RESEARCH ON USER EXPERIENCE OF STEREO PARKING EQUIPMENT BASED ON BEHAVIORAL EXPERIMENT AND EEG TECHNOLOGY

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Introduction. Mechanical parking equipment has become a solution to the problem of difficult urban parking, but in the process of use, many problems of poor user experience have been revealed, so the optimal design of user experience of the parking equipment has become particularly important. In the design of stereoscopic parking equipment, the driver, as one of the key users who interact with the stereoscopic parking equipment, is an important basis for the optimal design of the stereoscopic parking equipment. This paper analyzes the relationship between product features and user experience with the help of VR technology and EEG analysis technology, improves the comprehensiveness and scientificity of the optimized design of the three-dimensional parking equipment, and provides a theoretical basis for the design optimization of large mechanical equipment.

Research method. In the research field of user experience and human-computer interaction, user behavior analysis is the main research tool, among which the behavior experiment method is the common research method. Currently, the combination of this method with other cutting-edge technical methods and research tools has become a new trend, such as VR technology and EEG technology. VR virtual reality technology provides user-environment interaction by establishing a virtual information environment, which can provide new practical techniques for user experience evaluation and enhance the scientific and rational nature of the product optimization process [1-7]. EEG technology, as a more mature physiological research technology, provides data support for objective research on user behavior experience and assists in the development and optimization of product design [8-12].

3.Research process

3.1 Subjects

Referring to the principles of ERP subject selection by the International Physiological Society, a total of 40 subjects were selected for this experiment, 20 of each sex, no color blindness or color weakness, good psychological condition, intelligence, memory and physical condition, age range of 20 to 25 years old, and education level of bachelor or above. To ensure that the driving data had reference value, 14 of the subjects had more than 2 years of driving experience, 18 had 1~2 years of driving experience, and 8 had no driving experience.

3.2 Experimental equipment

The experimental apparatus for the immersive virtual experience part of the behavioral experiment was DeePoon Dapeng VR glasses (Figure 3.1). The experiments for the EEG experiment used the eego™mylab fully mobile EEG recording and analysis system developed by Shanghai Xinyi Technology, as shown in Figure 3.2.

Figure 3.1 Behavioral experiment VR equipment

Figure 3.2 EEG experiment acquisition equipment

3.3 Behavioral experiment study

The VR technology was used to establish a sample of double-decker stereo parking equipment for behavioral experiments based on variations of three design factors: light intensity, aspect ratio, and number of spatial arrangement combinations. Subjects were evaluated through an immersive virtual interaction scene.

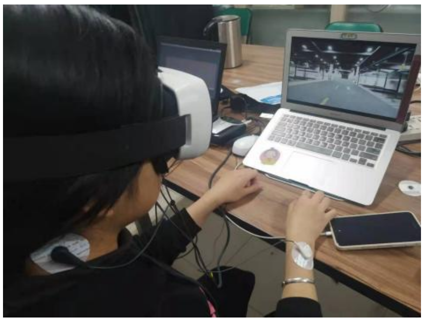

Figure 3.3 Behavioral experiment site diagram

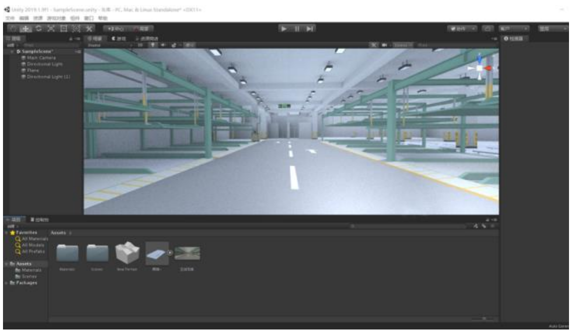

Figure 3.4 VR animation interface diagram

The data of the control group and the standard group were compared two-by-two by the Likert seven-level scale method between groups to study the cognitive differences and experience differences of users under the influence of different design features. Data analysis was conducted using SPSS multi-factor variance method to explore the relationship between the above three design factors and users' psychological perceptions.

According to the user behavior analysis, the light intensity, aspect ratio and the number of spatial combinations of the three-dimensional parking equipment will significantly affect the user's psychological perception, with the number of spatial combinations having a stronger impact. In order to further clarify the relationship between the above design factors and the user's psychological perception and physiological response, based on this, the quantitative measurement and analysis were conducted by EEG experiment.

3.4 EEG experimental design and analysis

The EEG experimental samples were subdivided into two parts: aspect ratio and height, and four groups of samples were designed based on the N400 experimental paradigm by combining the light intensity and the number of spatial permutations.

3.4.1 Experimental procedure

The EEG experiment is mainly divided into two parts: pre-recording and formal recording, and the experimental site diagram is shown in Figure 3.5.

(1) Pre-recording of EEG experiment

The subject wears 64 conductive polar caps for testing. Before the formal start of the experiment, it is necessary to record whether the basic waveform of EEG is normal and whether the EEG baseline is smooth; at the same time, the subject is allowed to perform eye movements to observe the effect of eye movements on EEG, etc.

(2) Formal recording of EEG experiments

During the formal experiment, in order to avoid EMG interference and relieve subjects' tension, a comfortable body position was used to reduce the effects of artifacts and signal-to-noise ratio on ERP signals. The subjects were asked to watch four groups of stimulus samples(Figure 3.7) displayed on the computer screen, and the display flow and time interval of the stimulus samples are shown in Figure 3.6. After each group of stimulus samples, the EEG device would automatically record the EEG data during the user's experience.

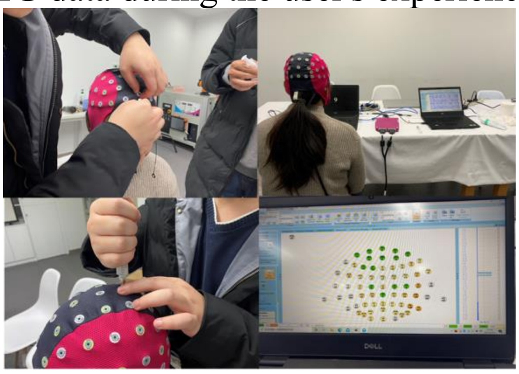

Figure 3.5 Experimental site diagram

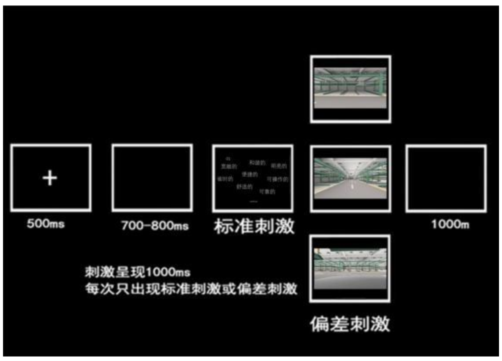

Figure 3.6 Example of stimulation format

3.4.2 EEG experimental data processing

The EEG signals collected from 40 subjects while watching the sample were exported, and the ASA4.10 software was applied to de-eye and noise cancel the raw data signals to reduce the amplitude range to between -100~100μV to improve the usability of the data （ (Figure 3.8）. Then waveform identification and statistical analysis were performed. According to the statistical results of the mean p-value of the variability of the sample EEG N400 changes in each site, it can be seen that the frontal part caused more significant N400 amplitudes than the other sites ($p=0.0035<0.01$). According to the EEG energy distribution statistics, it can be obtained that the regions with higher EEG energy were mainly concentrated in the 18 electrode locations, among which the N400 amplitude caused in the forehead part (FP1, FPz, FP2) and frontal part (F3, Fz, F4) ($p<0.01$) was more significant than the other parts. In the 3D EEG distribution topography (Figure 3.9), it can be seen that the active part of the brain marked in red and the peak electrical potential of N400 were mainly distributed in the forehead, frontal and lateral frontal regions.

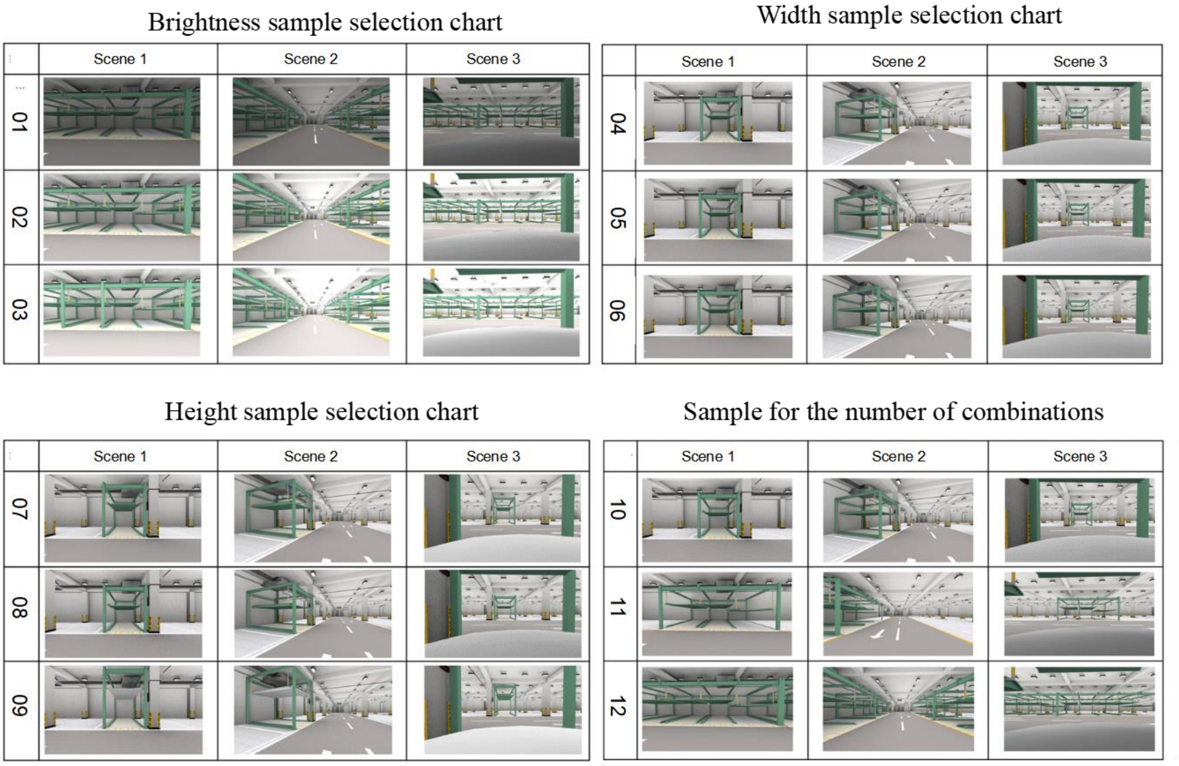

Figure 3.7 Four groups of stimulus samples

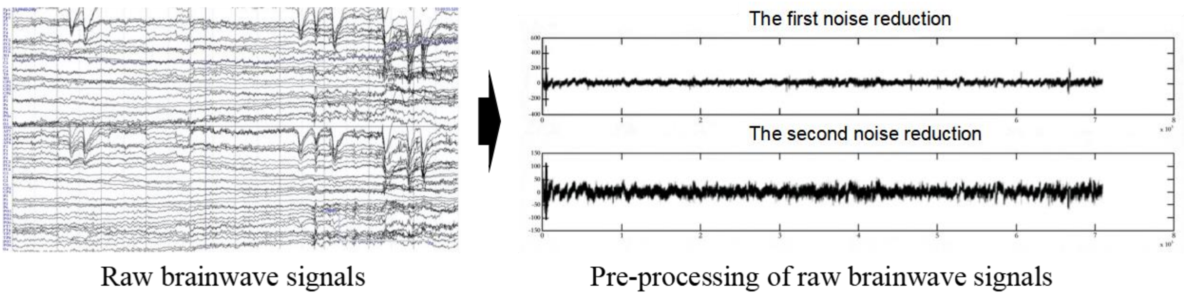

Figure 3.8Brainwave signal processing

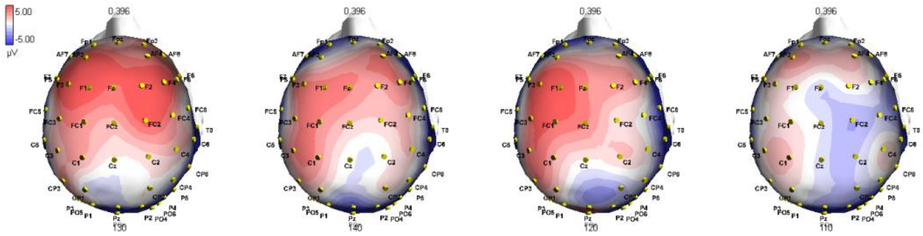

Figure 3.9 Topographical map of EEG distribution in subjects

3.4.3 Analysis of EEG experiment results

The EEG N400 changes in the prefrontal and frontal regions of the six electrodes between -200 and 800 ms in four sample groups were extracted in turn, and the ERP average waveforms were plotted for analysis.

(1)Light intensity sample group

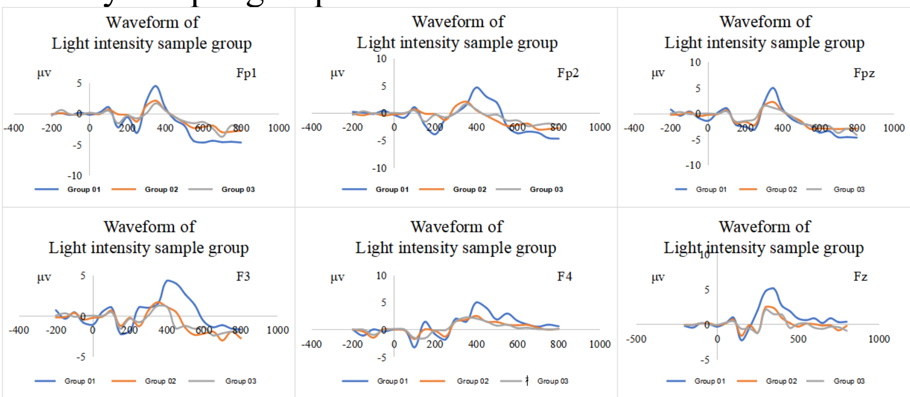

Figure 3.10 Mean EEG waveform map of the light intensity sample

According to Figure 3.10, there is a clear major effect of electrode sites in the time interval of 300-500 ms, reflecting the N400 component changes.Compared to the standard stimuli associated with positive adjective vocabulary, sample group 01 with light intensity value of 20 lx changed significantly, and sample groups 02 and 03 changed close to each other with light intensity values of 60 lx and 100 lx, respectively. it can be obtained that darkness values significantly affect perception and attention, with darker producing more significant cognitive effects on the user's, while samples with medium and high light intensity values resulted in little difference in mental perception.

(2)Aspect Ratio Sample Group

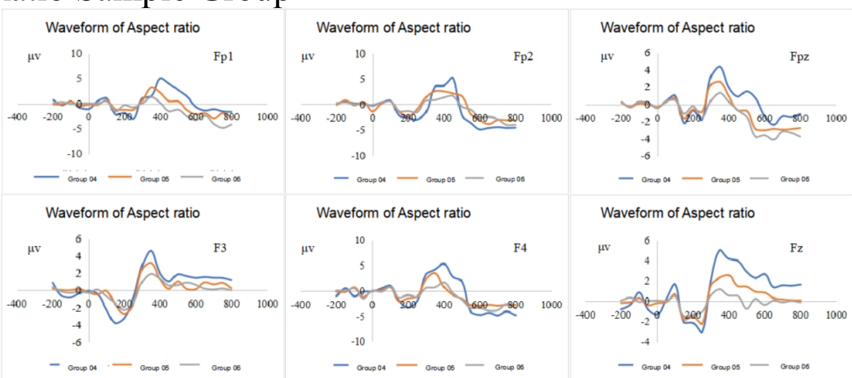

Figure 3.11 EEG amplitude maps for the aspect ratio samples

The results in Figure 3.11 show that there is a clear primary effect of electrode sites in the time interval of 300-500 ms, reflecting the change in N400 components. Compared to the standard stimuli associated with the positive adjective vocabulary, the most significant changes were observed in sample group 04 with a width value of 2500 mm, and the amplitude changes were diminished in order for sample group 05 with a width value of 2600 mm and sample group 06 with a width value of 2700 mm. This indicates that the aspect ratio significantly affects perception and attention, producing significant cognitive effects as the ratio decreases.

（3）Height ratio sample group

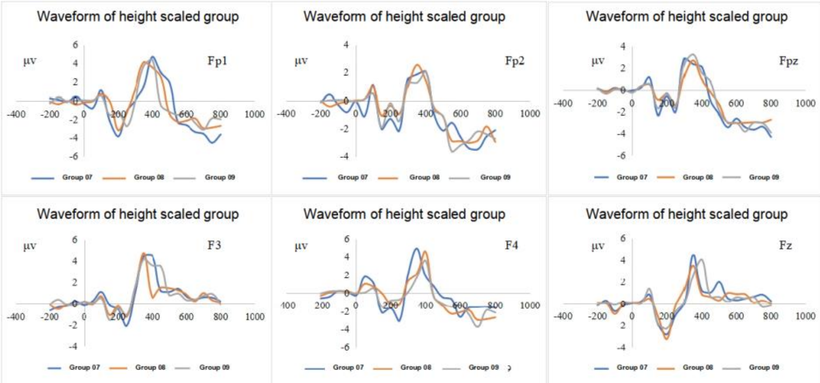

Figure 3.12 EEG amplitude map of height sample

According to Figure 3.12, there is a clear major effect of electrode sites in the time interval of 300-500 ms, reflecting the change in N400 component.Compared to the standard stimuli associated with the positive adjective vocabulary, there is little difference in the changes between the three groups of sample group 07 with a height value of 2750mm, sample group 08 with a height value of 2500mm and sample group 09 with a height value of 3000mm. It can be obtained that the effect of height value on perception and attention is not significant within the normal threshold.

(4)Spatial arrangement number sample group

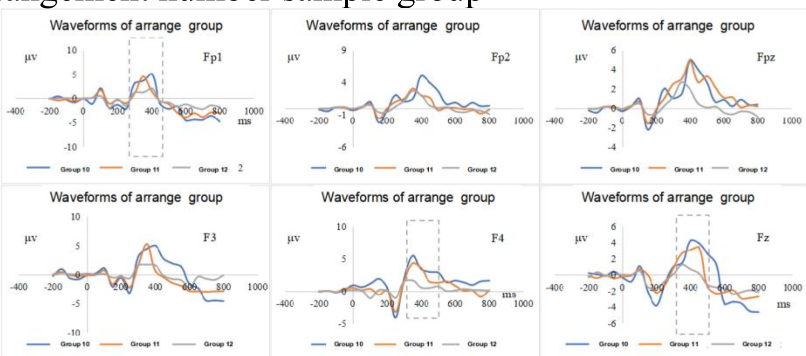

Figure 3.13 EEG wave amplitude map of the sample group of arrangement

The results in Figure 3.13 show that there is a clear predominant effect of electrode sites in the time interval of 300-500 ms, reflecting changes in the N400 component.Compared to the standard stimuli associated with the positive adjective vocabulary, the weakest changes were observed in sample group 012 with the number of arrangements of two rows of multiple, and the changes in N400 components were closer to those in sample group 010 with the number of arrangements of one and sample group 011 with the number of arrangements of three, diminishing in that order. This indicates that within the normal threshold, the number of arrangements greater than two rows has a more significant effect on perception and attention; while a smaller number of arrangements (less than three) does not have a significant effect on perception.

Conclusion. In order to study the interrelationship between user experience and three-dimensional parking equipment, the experimental sample was designed by using VR technology, and the sample values were set with reference to Chinese industry standards. By combining behavioral and EEG experiments, it was concluded that the light intensity, aspect ratio and the number of spatial arrangement combinations of three-dimensional parking equipment significantly affect users' mental perception. The darker the light intensity is, the more significant the cognitive impact on the user; the aspect ratio is the main significant factor, and the smaller the aspect ratio is, the more significant the cognitive impact; the number of spatial arrangements is mainly in the case of the number of rows larger than two, which significantly affects the user's cognition.

The relationship model between light intensity, aspect ratio and number of spatial arrangements and user parking experience constructed in this paper is a new research method in the field of practical three-dimensional parking equipment optimization, which quantifies the relationship between the above design factors and users' psychological and physiological perceptions, and effectively reflects the changes of user experience in the actual parking process. Based on the concept of "people-oriented" sustainable design, it enhances the functions and social values generated by the three-dimensional parking equipment and provides a new and effective direction to solve the urban parking problem. However, this study is only a sample setting and experimental study of some product features, and the accuracy of the experimental study needs to be further improved due to the influence of other design features, actual standards of each country, and the ethnicity and number of subjects.

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