

# Travel Behavior Analysis and Personalized Interaction Design of the Elderly Based on EEG Feedback

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**Abstract:** The study deeply analyzes the travel behavior of the elderly by integrating EEG feedback technology, and designs a personalized interactive interface for smart phones to improve the travel safety and quality of life of the elderly. Firstly, the EEG signals of the elderly over 60 years old in simulated and real travel scenes were collected by portable wireless EEG equipment, and the internal mechanism of the travel behavior of the elderly was revealed by combining behavioral and cognitive data, correlation analysis, cluster analysis and hidden Markov model. Based on this, the design principles of cognitive adaptation, dynamic feedback and security redundancy are put forward, and a prototype of personalized interactive interface integrating EEG feedback is developed. The experimental results show that the design significantly reduces the cognitive load and anxiety level of the elderly, and improves the task completion efficiency and user satisfaction. The research results provide a new theoretical basis and technical support for aging-resistant interactive design.

**Keywords:** EEG feedback; Travel behavior analysis; Personalized interaction design; Elderly.

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## 1. Introduction

In the process of traveling, the elderly often face many difficulties and risks due to the decline of physical function and cognitive ability [1]. At the same time, with the progress of science and technology, EEG feedback technology, as a new biofeedback technology, provides new possibilities for in-depth analysis and understanding of human behavior because it can objectively and real-time reflect the activity state of the brain.

Today, with the popularity of smart phones, personalized interaction design has become an important means to enhance the user experience. However, most of the mobile phone applications on the market are designed for young people, and the special needs of the elderly are rarely considered. When the elderly use mobile phones, they often feel confused and inconvenient because of the complicated interface and cumbersome operation [2-3]. Therefore, how to design a personalized interactive interface that meets the cognitive characteristics of the elderly in combination with their travel behavior characteristics has become an urgent problem to be solved.

Through the integration of EEG feedback technology, we can deeply understand the brain activity state of the elderly in the process of traveling and reveal the internal mechanism of their travel behavior. It provides a new perspective and method for the analysis of the travel behavior of the elderly, and enriches and develops the theoretical system of the research on the behavior of the elderly. The travel behavior analysis of the elderly based on EEG feedback can provide scientific basis for the travel safety and health of the elderly and guide the formulation and implementation of relevant policies. By designing a personalized interactive interface for mobile phones, we can meet the special needs of the elderly in the travel process and improve their travel experience and quality of life. Promote the popularization of smart phone applications among the elderly, promote the integration of technology and the elderly, and make technology better serve

the elderly. This topic combines EEG feedback technology to deeply analyze the travel behavior of the elderly, and on this basis, designs a personalized interactive interface for mobile phones to meet the special needs of the elderly and improve their travel safety and quality of life.

## 2. Analysis of Travel Behavior of The Elderly with EEG Feedback

### 2.1. Data acquisition and preprocessing

The EEG signals of healthy elderly people over 60 years old were collected by portable wireless EEG device Emotiv EPOC+. Experiments were conducted in simulated and real travel scenes, including indoor navigation, virtual crossing the road, community walking and public transportation, and the characteristics of brain activity under different tasks were evaluated [4-5]. The background balance of participants takes into account factors such as gender, education level and travel frequency, and the experimental design includes many tasks such as route planning and sudden interference response.

The study also collected behavioral and cognitive data to fully understand the needs and pain points of elderly users. The cognitive function was evaluated by standardized scales such as MMSE, and the usability of existing apps was evaluated by SUS, and the travel habits and technical acceptance were investigated by self-made questionnaires. Conduct semi-structured in-depth interviews with typical users, including high-frequency travelers and people who have encountered travel risks, and extract key behavior patterns and needs from them.

For EEG data, the EEGLab toolkit is used to denoise and filter, and the time domain and frequency domain features are extracted. For the behavior data, NVivo software is used to encode the topic, identify high-frequency keywords and establish a demand-behavior mapping table, so as to deeply understand the challenges and needs faced by the elderly when using intelligent travel services.

## 2.2. Modeling and analysis of travel behavior

Through Pearson correlation analysis and multiple linear regression, this paper discusses the correlation between EEG characteristics and behavioral indicators, such as the relationship between the enhancement of  $\theta$  wave activity in frontal lobe and cognitive load and decision delay. K-means cluster analysis is used to divide users into different types, such as "high anxiety type" and "low adaptability", so as to reveal the significant differences between different groups and their travel behavior characteristics.

In order to further understand the dynamic behavior of users, a hidden Markov model is constructed in this study, which combines real-time EEG data to predict the specific state of users, including distraction and spatial disorientation, and accordingly evaluates the risk level as low, medium or high risk.

## 3. Personalized Interactive Design Method

### 3.1. Design philosophy

Improve the convenience and safety of the elderly using smart devices through various methods. The design principles include cognitive adaptation, optimizing the size and contrast of interface elements according to Fitts law, and adopting easy-to-identify icons and voice guidance (Figure 1); The dynamic feedback mechanism uses real-time EEG data to adjust the interface complexity to adapt to the user's state, and simplifies the interface to reduce anxiety when  $\alpha$  wave suppression is detected [6]; Security redundancy measures involve setting a "one-click help" button to ensure that assistance can be obtained quickly in an emergency.

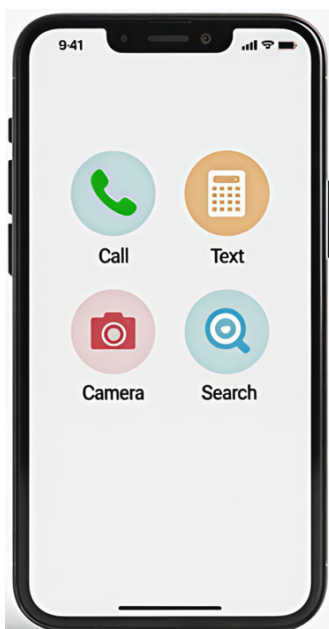


Figure 1. Interactive design of icon and voice guidance

### 3.2. Prototype development

In the prototype development stage, the information architecture is simplified and approachable, and the core functions are arranged in a flat structure with no more than three layers, and are directly displayed on the home page for easy access [7-8]. At the same time, the lightweight API interface is integrated to embed the EEG analysis model into

the application to realize the functions of fatigue warning and personalized route recommendation. The mixed operation mode of voice and gesture is designed, which reduces the requirement of touch accuracy and makes the interaction process smoother and more natural, especially suitable for the needs of elderly users (Figure 2).



Figure 2. Design of mixed operation mode of voice and gesture

## 4. Experimental Verification and Effect Evaluation

### 4.1. Experimental design

#### 4.1.1. Participant grouping

The experiment included 20 people in the experimental group and 20 people in the control group. The experimental group uses a personalized interactive interface (enhanced version of APP) that integrates EEG feedback, while the control group uses a conventional aging interface, which has no EEG feedback function and only provides basic navigation function. In order to ensure the validity of the experiment, the two groups of participants matched in age, gender, experience in using smart phones and MMSE cognitive score.

#### 4.1.2. Test task

Simulate four typical travel scenarios, and record behavior and EEG data:

Scenario 1 Route Planning: Navigate from the supermarket to the community hospital. The path complexity is moderate.

Scenario 2 Sudden interference: The original route is closed and needs to be re-planned.

Scenario 3 Emergency Help: Simulate the falling scene and trigger the one-button help function.

Scenario 4 Multitasking: Query real-time bus information while walking.

#### 4.1.3. Data acquisition tool

Behavioral indicators focus on task completion time, number of erroneous operations, and success rate of help requests; physiological indicators concentrate on prefrontal  $\theta$ -wave power (reflecting cognitive load) and parietal  $\alpha$ -wave suppression (indicating anxiety levels). Subjective evaluations are obtained through the System Usability Scale (SUS) and NASA-TLX cognitive load scores to comprehensively assess the system's user-friendliness and cognitive burden.

## 4.2. Experimental result

The experimental group was significantly superior to the

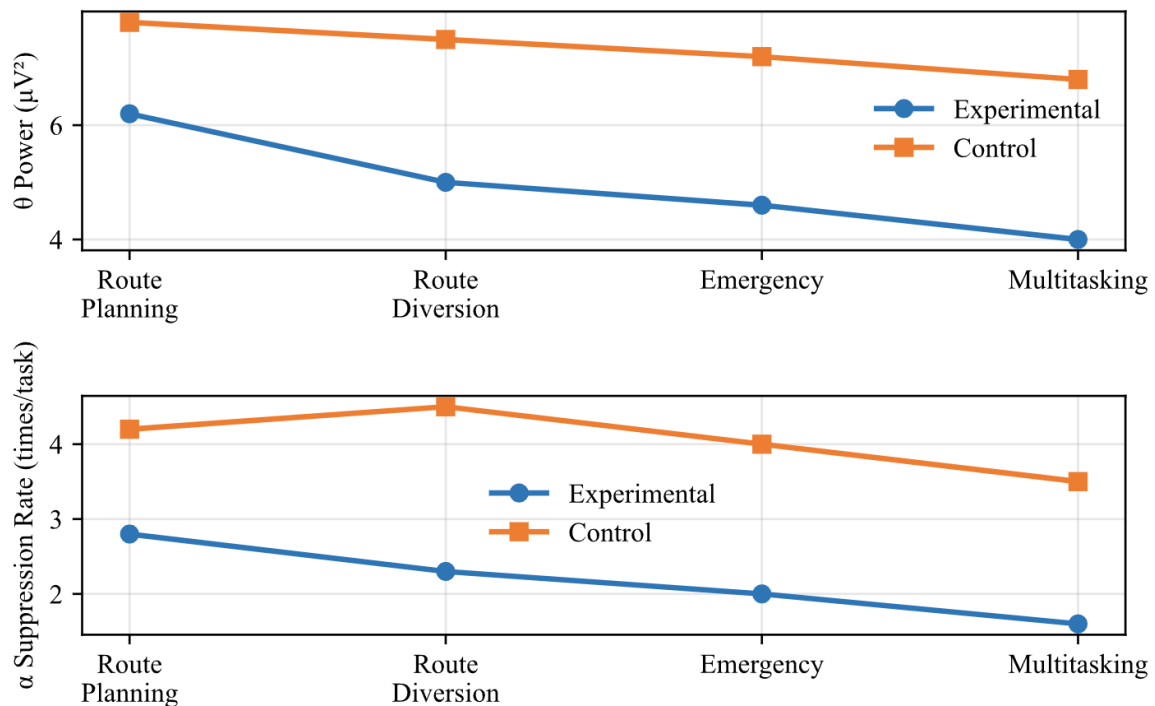
control group in task completion time and error rate ( $p < 0.05$ ). See Table 1.

**Table 1.** Behavior efficiency improvement

index	Experimental group (mean $\pm$ SD)	Control group (mean $\pm$ SD)	P value
Route planning time (s)	58.3 $\pm$ 12.1	89.7 $\pm$ 18.4	0.003*
Number of wrong operations	1.2 $\pm$ 0.8	3.5 $\pm$ 1.6	0.001*
Help trigger success rate	95%	70%	0.021*

The experimental group effectively reduced cognitive load and anxiety level through EEG feedback mechanism (Fig. 3). Compared with the control group, the average  $\theta$  wave power (reflecting cognitive load) of the experimental group was 4.8  $\mu V^2$ , significantly lower than 7.1  $\mu V^2$  of the control group, with a decrease of 32% ( $p = 0.008^*$ ). The times of  $\alpha$  wave

inhibition caused by anxiety in the experimental group were also significantly reduced, with an average of 2.1 times/task, which was 45% less than 3.8 times/task in the control group ( $P = 0.013^*$ ), indicating that the mechanism has a significant effect in reducing the psychological burden of users.



**Figure 3.** Dynamic change trend of two groups of  $\theta/\alpha$  waves

Users in the experimental group are significantly more

satisfied with interaction design, as shown in Table 2.

**Table 2.** Subjective evaluation results

Evaluation dimension	Experimental group (SUS score)	Control group (SUS score)	Cohen's d
Interface ease of use	82.5 $\pm$ 6.3	63.2 $\pm$ 9.7	1.21 (big effect)
Functional practicability	88.0 $\pm$ 5.1	71.4 $\pm$ 8.2	1.56 (large effect)
sense of security	90.5 $\pm$ 4.8	68.7 $\pm$ 10.1	1.89 (big effect)

Through interviews, users' high-frequency demands for the system and suggestions for improvement are extracted. Among them, the positive feedback includes simple and clear interface design, intimate voice prompts and the help button is very practical in an emergency. Users also put forward some suggestions for improvement, such as increasing the font size to improve readability, improving the route accuracy in rainy mode, and improving the comfort of EEG equipment for a long time.

## 4.3. Discussion

The performance advantages of the experimental group, such as the success rate of help-seeking reaching 95%, prove

that the dynamic interface adjustment driven by EEG feedback can effectively reduce the cognitive load of users. Users gave a high score (SUS=90.5) on the function of "one-click help", which not only confirmed the effectiveness of this function in providing help in an emergency, but also emphasized the importance of safety redundancy design.

However, the research has some limitations. First of all, some users (25%) reported that the EEG equipment felt oppressive when wearing, which affected the comfort of the experience; Secondly, the experimental scenes mainly focus on the community environment, failing to cover more complicated actual situations such as extreme weather or strange cities. In order to improve these problems, the future

research direction includes developing more comfortable flexible electrodes and wireless lightweight EEG devices, and introducing multi-modal sensors, such as heart rate and gait monitoring, to improve the accuracy and reliability of state monitoring.

## 5. Conclusion

Personalized interactive design based on EEG feedback is significantly superior to traditional aging design in many aspects. In the experimental group, when using the APP with integrated EEG feedback, the task completion time was significantly shortened, the number of wrong operations was reduced, and the success rate of help-seeking trigger was significantly improved. The EEG feedback mechanism effectively reduces the cognitive load and anxiety level of users, and improves the subjective evaluation of the system's usability, functional practicability and security. The experimental group performed better than the control group in route planning, sudden interference, emergency help and multitasking. Especially in the emergency help-seeking scene, the success rate of the experimental group reached 95%, which was much higher than that of the control group (70%). This shows that the "one-click help" function can provide effective help in an emergency, highlighting the importance of safety redundancy design. However, the study also found some limitations, such as some users feedback the oppressive feeling when wearing EEG devices and the limitations of experimental scenes. Future research should focus on developing more comfortable EEG equipment and introducing multi-modal sensors to improve the accuracy and

reliability of state monitoring.

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