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Research on Application of Eye Tracking Technology on Criminal Psychological Test - A Case of Simulate of Murder

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Abstract Two groups (A: murderer; B: innocent person) were arranged in the psychological test of simulated murder case, and the index of fixation duration (FD), fixation count (FC) and visit duration (VD), etc. was recorded by eye tracker during the experiment. It was found that the index of FD, FC, VD on stolen item (pictures of ring), offence site (pictures of murder house), murder tool (pictures of hammer) and the victim (pictures of victim) of group A was higher than that of group B, but the significant difference was only shown from murder tool and victim ($P < 0.05$); The FD on murder involved pictures of group A was longer than that of unrelated pictures (but not so obvious), and the FD on murder involved pictures of group B was un-obviously longer (or less) than that of unrelated pictures.

Keywords: Forensic science; Eye movement, Psychological test, Experiment; Criminal psychology.

1 Introduction

1.1 Introduction on psychological testing technology

Psychological testing technology (polygraph) was introduced to our country in the early of 1980s, and it was officially enrolled into the order of criminal science and technology as an independent major in 2004. It is a technology that testing the related psychological information in individual case, and psychological test is that the equipment which is capable of detecting the individual physiological index condition is used to search related psychological information of individual (subject) on specific events or special purpose and deduce its behavior.

The traditional multi-channel physiological and psychological tester (polygraph) is the most common one for criminal polygraph at present, and the traditional multi-channel physiology recorder has been in dominant position in psychological testing technology until

the middle 1980s (Rosenfeld, Shue & Singer, 2007). This method is used to judge the subject whether lying or not with the help of the change of plant nerve activity (breathing rate, blood pressure, skin resistance, etc.) (Elizabeth, 2006). Its principle is to measure the accompanied physiological parameters of the emotional reaction, and not the cognitive process itself, which makes the validity of this technology low, especially it is hard to avoid the false positive questions. So many researchers put forward the challenges on the accuracy of this method after the 1980s. Some researchers are developing the new technology and psychological test, and that using the event related potential (ERP), functional magnetic resonance imaging (fMRI), and other brain imaging technology to do psychological test is the main method (Zheng Hong-li, Ding Tong-chun, 2007).

1.2 Eye tracking technology

Eyes are the windows of the soul,

and some people investigated eyeball movement to research the human psychological activities in the 19th century. Psychologists think that eyeball movement is the direct reaction of visual process and cognitive activities of a variety of humans. The information processing of human brain depends heavily on vision, and about 80%-90% of the external information is obtained through the eyes. Eye tracking technology can record the process and level of cognitive processing. The research of O'Regan, McConkie and Rayner, etc. showed that eye movement speed, eye beating distance, fixation time and scan route etc. were effective index for analyzing the brain cognitive process, the comprehensive analysis of the index could reveal the change of complex cognitive activities. At the same time, eye movement characteristics are a physiological index for emotion, so the people's cognitive process can be analyzed through the eye tracking technology.

Functional magnetic resonance

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imaging (fMRI) has a high requirement on equipment, and the price of equipment is extremely expensive, therefore, there are a few equipments in domestic. So many researchers have applied the event related potential (ERP) technology to polygraph research in recent years, and they have achieved good results. The event related potential polygraph technology gives subjects some irritant (visual, auditory) to detect the generated evoked potential, and directly investigate cognitive process of lying, so there is higher reliability and validity. But the complexity of evoked potentials has extremely high requirement on the polygraph technology operators, so the operators need to acquire a lot of psychology knowledge such as cognitive neuroscience, experimental psychology, cognitive psychology and so on, at the same time, they should also have the knowledge of criminal investigation, and strictly control the experimental condition in the test. The strict requirement for test condition of ERP makes it difficult to be popularized in the public security bureau practice.

Compared with the two technologies above, eye tracking technology has distinct characteristics. On one hand, it is the ease of use, this equipment has a simple operation, and the data analysis is also relatively visual in image; On the other hand, it is the ecology, this equipment often takes non-contact ways, so it will not affect the processing of normal cognitive information, and electrode cap needed in ERP technology is not needed here. The picture stimulus is the priority to eye tracker, sight change is continuously recorded through infrared ray reflected from human cornea and pupil, and eye movement data of subjects can be recorded and analyzed after seeing the stimulated pictures, so there is no need to directly connect subjects, and operability and concealment are good. At present, the sight tracking technology is gradually mature, and it has already been extensively applied to the plane design, product testing and other fields. There is a good theoretical and physical basis with the application to the psychological test in criminal cases.

1.3 Eye tracking index

Eye tracker can collect many indexes such as FD, FC, VD, eye movement trajectory, pupil diameter, the first viewpoint and so on. It was found that in

the experimental study, eye movement trajectory was difficult to be quantified, and the calculation of pupil diameter was also complicated, therefore, combining with previous relevant studies on eye movement, the only first three indexes were temporarily conducted statistical analysis considering the efficiency of research and application of research conclusion.

1.3.1 FD refers to the fixation time of an unit area, which is combined with a specific research area (interest area). The data from the Immediacy Assumption and Eye-mind Assumption of American psychologists Just and Carpenter till present have shown that the fixation to something is the cognitive process of it. When cognitive process is difficult, the fixation time will be extended accordingly. FD is a relatively effective test index in criminal fluttering, because it can show the familiarity of subject to certain information such as information on spot scene, murder tool and face, etc.

1.3.2 FC refers to the fixation times of an unit area, which is combined with a specific research area (interest area). The parameter shows the familiar and interesting degree of the subject to a certain region, especially in a criminal fluttering, something in the spot scene can be regarded as a stimulation material, delimiting the murder related special area which murderer is familiar with, and testing the fixation times of murderer to this area. This parameter can clearly reflect the informed degree or familiarity of subjects.

1.3.3 VD is similar to FD, and VD will not be longer than FD. If the VD reaches above a standard (such as 0.75 seconds) when the eyes of a subject sweep an area, then VD is equal to FD, if not, then VD is regarded as zero and FD is recorded. This study was based on a simulated murder, and role-playing method was used for subjects to get real feelings. Group A and B were asked to look at murder involved pictures and unrelated pictures in this experiment, and VD, fixation point, FD, etc. of the subjects were recorded with eye tracker to explore eye movement index which could be used for criminal case psychological test. The results of this experiment showed that the index on FD, FC and VD to murder involved pictures (ring, hammer, scene and victim) of group A was larger than that of group B as well as the unrelated pictures, while the index on murder involved

pictures was not obviously larger than that of unrelated pictures for group B.

2 Methods

2.1 Subjects

Subjects are the cops from criminal police corps of public security bureau in Chongqing city, including 26 males and 2 females. The subjects were healthy, without mental disorders, and corrected visual acuity was above 1.0, no color blindness, color weakness, and not illiteracy; mental health was in good condition. The data of a total of 24 people were collected after eliminating invalid data caused by unfinished experiment or the head movement in experiment, etc., and the average age of subjects was 22.3 years old. The subjects are right handedness and get some gifts after experiment.

2.1.1 Experimental group A (Murderer Group)

A total of 14 people (including a female) acted as murderers respectively, and implemented simulated murderous activity.

2.1.2 Control group B (Innocent Group)

A total of 14 people (including a female) acted as innocent people respectively, and generally understood the information in this case. The gender, age, education background of people in control group should be similar with those of experimental group subjects, and it could become the matched group for experimental group.

2.2 Experimental materials

2.2.1 Script of simulated murder

Murderer committed a burglary and found a ring after rummage, and he was about to leave when the victim was returning. The victim wanted to catch him, and the murderer hit the head of victim with a hammer inside the house in order to run away, but the victim died. Murderer ran away quickly in the end.

2.2.2 Materials for psychological testing program

The pictures are the stimulus and involve 4 kinds of photos in the script: stolen item (pictures of ring), offence site (picture of murder house), murder tool (picture of hammer) and the victim (picture of victim), these four kinds of information photos are made into

experimental materials for four groups, and used to these four groups. Each stimulus picture is consist of multiple combined photos in each experimental material, of which there is one murder involved picture, and the others are not, which are the foils of it (selecting the picture which has similarity and difference with the murder involved picture). Combine, gray and brighten the pictures with Photoshop software. The testing picture in the group of stolen items (ring photo) includes one murder involved picture and five unrelated pictures, and these six pictures are put into one photo with 3 pictures above and 3 below, then change the position of murder involved picture, therefore, there are six testing pictures; the design of picture is the same as that in the group of murder tool (picture of hammer) and the victim (picture of victim). The testing picture in the group of offence site (picture of murder house) includes one murder involved picture and three unrelated pictures, and these four pictures are put into one photo with 2 pictures above and 2 below, then change the position of murder involved picture, therefore, there are four testing pictures.

2.3 Experimental procedure

2.3.1 Simulation of murder scene

The subjects were asked to read and memorize the simulated murder script and complete the process of murder by the experiment "director", the more subjects were involved, the better the result would be, and they could repeat until their performance involved all the key plots of the script. The "director" would take the subjects to psychological testing laboratory after the show. Before entering the lab, "director" told subjects that the lord in this lab was equivalent to the police, and she was investigating the case. She would do the polygraph to all the suspects, and find out who was the real murderer. Only you and I knew your real identity, and I would not tell her. You had to conceal your identity, and didn't be found by her. Only you were the real murderer and knew the crime details of this case in all suspects, so you could not be measured out when she did psychological tests to you. The "director" left after taking the subjects into the lab.

2.3.2 Psychological testing program

Present the psychological test instruction to the subjects: "A case of burglary homicide happened just now,

we had already explored the scene, and got some details of the case, the murderer stole a ring and killed the victim with a hammer, but we did not know who was the real murderer. Everyone in the group could be the suspect, so we need to do the psychological test for you respectively. Some pictures will appear on the screen in the process of the psychological test, please look at the pictures and see whether you have seen the things in the pictures or not, and a white "+" will appear at the center of blank screen before and after the appearance of each picture, and please look at the white "+" during the appearance of blank screen. In order to test whether you have carefully watched these pictures or not, we will ask you some simple questions related to those pictures after psychological test, and you can answer them if you have watched them carefully. If you can't answer, we will think you want to hide something. In a word, your task is to cooperate with us, and that is the only way to prove your innocence". The subjects can rest for some time in each testing group. The subjects are asked to sit in the laboratory, keep still when testing, and their eyes need to look at the center of screen, the distance between eyes and screen is about 60 cm, and their eyes can not blink frequently. Formal experiment includes four experimental groups, and each group tests one class of murder involved information respectively. The testing process is that a white "+" will appear at the center of blank screen, and it will last for 1s, then the stimulus picture appears and lasts for 5s, the subjects can recognize the stimulus but do not need to make response; a white "+" will appear at the center of blank screen again after stimulus disappears, and it will last for 1s, then the stimulus picture appears; cycle this process until the end of a set of tests (Figure 1).

2.4 Record and analysis of eye tracking data

T120 eye tracker (tobii studio 3.0.2) produced by company tobii in Sweden was used. The imperceptibility of this eye tracker display is good, because it is not easy to be perceived, and it only needs the subjects to look at that display in 60 cm distance, then the data of fixation point, FD and VD can be collected well. The data was derived from tobii studio and statistical analysis was conducted with

spssl6.0.

3. Result

FD (unit: S); FC (unit: Number); VD (unit: S). The picture with No.1 is the murder involved picture and the others are unrelated pictures.

3.1 Murder tool (picture of hammer)

The FD average on hammer pictures of group A was obviously longer than that of group B ($P=0.002<0.01$), and the FD of group A on hammer pictures was longer than that of unrelated pictures ($P=0.137$), but not so obvious, and according to the principle of statistics, it could be said that the false probability of "longer" in conclusion is only 13.7%. There was obvious difference on FD between hammer pictures and other pictures for group B ($P=0.002$), but the former one was shorter than that of later one. In fact, that the FD on pictures of murder hammer was not longer than that of unrelated pictures was corresponding characteristics for group B. The results of FC and VD were almost similar with that of FD, and specific data interpretation was as above.

3.2 Offence site (picture of murder house)

The FD average on offense site pictures of group A was longer than that of group B ($P=0.562$), but not so obvious, it could be said that the false probability of "longer" in conclusion is only 7.3%; Moreover, the FD on offence site pictures of group A was longer than that of unrelated pictures ($P=0.643$), the difference was not obvious, and according to the principle of statistics, it could be said that the false probability of "longer" in conclusion is 64.3%. There was not an obvious difference on FD on offense site pictures and other unrelated pictures for group B ($P=0.104$). In fact, that the FD on pictures of murder house was not longer than that of unrelated pictures was corresponding characteristics for group B. The results of FC and VD were almost similar with that of FD, and specific data interpretation was as above.

3.3 Victim (picture of victim)

The FD average on victim pictures of group A was obviously longer than that

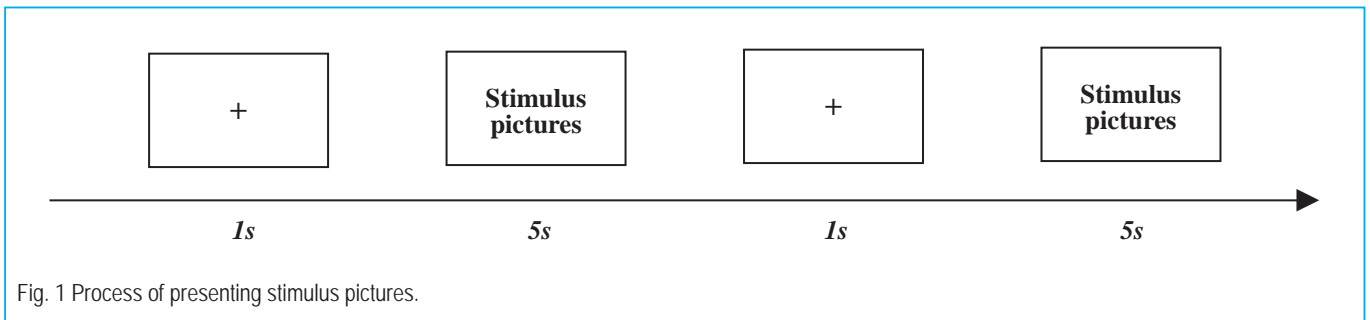


Fig. 1 Process of presenting stimulus pictures.

Table 1. Average and difference test of FD, FC and VD with the sight of murder tool picture

Classification	FD		FC		VD		
	A	B	A	B	A	B	
Average	1	4.7408	2.4733	19.33	12.17	5.1558	2.6508
	2	4.5558	4.0650	18.08	18.67	4.9125	4.6117
	3	3.7917	3.6025	16.92	18.25	4.1500	4.0400
	4	3.0842	3.1483	13.42	14.08	3.3150	3.3808
	5	3.5175	2.9033	14.50	14.75	3.7767	3.2450
	6	3.0358	2.8958	13.17	15.25	3.2267	3.3058
Difference test	Intra-group	0.137	0.002	0.105	0.002	0.163	0.006
	Among group	0.002		0.004		0.001	

Table 2. Average and difference test of FD, FC and VD with the sight of offence site picture

Classification	FD		FC		VD		
	A	B	A	B	A	B	
Average	1	4.3933	3.1767	18.75	15.58	4.9533	3.6525
	2	3.4342	3.1575	14.50	14.75	3.8683	3.8450
	3	3.7733	4.4750	15.58	20.25	4.2392	5.2958
	4	3.8658	2.5325	16.42	12.50	4.3180	3.0740
Difference test	Intra-group	0.643	0.104	0.273	0.030	0.669	0.101
	Among group	0.073		0.004		0.001	

Table 3. Average and difference test of FD, FC and VD with the sight of victim picture

Classification	FD		FC		VD		
	A	B	A	B	A	B	
Average	1	6.0264	3.3392	21.18	15.58	6.4555	3.6583
	2	3.4773	3.6208	15.36	15.50	3.8491	4.0417
	3	3.1118	3.1442	15.45	15.75	3.3936	3.4525
	4	3.0245	2.8892	13.27	13.92	3.2645	3.3017
	5	2.7509	3.1642	13.55	14.25	2.9527	3.6367
	6	4.1145	3.0858	16.45	14.08	4.4782	3.3258
Difference test	Intra-group	0.051	0.505	0.113	0.714	0.064	0.472
	Among group	0.002		0.013		0.002	

Table 4. Average and difference test of FD, FC and VD with the sight of stolen item picture

Classification	FD		FC		VD		
	A	B	A	B	A	B	
Average	1	4.4467	4.0675	21.67	20.58	4.9308	4.6400
	2	3.1720	3.4320	14.83	17.08	3.4070	3.7730
	3	3.1758	2.8483	15.17	13.67	3.4817	3.0925
	4	3.5425	3.2808	17.92	15.92	3.8258	3.6067
	5	4.0450	3.3292	18.92	16.83	4.4400	3.6858
	6	3.1992	3.1642	16.50	16.08	3.4767	3.4825
Difference test	Intra-group	0.495	0.372	0.374	0.160	0.281	0.292
	Among group	0.562		0.619		0.685	

of group B ($P=0.002<0.01$); Moreover, the FD on victim pictures of group A was longer than that of unrelated pictures ($P=0.051$), the difference was almost obvious, and according to the principle of statistics, it can be said that the false probability of "longer" in conclusion is only 5.1%. There was not an obvious difference on FD on victim pictures and other unrelated pictures for group B ($P=0.505$). In fact, that the FD on pictures of murder house was not longer than that of unrelated pictures was corresponding characteristics for group B. The results of FC and VD were almost similar with that of FD, and specific data interpretation was as above.

3.4 Stolen item (picture of ring)

The FD average on stolen ring pictures of group A was longer than that of group B ($P=0.562$), but not so obvious, it could be said that the false probability of "longer" in conclusion is 56.2%; Moreover, the FD on stolen ring pictures of group A was longer than that of unrelated pictures ($P=0.495$), the difference was not obvious, and according to the principle of statistics, it could be said that the false probability of "longer" in conclusion is 49.5%. There was not an obvious difference on FD on offense site pictures and other unrelated pictures for group B ($P=0.372$), but the former one was longer than the later one. In fact, that the FD on pictures of murder house was not longer than that of unrelated pictures was corresponding characteristics for group B. The results of FC and VD were almost similar with that of FD, and specific data interpretation was as above.

4. Discussion

The control on experimental condition should be strengthened. There must be some similarities between murder involved picture and unrelated picture besides the difference. It can't be significantly different from irrelevant picture, the ring picture of experiment is not good enough in this point, because it caused the attention to stolen ring photo of group A and B to be in the first level, and in the experiment, some people in group B had tried to guess "that picture" should be stolen ring picture, and said "the picture" was obviously different from other photos, and it was proved through the review of the experiment. It should be ensured that group B can hear but absolutely not see the related information of murder; To try to guide the subject to a deeper role, and not only pay attention to group A, but also to group B.

Design some methods which can identify the anti-test behavior of subject, for example asking the subject to make the corresponding reaction key in the experiment, and collecting the reaction time and accuracy of subject as analysis indicators.

5. Conclusion

The index of FD, FC, VD on stolen item (picture of ring), offence site (picture of murder house), murder tool (picture of hammer) and the victim (picture of victim) of group A was higher than that of group B, but the significant difference was only shown from murder tool and victim ($P<0.05$). The FD on murder involved pictures of group A was longer than that of unrelated pictures (but not so obvious), and the FD on murder involved pictures of group B was un-obviously longer (or less) than that of unrelated pictures.

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