	4	critical
2. in a flutter	nil	0	1	2	3	4	critical
3. Want to sleep	nil	0	1	2	3	4	critical
4. dizziness	nil	0	1	2	3	4	critical
5. Physical fatigue	nil	0	1	2	3	4	critical
This column is filled in by the experimenter after the subject has completed the above							
Experimental date and time :							
Subject mental state :							

Table 2: Post-experimental subjective evaluation questionnaire.

1. Do you feel tired during the experiment	A.Yes B.No						
2. How long do you feel tired after driving	A.20min B.30min C.40min or more						
3. You think the emotional type of music you just heard is	A. Happy and emotional (positive emotional) BSad and emotional (negative emotional) C. Unclear						
4. Do you think fatigue has improved after music stimulation	A.Yes B.No C. Unclear						
5. aprosexia	nil	0	1	2	3	4	critical
6. in a flutter	nil	0	1	2	3	4	critical
7. Want to sleep	nil	0	1	2	3	4	critical
8. dizziness	nil	0	1	2	3	4	critical
9. Physical fatigue	nil	0	1	2	3	4	critical
This column is filled by the main test							
Experimental date and time:							
Subject mental state:							
Background music type: positive emotion music / negative emotion music							
Wake up music type: positive emotional music / negative emotional music							

The ' negative emotional ' music and driving noise were mixed as the background sound of Table 3, and the experimental process was carried out with reference to Table 2. Each subject needs to complete the background music and wake-up music combination of the four experimental group experiments. Each subject only completes one experiment a day. The specific content is randomly selected from the four experimental group experiments. Each participant had to complete all five experiments in a week.

Table 3: Experimental content.

	No music stimulation	Positive music stimulation	Negative music stimulation
No music background + driving noise	experiment1		
Positive music background + driving noise (experimental group 1)		experiment2	experiment 3
Negative Music Background + Driving Noise (Experiment 2)		experiment 4	experiment 5

3.4. Experimental Results and Data Analysis

3.4.1. Subjective Evaluation Questionnaire Results and Analysis

In order to make the experiment more complete, each participant conducted a subjective evaluation questionnaire survey before and after each experiment to determine the effect of sound background and wake-up stimulation. The results of the subjective evaluation questionnaire before the experiment showed that all the subjects were awake before the experiment, without dizziness, fatigue, and want to sleep.

Question 1 ' Do you feel fatigue during the experiment ' There were 58 people who felt fatigue, accounting for 96.7 %. In the experiment, regardless of whether the sound environment had background music, the subjects would feel fatigue, indicating that the introduction of background music during driving could not improve the fatigue caused by long-term driving, and people would still gradually develop fatigue. According to the experimental number of the statistical questionnaire, 2 people in the experimental group did not feel tired and appeared in the ' positive emotion ' background music experiment, accounting for 4.17 %; 36 people who felt tired thought that the sense of fatigue was the same as that of the control group without background music, accounting for 75.00 %. The remaining 10 people considered unclear, accounting for 20.83 %. The results showed that there was no significant difference in subjective fatigue after the experiment under different monotonous sound backgrounds. This result may be related to the different subjective measurement standards of fatigue for each subject, or it may be caused by the driver 's fatigue in a long-term monotonous sound environment.

Question 2 ' How long do you feel tired after driving ', 2 people felt tired at 20min, 47 people felt tired at 30min, and 81.66 % of them felt tired 30 minutes before simulated driving. It shows that the time point of fatigue is mostly within 30 minutes. In addition, because the subjects can not accurately know the time during the experiment, the accuracy of the subjects ' perception of time is also different. Therefore, it is considered that it is in line with objective reality to determine the subjects ' driving fatigue state when the experiment is carried out to 40 min.

Question 3 ' do you think the emotion type of music you just listened to is ', in the experiment group, 97.92 % of people can judge the emotion type of music they listened to during the experiment, and 1 person cannot make an accurate judgment on the music type; according to statistics, 4 people misjudged the emotional type of music, accounting for 8.33 %. In general, the accuracy of the participants ' judgment on the type of music emotion is 89.59 %. Therefore, it is believed that the music materials selected in the experiment basically meet the requirements of emotion classification.

Question 4 ' Do you think that fatigue has improved after music stimulation ', 37 people think that driving fatigue has improved after music stimulation, accounting for 77.08 %; 9 people thought that driving fatigue did not improve after music stimulation, accounting for 18.75 %; 2 people considered unclear, accounting for 4.17 %. The results show that the introduced fatigue wake-up music stimulation has a certain effect.

3.4.2. Experimental Data Collection and Analysis

A total of 60 experiments were conducted by 12 subjects, and the data of each experiment were processed. In order to ensure the validity of the experimental data, the data of the first 5 minutes after the start of the experiment was removed. Taking 5 min as the interval unit, the experimental data were segmented, the mean value of eye index data in each unit interval was calculated, the icon was drawn and the data were statistically analyzed.

(1) Analysis of pupil diameter variation coefficient under different monotonous sound background

Repeated measures analysis of variance was performed on the data of pupil diameter variation coefficient in the first 40 min of the experimental group and the control group. The results showed that the spherical test $P = 0.093 > 0.05$ met the spherical distribution hypothesis, and the main effect test results $F(2, 14) = 12.106$, $p = 0.001 < 0.05$. Therefore, there were significant statistical differences between the two experimental groups and the control group. The paired sample T test was performed on the pupil diameter variation coefficient data of the experimental group and the control group. The results showed that: 1) experimental group 1 and control group ($t = -4.074$, $p = 0.005 < 0.05$); 2) Experimental group 2 and control group ($t = -2.368$, $p = 0.055 > 0.05$); 3) experimental group 1 and experimental group 2 ($t = -2.992$, $p = 0.020 < 0.05$).

The mean value of pupil diameter variation coefficient in each unit interval within 40 min was calculated, and the variation map of pupil diameter variation coefficient in the first 40 min was drawn, as shown in Figure 5.

As can be seen from the figure, the control group relative to the experimental group pupil diameter variation coefficient level range in a higher position, the experimental group 1 at a relatively low level. In the three groups of data level starting point close to the case, the experimental group 1 within 15 min a slight downward trend, while the control group and experimental group 2 showed an upward trend. At 15 min, the pupil diameter variation coefficient level of the control group and the experimental group 2 showed a significant growth trend, and the growth trend of the control group tended to be stable and the growth rate gradually slowed down. The experimental group 2 showed a rapid growth trend at 25 min after the growth rate slowed down at 20 min, and the pupil diameter variation coefficient level tended to

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be stable after 30 min. The growth trend of experimental group 1 after 20 min was similar to that of the control group, but it was relatively low, and the level of pupil diameter variation coefficient tended to be stable after 35 min.

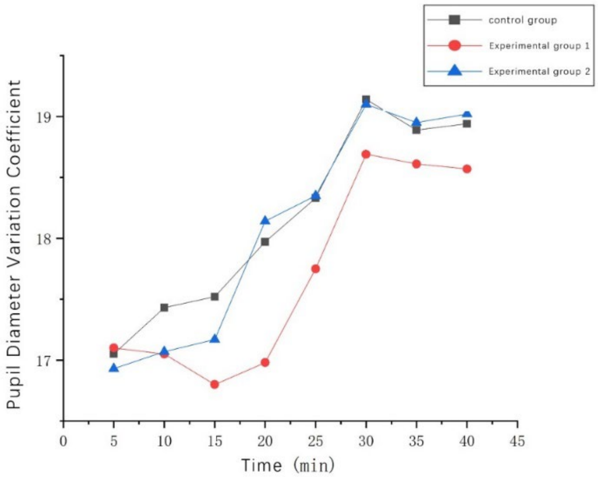

Figure 5: Changes of PDVC in the first 40 min.

Paired sample T test was performed on the pupil diameter variation coefficient data within 20 min ~ 40 min and 40 min ~ 60 min in experiment 2 ~ 5. The results showed that: 1) experiment 1 (t = -0.877, p = 0.04 < 0.05); 2) experiment 2 (t = 2.032, p = 0.049 < 0.05); 3) Experiment 3 (t = -0.427, p = 0.672 > 0.05); 4) Experiment 4 (t = 2.569, p = 0.0140.05). Draw the coefficient of variation of pupil diameter before and after arousal stimulation changes are shown in Figure 6.

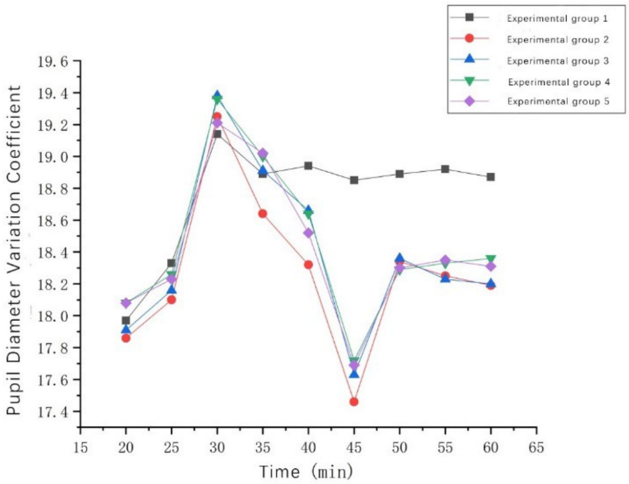

Figure 6: Changes of PDVC before and after arousal stimulation.

According to the results of the experimental data processing and the performance of the indicators in the figure, the average value of the pupil diameter variation coefficient of the subjects before and after the introduction of the stimulus at the 40 th minute of the experiment in Experiment 2 (that is, the introduction of positive music wake-up stimulus in the positive music background) and Experiment 4 (that is, the introduction of positive music wake-up stimulus in the negative music background) has significant statistical difference; there was no significant statistical difference in the average value of pupil diameter variation coefficient before and after the introduction of stimulation at the 40 th minute of the experiment in experiment 3 (that is, the introduction of negative music arousal stimulation under the background of positive music) and experiment 5 (that is, the introduction of negative music arousal stimulation under the background of negative music). At the same time, compared with Experiment 4, the mean value of pupil diameter variation coefficient in Experiment 4 (p = 0.014) was more significant than that in Experiment 2 (p = 0.049) before and after the introduction of arousal stimulation.

(2) Average blink rate

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Repeated measures analysis of variance was performed on the average blink rate data of the experimental group and the control group in the first 40 min. The results showed that the spherical test p = 0.130 > 0.05, which satisfied the spherical distribution hypothesis, and the main effect test result was F (2, 14) = 11.050, p = 0.001 < 0.05. Therefore, there were significant statistical differences between the two experimental groups and the control group. Then the average blink rate data of the experimental group and the control group were tested by paired sample T test. The results showed that: 1) experimental group 1 and control group (t = 3.130, p = 0.017 < 0.05); 2) Experimental group 2 and control group (t = -0.146, p = 0.888 > 0.05); 3) experimental group 1 and experimental group 2 (t = 6.416, p = 0.000 < 0.05).

The average blink rate of each unit interval in the first 40 minutes was calculated, and the average blink rate change chart of 40 minutes before the experiment was drawn, as shown in Figure 7.

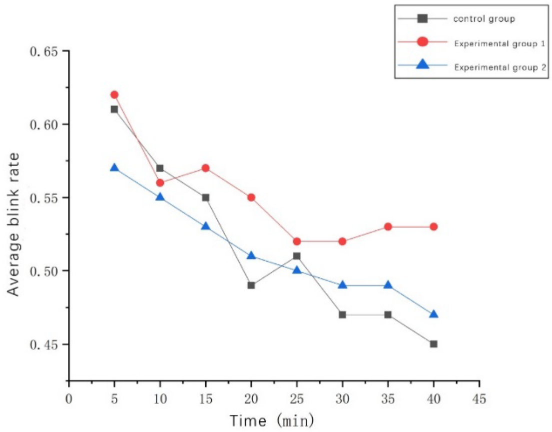

Figure 7: Changes of BRPS in the first 40 min.

The average blink rate data of 20min ~ 40min interval and 40min ~ 60min interval in experiment 2 ~ 5 were tested by paired sample T test. The results showed that: 1) Experiment 1 (t = 1.532, p = 0.041 < 0.05); 2) experiment 2 (t = -0.632, p = 0.035 < 0.05); 3) Experiment 3 (t = 0.388, p = 0.700 > 0.05); 4) Experiment 4 (t = -1.725, p = 0.0090.05). The changes of average blink rate before and after arousal stimulation were drawn as shown in Figure 8.

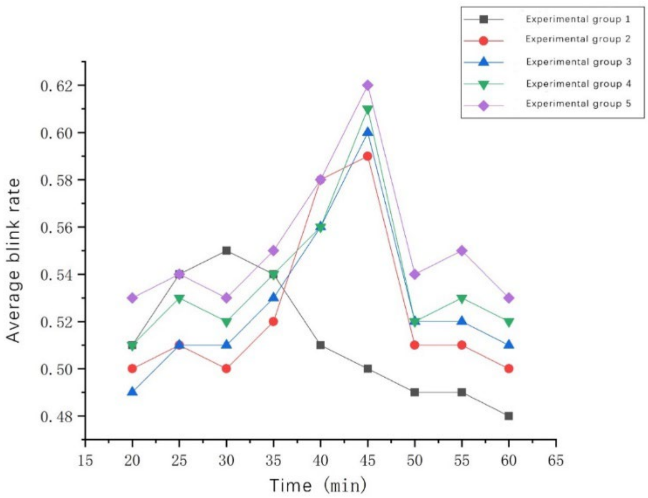

Figure 8: Changes of BRPS before and after arousal stimulation.

The average blink rate showed similar characteristics to the coefficient of variation of pupil diameter. In the first 40 min data comparison, the average blink rate of experimental group 1 was higher than the other three groups. The trend of the experimental group 2 was similar to that of the control group. The average blink rate decreased significantly within 40 minutes, and the control group decreased the most.

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4. Conclusions

Combined with the subjective evaluation questionnaire and the comparative analysis of experimental data, the subjects were in a state of fatigue after the experiment. This shows that the introduction of background music with different emotions in the driving process can not effectively improve the driving fatigue caused by long-term driving, and the driver will still accumulate fatigue. But in the data comparison, it can be found that the fatigue depth of the subjects in the positive music background is lighter than that in the negative music background and no background music, and there is no significant difference between the fatigue degree of the subjects in the negative music background and no music background.

In the comparison results before and after the introduction of music arousal stimulation, the fatigue state of the subjects was greatly improved, which was also consistent with the results of the subjective evaluation questionnaire, indicating that the introduction of music stimulation after driving fatigue could awaken the driver. Among them, whether the subjects are in a positive music background or a negative music background, the introduction of positive music as a fatigue wake-up stimulus, the fatigue degree of the subjects has been significantly improved; when negative music was introduced as fatigue arousal stimulation, there was no significant difference before and after stimulation. It shows that the introduction of positive emotional music can be used as a wake-up strategy for driving fatigue during driving. When introducing positive music as a fatigue wake-up stimulus, the effect of positive music as a driving sound background is better than that in a negative music background. There may be two reasons for this difference: First, when positive music is used as the driving background sound, the driver 's fatigue depth is shallower than when negative music is used as the driving background sound, so when fatigue arousal stimulation is introduced, it performs better in positive music background sound; secondly, the rhythm of positive music is more cheerful, and the content is easy to cause the driver to be excited, so as to obtain mental improvement and fatigue relief, while the rhythm of negative music is more soothing and the content is more depressed, so it is not easy to stimulate the driver, so as to relieve fatigue.

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