Exploration of New Indexes of Event-Related Potentials in Polygraph

LEI Dan [*, a, b], *WANG Jing* [a, b], *GAO Feng* [a, b], *LIU Zicheng* [a, b]

a Institute of Forensic Science, Criminal Police Corps of Chongqing Public Security Bureau, Chongqing 400021, China.
b Chongqing Engineering Research Center for Criminal Investigation Technology, Chongqing 400021, China.

* Corresponding author. E-mail: 290496346@qq.com. Address: Institute of Forensic Science, Criminal Police Corps of Chongqing Public Security Bureau, Xiahuayuan No.101, Shimahe, Jiangbei District, Chongqing 400021, China.

Abstract The research adopts the method of the simulation of crime situation, takes waveform deviation and wave area as the indexes, explores the EEG response of the guilty individuals and innocent individuals to target pictures, as well as familiar and unfamiliar pictures. The results show that there is no significant difference in the waveform deviation and wave area of the EEG response of the individuals of different genders to the three types of pictures; the response of the guilty individuals to the target pictures and familiar pictures is more similar; the response of the innocent individuals to target pictures and unfamiliar pictures is more similar. In the future research and practice, waveform deviation and wave area can be acted as the effective new indexes by which to examine whether an individual is guilty.

Keywords: Forensic science, Polygraph, EEG, Waveform Deviation, Wave Area, New Indexes.

1 Introduction

Legal case (including civil cases and criminal cases) related brain potential polygraph (lie detection) is based on event-related potentials (ERP) technology and is the brain cognitive process scalp potentials in which identification or recognition and judgment are conducted on the strange and familiar, case-related (probing stimulus) pictures and statements with different cognitive attributes through the recording-comparing the tested brain, so as to analyze the relationship between the tested individual and the investigated cases[1]. Because ERP test is mainly conducted on the suspicious criminal suspect that policemen find, it can make unique contributions to the case detection in the stage of criminal interrogation[2].

Miyake et al. (1986) first reported the use of the physiological parameter ERP in deception detection and found that the P300 amplitude of the key project (name of the subject) was significantly higher than that of the non-critical projects (the name of the other)[3]. Rosenfeld (1989) used ERP to conduct lie detection study successfully in the laboratory for the first time, taking the related words as the target stimulus and P300 amplitude as the index, found that the P300 of the experimental group (subjects pretend to steal items) was significantly greater than that of the control group (innocent subjects), and proved that ERP was feasible for lie detection[4].

It is Yang Wenjun (1992) who first conducted the preliminary researches on the possibility of ERP for lie detection in China; in the experiment, the memorized pictures of people were considered as target stimulus and pictures of strangers without memorization were regarded as non-target stimulus; the results showed that after the subjects saw strangers' pictures, no matter whether they admitted that, P300 amplitude and wave area could provide the basis for determining the true situations (95% of positive rate)[5]. Chen Xingshi et al. (1994) also conducted ERP test on subjects with strangers' pictures as the target stimulus, and again proved the feasibility of P300 for lie detection[6]. In 1999, Zhou Liang et al. conducted the experimental research of simulation of theft cases for the first time, made the lie detection research with the P300 wave as indexes, and found that under the experiment condition, P300, as an objective index was feasible for lie detection and the subjects who were familiar with the scene did not produce false positive results in the lie detector[7].

As for Guilty Knowledge Test (GKT) technology in the traditional criminal polygraph, whether the subjects have specific plot memory of the cases is determined on the of basis

of the difference of the physiological changes such as skin conductivity, respiration, heart rate and blood pressure on the related questions and unrelated questions to the cases and the purpose of distinguishing between perpetrators and the innocent ones is achieved[8]. In the lie detection of ERP, the combination of Oddball model and GKT technology forms the P300-GKT paradigm. The study tries to explore the subjects' EEG response by adopting more intuitive and simpler waveform deviation and wave area so as to obtain simpler solutions of distinguishing the criminals and the innocent.

2 Research Methods

2.1 Subjects

102 subjects were randomly selected, including 62 simulating perpetrators and 40 simulating innocents; the statistics showed that only 102 subjects were valid, including 74 men and 28 women, at the age from 18 to 32, with the average age 22.36; all of them had no physical or mental illness, had normal vision or corrected visual acuity, and got adequate compensation after the experiment.

2.2 Experimental Materials

The pictures that the tests rendered were divided into three groups; each group contains three types of pictures, that is, target pictures, familiar pictures and unfamiliar pictures.

2.2.1 The Stolen Item

The target picture of the test is one picture of the stealer, the familiar picture is one picture of one famous actor; the unfamiliar pictures are a total of seven other strangers' pictures.

2.2.2 Theft Place

The target picture of the test is one picture of the lab; the familiar picture is one picture of the work learning environment of the subjects; the unfamiliar pictures are a total of seven

space pictures picture that subjects have never seen.

2.2.3 Packaging of the Stolen Item

The target picture of the test is one picture of the insurance company envelope; the familiar picture is one picture of the envelope of the subjects' unit; the unfamiliar pictures are a total of seven envelopes of other units that the subjects have never seen.

2.3 Experiment Design

The research simulates a burglary case in the laboratory environment and the articles in Room 808 include cabinets, tables, chairs, etc. The host forgets to lock the door before going out; after coming back 30 minutes later, the host finds a picture of the important personnel in the envelope inked with future insurance company in the cabinet is stolen and the envelope is thrown to the ground.

2.4 Experiment Program
2.4.1 Theft Simulation

Simulation of the perpetrators: the subjects read instructions and complete the burglary personally: first enter the specified simulation scene Room 808, carefully observe its internal environment and articles agreement inside, and then rummage through the pictures; observe the characteristics of the pictures and packing materials, and then remove the pictures and throw the packing materials away, next leave the room. The simulating perpetrators don't admit theft during the test.

Simulation of the innocent: Inform an important item in Room 808 is stolen and now the suspects have been listed by the public security organs, so we will conduct the polygraph.

2.4.2 EEG Test

In accordance with the order of the stolen item, the theft place and the packing of the stolen item, the subjects are required to observe the pictures carefully and then answer the problems of the experimenter. Each

group test is repeated for three times; the target pictures, familiar pictures, and unfamiliar pictures are randomly presented in the tests of each group; the target pictures appear for four times; familiar pictures appear for three time and the seven unfamiliar pictures respectively present once; each picture appears as long as 500 milliseconds and appears once every other 2000 milliseconds; the test records the data after the picture is shown for 1000 milliseconds. The test equipment is TH-B polygraph (lie detection) machine prototype researched and developed by Beijing Tongfang Shenhuo Joint Technology Development Co., Ltd.

Statistical analysis is conduced on all the experimental data by using SPSS16.0 software.

3 Results and Analysis

The EEG test mainly inspects EEG data at CZ point. According to the previous results of the researches on the effectiveness and practicability of ERP polygraph patterns, the study investigates the data within 1000 milliseconds in CZ point after the subjects' stimulus presentation, and tries to investigate indexes waveform deviation and wave area.

3.1 Difference Test of Waveform Deviation of Three Kinds of Pictures

The research conducts the analysis of variance on the subjects' waveform deviation of the three kinds of pictures, namely the picture of the stolen item, picture of the theft place and picture of the packing of the stolen item; the results show that as for the stolen picture, there is no significant interaction to the three kinds of pictures among gender, guilt and waveform deviation ($F = 0.501$, $p = .608$; $F = .968$, $p = .383$; $F = .070$, $p = .933$); there is significant interaction between guilt and the waveform deviation of

three kinds of pictures (F = 182.654, p < .001; F = 182.698, p < .001; F = 153.403, p < .001); the back testing shows that guilty subjects and innocent subjects are significantly different in the waveform deviation of the three kinds of pictures.

3.2 Differences Test of Wave Area of Three Kinds of Pictures

The research conducts the analysis of variance on the subjects' wave area of the three kinds of pictures on the picture of the stolen item and the results show that there is significant interaction between three kinds of pictures and the guilt (F = 83.26, p < .001; F = 111.45, p< .001; F = 55.68, p < .001). The back testing shows that the guilty subjects are not significantly different in the wave area of the response to the target pictures and familiar pictures; the guilty subjects are significantly different in wave area of the response to target pictures and unfamiliar pictures; the innocent subjects are significantly different in the wave area of the response to the target pictures and familiar pictures; the innocent subjects are not significantly different in wave area of the response to target pictures and unfamiliar pictures.

4 Discussions

4.1 Waveform Deviation Variance Analysis of Three Kinds of Pictures

The waveform deviation adopted by the research refers to the average of amplitude difference of three types of pictures at various time points within 1000 milliseconds of stimulation. The degree of similarity between different types of pictures is determined by investigating the pair-wise waveform deviation of the three kinds of pictures.

Statistical tests show that individuals of different genders, whether guilty subjects or innocent ones, show no significant difference in

the picture of people, the picture of the theft place and the picture the stolen item packaging; there is no significant difference in male and female's judgment of pictures; therefore, in the future research and practical use, special stimulus materials for the individuals with different genders are not needed to be set.

The research results show that as for picture of people, picture of the theft place and picture of the stolen item packaging, the waveform deviation of guilty individuals to the target pictures and familiar pictures is significantly lower than the that of the target pictures and unfamiliar pictures, namely, guilty individuals have more similar reactions to the target pictures and familiar pictures; the waveform deviation of innocent individuals to target pictures and unfamiliar pictures is significantly lower than the that of the target pictures and familiar pictures, namely, innocent individuals have more similar reactions to the target pictures and unfamiliar pictures. The result is consistent with the research results of Zhou Let al. Because the guilty individuals contacted the information relating to the case in the past, the stimuli is familiar ones for guilty individual and there are more similar reactions; for innocent individuals, the information relating to the case is also strange stimulus, so the innocent individuals have more similar reactions to the target pictures and unfamiliar pictures. The results validate the assumptions. Therefore, in the future researches and practice, comprehensive consideration can be conducted with waveform deviation as an effective analysis index.

4.2 Wave Area Variance Analysis of Three kinds of Pictures

The study investigates the wave area of the subjects within 1000 milliseconds of stimulus presentation

and the results show the individuals of different genders, whether guilty ones or innocent ones show no significant difference in wave area of the response to the three kinds of pictures; thus, in the future research and practice, special stimulus materials for the individuals with different genders are not needed to be set.

Research results show that the wave area of the guilty subjects shows no significant differences in the reaction to the target pictures and familiar pictures, and shows significant differences in the reaction to the target pictures and unfamiliar pictures; the results indicate that the guilty subjects have more similar reactions to the target pictures and familiar pictures, namely, for them, the target picture also belongs to the familiar one; while they have significantly different reactions to the target pictures and unfamiliar pictures; wave area of innocent subjects shows significant differences in the reaction to the target pictures and familiar pictures, and shows no significant differences in the reaction to the target pictures and unfamiliar pictures; the results indicate that the innocent subjects have more similar reactions to the target pictures and unfamiliar pictures, namely, for them, the target picture also belongs to the unfamiliar one, and they have more significantly different response to the target pictures and familiar pictures, namely, they belong to different types of pictures. Thus, in practical use, preliminary investigation on wave area of the three types of pictures can be more directly made through the bar chart so as to distinguish criminal individuals and the innocent ones.

4.3 Variance Analysis of the Response of Criminals and Innocent of Different Genders to Three Types of Pictures

The research results show that there is no significant difference in the

response of the individuals of different genders to the three types of pictures. The previous researches showed that male and female had different response to picture stimulus, but there is no such difference in the study because what the research inspects is ERP differences rather than non-behavior data; male and female have bigger differences in behavior, but no great differences in EEG. Therefore, in the future practice, the impact of gender factor doesn't need to be considered and different stimulus materials do not need to be set for subjects of different genders.

Research results show that as for the factors waveform deviation and wave area, guilt subjects have more similar response to the target pictures and familiar pictures; innocent individuals have more similar response to the target pictures and unfamiliar pictures. By investigating the ERP reaction of the individuals to the target pictures, familiar pictures and unfamiliar pictures, criminals and innocent can be effectively identified, thus, it can provide directions for detection work.

The case-related information the study investigates including the stolen item, the theft place and the packaging of the stolen item is related to the typical elements of the case and has strong stimulus for criminals; thus, when hey are presented to the individuals, the stimulus will be stronger than the other two types of stimuli for the real culprits. Besides, since the stimulus is the information that criminals know and is familiar stimulus, the reaction is consistent with the familiar stimulation. It is converse for the innocent subjects.

4.4 Problems and Prospects

Endogenous component P300 is the commonly-used identification index in ERP lie detection; it is incurred by extraneous stimulus of small

probability; its amplitude is determined by the amount of the allocated attention resources and it reflects the context updating level in working memory. It is generally believed that P300 is mainly related with attention, episodic memory, working memory and other psychological factors [9]. The existing researches that involve the plots of cases basically adopt the form of case simulation and so the study does; the psychological pressure it makes the subjects produce and the psychological stress that the actual cases bring to criminal suspects are different, so it brings some difficulty to the promotion of the conclusions. Besides, in the experiments in the laboratory, the relevant conditions of the experiments are strictly controlled and the results of the study are relatively ideal; however, the actual case investigations may be affected by various factors; thus, relatively ideal target stimulus can't be collected and deviation emerges. Therefore, in actual practice, the researchers should try to protect scene information, especially the important related information, so as to ensure more accurate results can be obtained in the tests.

Although the existing researches have compared different types of stimulation EEG indexes and have found the differences, they do not give feasible test procedures and marking criteria; thus, further analysis can be conducted in the future researches. Furthermore, there are not enough researches on special group, especially people with psychopathy and antisocial personality disorder; whether the lie detection of the special group has the same effectiveness as the general population remains to be thoroughly discussed [10].

5　Conclusions

5.1 There is no significant difference in the response of individuals with different genders to the three types of pictures.

5.2 The response of the guilty individuals to the target pictures and familiar pictures is closer; the response of the innocent individuals to the target pictures and unfamiliar pictures is closer.

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