Analysis of Electroencephalograms of Children with ASD During the Driving Game

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Abstract: Autism spectrum disorder (ASD) is a neurodevelopmental disorder. Its core symptoms are social communication and communication disorder, narrow interest, stereotyped behavior and cognitive impairment. The ASD people also shows atypical characteristics in non-social information processing. These defects are serious to weaken their social adaptability. Driving is a complex and simple independent adaptive skill, involving not only multiple task operations at the same time, but also attention, automatic motor execution, memory and navigation of cognitive functions. At present, the researches focus more and more on the driving behavior for individuals with autism in order to explore the feasibility of intervention treatment. The aim of this paper is to use a virtual driving test to investigate electroencephalogram (EEG) characteristics of the children with autism during complex environments. Since it is easy for EEG records to contain significant motion artifacts and electrode artifacts, an acquisition method with the wired and wireless transmission is used to collect EEG. This paper applies the power spectrum method to analyse the recorded EEG. It is found that the recorded EEG can reflect the brain dynamical activity of subjects during driving. The results indicate that this acquisition method can be used to record the EEG during driving for the brain analysis of autism. This study provides insights for the further research on the mechanism of autism and its diagnosis, evaluation and intervention.

1 INTRODUCTION

The research on driving behavior of people with autism can be traced back to the late 1970s. In early studies, the questionnaires for investigation found that traffic accidents more likely increased for individuals with attention deficit hyperactivity disorder during driving. In recent years, the research on driving behavior of autistic people has gradually increased. Sheppard et al. (2010) found that young autistic individuals lack the ability to identify obvious driving risks when watching driving video clips, comparing with healthy individuals (Sheppard et al., 2010). It is a great challenge for autistic individuals to learn driving, especially dealing with multitasking in driving. However, autistic children can do well in simple situations (such as speed control and keeping driving) (Cox et al. 2012). For high functional autistic adolescents, 12% of them received driving tickets or involved in vehicle collisions. The percentage was lower than that of ordinary adolescents. And there are no differences in driving status or driving behavior in terms of gender, type of autism, parental age or education or access to public transport (Huang et al. 2012). Lindsay et al. (2016) pointed out that it is very necessary to train the driving skills of autistic people as well as develop the suitable transportation for people with autism (Lindsay, 2017). However, it is difficult to carry out the real driving experimental researches for autistic individuals, due to a lot of potential safety hazards in the real driving environment.

With the development of science and technology, virtual driving environments provide convenience for people with autism (Wade et al. 2016). And many autistic teenagers prefer to interact with machines, such as robots and video games in virtual reality environment, rather than people (Tanaka et al. 2010; Zheng et al. 2014). The virtual driving games may be more conducive to train the adaptive independence of

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autistic individuals. Monahan et al. (2013) used the driving simulation system with the real vehicle operation to evaluate and analyse the behaviors individuals with attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) under the guidance of occupational therapists. It was found that ADHD / ASD adolescents made more mistakes in keeping the direction, visual sense, acceleration during driving than healthy subjects (Monahan et al. 2013). Classen et al. used professional driving rehabilitation experts to comprehensively evaluate the simulated driving of 7 autistic individuals and 22 healthy controls. The study found that young autistic people performed worse in driving skills or related driving skills (such as cognition, visual motor integration, motor coordination, speed regulation, road maintenance notices or signs) (Classen et al. 2013). Cox et al. reported the simulation driving performance research of novice drivers with autism. But on the whole, their driving ability is lower than that of healthy subjects (Cox et al. 2016). Reimer et al. (2013) used the driving simulation system to conduct a comparative study between young people with high-functioning autism and normal people. For individuals with high functioning autism, the gaze of them was higher in the vertical direction and a little right in the horizontal dimension. However, they did not find a significant difference in driving performance between the two groups, except gaze states. The authors thought that the gaze deflection of the young people with high functioning autism may be a dangerous driving behavior in actual driving (Reimer et al. 2013). Wade et al. (2014) also found similar results using the virtual driving simulation system (Wade et al. 2014). Furthermore, Brooks et al. (2016) found that the driving simulation system as a training tool can enable autistic subjects to achieve the same good driving ability as the control group (Brooks et al. 2016).

With the behavior researches of autistic individuals based on the virtual driving system, some scholars also have carried out research on the analysis of physiological signals for autistic individuals during virtual driving states, such as electrodermal activity-EDA, heart rate, eye movement, EMG, RSP, peripheral temperature, and so on. Fan et al. (2015) used the spectral analysis of EEG signals to study emotional states of autistic subjects during the virtual driving test (Fan et al. 2015). For the driving evaluation and intervention research on autism, Zhang et al. (2015) used eye movement analysis to study the effect of the difficulty level of cognitive load during driving on autistic individuals (Zhang et al. 2015). Lei Min et al. (2016) explored the characteristics of brain activity of autistic children during driving by analysing the sample entropy values of EEG signals for autistic children during simulated driving (Lei et al. 2016). There are few studies on the physiological signals of autistic individuals during driving, especially the research on the electrical signals of brain activity (such as EEG, magnetoencephalogram and so on). At present, there have been many studies on the brain activity of autistic individuals (Menaka et al. 2021; Abdulhay et al. 2020; Wang et al. 2014; Zhu et al. 2014). However, due to measurement limitations of EEG signals, especially requiring the head and body not to move, it is difficult for autistic children to record the EEG signals during movements in the complex environments. Therefore, the experimental designs of EEG research on autistic EEG are often very simple and single, such as the close or open eyes in the resting state, picture recognition (Hashemian et al. 2014; Ahmadlou et al. 2012; Bosl et al. 2011; Catarino et al. 2011). There is still a lack of research on the brain dynamical activity of patients with autism under complex multi task stimulation. This paper aims to apply the virtual driving environment to study the feasibility of electroencephalogram (EEG) of autistic children during driving a car.

2 METHODS

2.1 Virtual Driving Environment and Data Collection

The study was conducted in a virtual driving environment consisting of a driving simulator, two computer screens, a computer, and City Car Driving software. The driving simulator is a Logitech G29 driving game device including steering wheel, pedal, gear lever, driving software and development kit (SDK). For two screens, one is a monitor for doctors and technicians. The other is for subjects to watch a virtual driving roadway. The computer is used to collect the EEG data, display and monitor data online, as well as subsequently deal with data and so on. In order to reduce the interference of EEG data by noise, the experiment adopts the combination of wired and wireless data transmission. According to the international standard 10-20 electrode placement system, the 16 lead EEG signals are recorded from EEG electrode cap for children into the EEG amplifier equipment (Type: Nation-BTV, manufactured by Shanghai NuoCheng Electric Co., Ltd.) through a set of the short-distance wire lines. The sampling frequency is 256Hz. Then, the recorded EEG data are sent to the computer by the wireless transmission format (see Figure 1). This wired and wireless data acquisition method can effectively reduce the interference of wire motion in data acquisition.

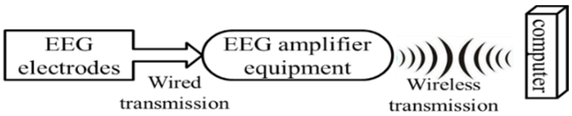


Figure 1: Schematic diagram of the wired and wireless transmission for EEG signals during driving.

2.2 Participants

Three boys about 13 years old in this study were diagnosed with the high functioning autism by a psychiatrist in Shanghai Mental Health Center in terms of DSM-V diagnostic criteria. They had IQs 70 or greater (WISC-IV), right-handed. The subjects did not suffer from organic mental disorders, schizophrenia, personality disorders and other mental diseases, nor did they suffer from nervous system degenerative diseases, brain trauma or cerebrovascular diseases, and had no history of major physical diseases such as severe heart, liver and kidney dysfunction or drug dependence. The subjects did not take any psychotropic drugs before this experiment. The guardians of the children signed an informed consent form.

2.3 Experiment

All subjects first were familiar with the driving environment and operation under the guidance of technicians (see Figure 2). Then, they took about 10 minutes of training to habituate to the driving simulator. The driving period mainly included startup, road driving, parking with no on-coming traffic. The speed limit was gradually increased to 50 KMH.

2.4 Data Analysis

Since the reference electrodes could be contaminated by artifacts, the average of all channel data per subject is used as a common reference. The EEG data first were offline re-referenced to the average reference. Then, EEG signals were filtered into the frequency band 0.2 to 50 Hz in order to remove the artifacts of eye movement, eye blink and muscle activity. Meanwhile, the spikes in EEG signals were also removed. The length of the analysed data is 5 minutes of driving state. EEG power can be measured by the Welch's power spectral density estimate method. The analysed data were segmented into one-second epochs with 75% overlap.

Figure 2: Experimental environment.

3 RESULTS

In this paper, the absolute power spectral density of each channel is calculated in order to verify the feasibility of EEG analysis in this study. Figure 3 shows the EEG signals of 16 channels in one second period during the driving state. It can be seen that from the time domain, the EEG data can be used. Figure 4 shows the power spectral characters of all channels for three subjects. As can be seen in Figure 4, spectrum ridge ranges are in the alpha band. The results indicate that it is feasible to apply the EEG acquisition system of this study in the virtual driving experiment.

Moreover, we compute mean absolute power spectral density (μV2) in alpha and beta frequency bands, as well as the peak frequency (Hz) in alpha and beta frequency bands. In Figure 5, we can see that the spectral energy of the prefrontal region is higher than those of other brain functional regions for the alpha and beta frequency bands. However, the maximum peak frequency can not be in the prefrontal region (see Figure 6). In the alpha band, the power spectrum peak frequencies in C4, T4, P4, T6, O2 locations are greater for three ASD subjects. In the beta band, the peak frequency in O2 location is lower for each ASD individuals. Although these results can not meet the statistical requirements due to the small number of subjects, the results can still provide reference for the sequential study of brain dynamic activities in virtual driving environment.

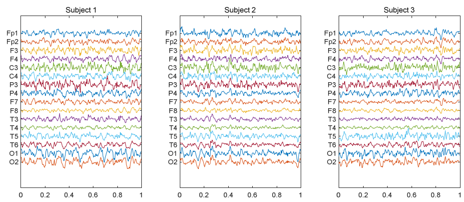


Figure 3: One second epochs of EEG signals for three subjects.

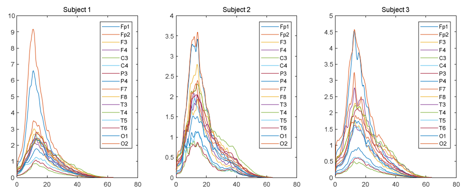
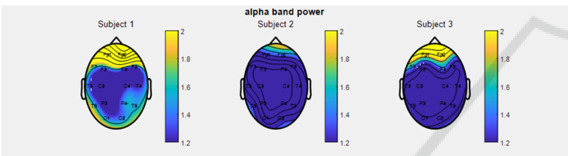
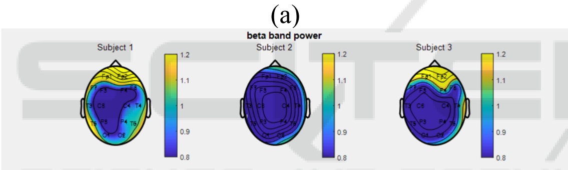


Figure 4: The power spectrum of EEG signals for three subjects.

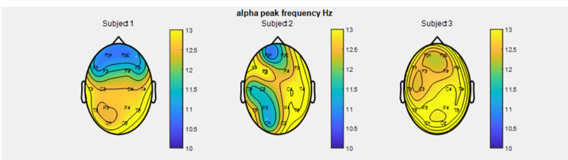


(a)

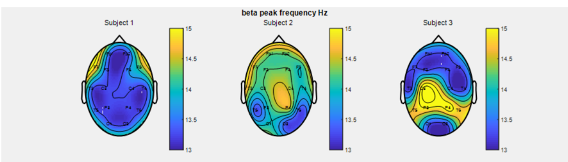


(b)

Figure 5: The topographic maps of the mean absolute power spectrum of EEG signals for three subjects: (a) the average in the alpha frequency band; (b) the average in the beta frequency band.



(a)



(b)

Figure 6: The topographic maps of the power spectrum peak frequencies of EEG signals for three subjects: (a) the peak frequency in the alpha band; (b) the peak frequency in the beta band.

4 CONCLUSIONS

This paper applies the wired and wireless data acquisition system to collect the electroencephalogram (EEG) characteristics of the children with autism during a virtual driving test. The recorded EEG signals are analyzed by the spectral analysis method. The results find that from the time and frequency domains, the recorded EEG signals can be used. Moreover, the higher spectral energies of the prefrontal region in the alpha and beta frequency bands are shown for three subjects during driving. The alpha peak frequencies in C4, T4, P4, T6, O2 locations are higher than those in other locations. The beta peak frequencies are lower in O2 locations of all subjects. These results indicate that the acquisition method with the wired and wireless transmission can collect the EEG signals of the individuals with autism during driving for the autistic brain dynamic analysis. This study provides an experimental and analysis basis for further study on autism.

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