ISSN 2616-5783 Vol.7, Issue 6: 189-194, DOI: 10.25236/AJHSS.2024.070630

An Eye Tracking Study Assessing Attention Biases of Suspects in Simulated Crime Scenarios

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Abstract: *Crime is prevalent worldwide, with criminal rates on the rise in recent years. Understanding criminal psychology can aid in detecting cases by providing additional clues. This study utilized eye-tracking technology to investigate the psychological behaviors of both perpetrators and innocents. Since gaze patterns can reflect individuals' inner cognitive processes, the research simulated a criminal case, dividing subjects into two groups: perpetrators and innocents. Each group was immersed in the case based on their respective identities. Following the identification and background briefing, participants viewed both crime-related and irrelevant stimuli on a screen. Their eye movements were recorded throughout the process. Eye tracking parameters, such as fixation duration, fixation count, first fixation duration, time to first fixation, as well as average amplitude of saccade were analyzed to assess attention bias and psychological activities. The results revealed that individuals in the criminal group exhibited longer first fixation duration and shorter time to first fixation for crime-related stimuli, suggesting higher alertness to relevant cues. Additionally, they displayed shorter total fixation duration and fewer fixation counts for these stimuli, indicating intentional avoidance of further gaze. Moreover, the perpetrator group exhibited shorter saccadic amplitudes, indicative of a higher state of psychological tension. This study offers a novel approach to understanding the attentional characteristics of criminal suspects and provides a theoretical foundation for future applications in real-world cases.*

Keywords: *Criminal psychology; Attention vigilance; Attention avoidance; Attention bias; Eye tracking*

1. Introduction

According to the Office for National Statistics and the Global Initiative, the crime rate has risen worldwide in recent years[1][2]. Public security is a fundamental aspect of people's basic rights. Effectively detecting cases is essential, as a high crime rate instills fear and insecurity among people. Rapid and efficient resolution of criminal cases can thwart criminal activities and deter offenders. During the investigation and resolution process, it is imperative to gather information from individuals, objects, and locations pertinent to the crime[3]. However, in practice, determining the veracity of confessions can be challenging due to factors such as intentional deception. Incorrect investigative outcomes may result in the release of actual perpetrators or lead to wrongful convictions[4].

Criminal psychology, a cross-disciplinary field bridging natural science and social science, encompasses both psychology and criminology. Eye tracking analysis is a method used to assess the cognitive and psychological processes of individuals by analyzing their eye gaze behaviors. As early as the 19th century, scholars began exploring the relationship between eye movements and internal human activity through the analysis of recorded eye movement data. American psychologists Just and Carpenter proposed the Direct Hypothesis and Eye-Brain Hypothesis, respectively, suggesting a direct link between eye movements and cognitive processing[5]. From this perspective, individuals, regardless of their involvement in criminal activities, exhibit distinct cognitive and psychological processes, which may be reflected in their eye gaze behaviors captured by eye-tracking technology. Moreover, eye movement analysis, characterized by its non-invasive nature, minimal impact, and high efficiency, mitigates the influence of external pressures and stressful environments on subjects, thereby potentially enhancing the accuracy of investigations[6].

At the beginning of the twenty-first century, the eye tracking research method emerged in the field of criminal psychology[7]. Many studies employing eye tracking have been conducted by criminal psychologists. For instance, Jacques et al.utilized eye tracker to investigate the perspective of shoplifters[8], while Guedes et al. explored contextual cues associated with fear of crime through eye tracking technique[9]s. However, due to experimental constraints and ethical considerations, most studies primarily focused on analyzing the psychological processes and intentions of offenders, with limited

ISSN 2616-5783 Vol.7, Issue 6: 189-194, DOI: 10.25236/AJHSS.2024.070630

research addressing attention bias regarding the cases. This study utilized eye-tracking methodology to investigate attention bias and psychological states among suspects of different identities, i.e. criminals and innocents. Subjects were divided into the above groups and were instructed to immerse themselves in case-related backgrounds to enhance their sense of identity. Subsequently, a simulated interrogation was conducted during which both crime-related and unrelated stimuli were presented as images on a screen. Subjects' gaze behaviors were recorded throughout the process using an eye tracker. Statistical analyses of eye tracking parameters were conducted to discern attention bias towards different stimuli. The findings offer novel insights for distinguishing individuals with varying identities. This study introduces innovative experimental designs for scholars in this field facing constraints in experimental settings and provides a theoretical foundation for future applications in real-world cases.

2. Method

2.1. Participants

Nineteen individuals, ranging in age from 15 to 69 years old (M=37.2, SD=13.3), were randomly recruited in Shanghai, China. Of these, 8 participants were male and 11 were female. All participants were randomly assigned to one of two groups: the Criminal Group (M=39.6, SD=13.1) and the Innocent Group (M=34.6, SD=13.7). Females and males were approximately equal in two groups. Prior to the experiment, all participants were informed about the use of an eye tracker and provided voluntary consent to participate.

2.2. Stimuli

Stimuli were presented as images on a screen and categorized into crime-related and non-related stimuli. The stimuli consisted of three groups of images presented sequentially. Each group contained four images, with one being crime-related and the remaining three being non-related stimuli.

In the first group, the images depicted faces of four individuals: one representing the victim (V) and the others depicting unrelated individuals (P1, P2, P3). The photo of the victim (V) was considered the crime-related image.

In the second group, the images included a knife (K), a dog (O1), a pencil (O2), and a water bottle (O3). Although the knife was not the actual weapon used in the crime case, it was considered a crime-related stimulus due to its association with the nature of the crime.

In the final group, the images featured footprints (F), a photo of colorful hands in animation (S1), a fig (S2), and a toy pig (S3). Though the footprints (F) were not directly related to the case, they were considered crime-related stimuli as they represented a general form of clue.

2.3. Design and procedure

The study employed a between-subject design. The participants were randomly assigned to either the criminal group or the innocent group. Initially, the participants were asked to read and sign a consent form after being briefed on the risks and procedures involved in the experiment. Subsequently, they were seated in front of a screen connected to a laptop and an eye tracker (Tobii 4C).

Rather than directly assigning identities, both groups were led through separate storylines tailored to their respective roles to enhance their immersion in the study. In both scenarios, participants knew the victim before the case. For the criminal group, the materials presented on the screen depicted the motive and process of a passion killing, along with images of the victim and the crime scene. Conversely, the innocent group's storyline described the subject's chance encounter with the victim near the scene, with clear images of the victim presented as well. The innocent group remained unaware of the subsequent events following their encounter.

At the conclusion of the narratives, a mock inquiry was conducted through image presentations. Both groups were summoned to the police station as they were suspected of being involved in a case. Following this, a nine-point calibration was conducted to ensure accurate gaze capture, and stimuli were presented on the screen. Each group viewed three sets of pictures as stimuli, with each set displayed for approximately 15 seconds.

The entire process took approximately 10 minutes to complete. Upon completion of the experiment,

ISSN 2616-5783 Vol.7, Issue 6: 189-194, DOI: 10.25236/AJHSS.2024.070630

participants were informed of the experiment's purpose in detail to mitigate any potential negative effects and were provided with a small gift as appreciation for their participation.

Each picture in the three groups was defined as an area of interest (AOI), and these AOIs were consistent for both groups of subjects. Eye-tracking parameters, including Total Fixation Duration (TFD), First Fixation Duration (FFD), Time to First Fixation Duration (TFF), Fixation Count (FC), and Average Amplitude of Saccades (AAS), were utilized to analyze participants' visual attention while viewing the stimuli. Subsequently, the data was categorized, and analysis and discussion ensued.

2.4. Data Analysis

To compare the differences in gaze data between the perpetrator and innocent groups while viewing the materials, within-group single-factor ANOVA and between-group t-tests were conducted among AOIs.

3. Results

3.1. Single-factor ANOVA analysis for Criminal Group

The single-factor ANOVA analysis of Total Fixation Duration (TFD) and First Fixation Duration (FFD) for subjects in the criminal group, as depicted in Tables 1, 2, and 3, revealed no significant differences across any of the three groups of experimental materials (*TFD: F=1.58, p>0.05; FFD: F=0.91, p>0.05; FFD: F=0.08, p>0.05*). Similarly, there were no significant differences observed in Time to First Fixation (TFF) for the majority of stimuli (*F=0.69, p>0.05; F=1.27, p>0.05; F=0.77, p>0.05*). However, upon analyzing TFF, it was found that for the first group of materials, subjects' TFF for the victim (V) was significantly shorter than for other pictures in that group (*M=0.55, SD=1.40; F=5.58, p<0.05*).

Furthermore, subjects exhibited significantly higher Fixation Count (FC) (*M=14.00, SD=5.64; F=3.36, p<0.05*) and significantly shorter TFF (*M=0.23, SD=0.21; F=3.66, p<0.05*) for O1 compared to other pictures in the second group of material.

3.2. Single-factor ANOVA analysis for Innocent Group

The single-factor ANOVA analysis of the innocent group, as presented in Tables 1, 2, and 3, revealed significant findings. Subjects exhibited significantly higher Total Fixation Duration (TFD) and Fixation Count (FC) for the victim (V) in the first group of materials (*TFD: M=3.66, SD=3.8, F=2.43; FC: M=12.22, SD=4.35, F=2.43, p=0.08>0.05*). In the second group of materials, both TFD and FC were significantly higher for O1 (dog) (*TFD: M=3.81, SD=1.22, F=4.96, p<0.05; FC: M=15.22, SD=4.35, F=5.51, p<0.05*). Similarly, in the third group of materials, TFD and FC were significantly higher for F (footprint) (*TFD: M=4.42, SD=2.69, F=3.90, p<0.05; FC: M=15.44, SD=7.88, F=3.39, p<0.05*) compared to other pictures. Additionally, Time to First Fixation (TFF) was significantly shorter for V (victim) and O1. However, no significant differences in subjects' First Fixation Duration (FFD) were observed across any of the three groups of materials (*F=1.06, p<0.05; F=1.18, p<0.05; F=0.89, p<0.05*).

3.3. Between-group T-test analysis of Criminal Group and Innocent Group

As demonstrated in Tables 1, 2, and 3, between-group t-tests were conducted on eye-tracking data from two groups of subjects, the criminal group and the innocent group, focusing on three pictures: V (victim), K (knife), and F (footprint). The results indicated that the Fixation Count (FC) of the criminal group (*M=9.60, SD=4.30; M=9.60, SD=4.30; M=8.90, SD=5.69*) was significantly lower (*t=-1.32, p=0.10>0.05; t=-2.21, p<0.05; t=-2.06, p<0.05*) than that of the innocent group (*M=12.22, SD=4.35; M=11.9, SD=3.48; M=15.4, SD=7.88*). However, their First Fixation Duration (FFD) was greater than that of the innocent group: the difference in FFD between the two groups for F (footprint) was significant (*M=0.35, SD=0.47; M=0.25, SD=0.10; t=1.74, p=0.05*). The mean FFD for V (victim) (*M=0.29, SD=0.22; M=0.26, SD=0.18; t=0.31, p>0.05*) and K (knife) (*M=0.29, SD=0.22; M=0.26, SD=0.18; t=0.31, p>0.05*) was not significant, although the p-value was close to 0.05.

Additionally, as shown in Table 4, between-group t-tests for the Average Amplitude of Saccades (excluding invalid data > $|\pm 3\sigma|$) during the experiment revealed that the Average Amplitude of Saccades (AAS) of the criminal group (*M=6.03, SD=1.72*) was significantly smaller (*t=-1.89, p<0.05*) than that

ISSN 2616-5783 Vol.7, Issue 6: 189-194, DOI: 10.25236/AJHSS.2024.070630

of the innocent group (*M=6.82, SD=1.44*).

Table 1:AOIs in Group 1: the TFD,TFF, FFD and FC of the criminal group and innocent group.

	TFD (s)		TFF (s)		FFD (s)		FC (freq)	
	Criminal	Innocent	Criminal	Innocent	Criminal	Innocent	Criminal	Innocent
V	2.98	3.66	0.55	0.55	0.28	0.21	9.60	12.20
P1	2.93	2.82	1.34	1.35	0.20	0.23	10.80	11.20
P2	1.94	2.02	0.92	0.92	0.24	0.26	6.80	7.44
P3	2.74	2.55	0.52	0.55	0.31	0.31	9.50	10.10

Table 2: AOIs in Group 2: TFD, TFF, FFD and FC of the criminal group and innocent group.

	TFD (s)		TFF (s)		FFD (s)		FC (freq)	
	Criminal	Innocent	Criminal	Innocent	Criminal	Innocent	Criminal	Innocent
K	2.52	3.02	1.46	1.31	0.29	0.26	8.50	11.90
O1	2.88	3.81	0.27	0.24	0.26	0.19	10.20	15.20
O2	3.04	2.00	1.09	1.05	0.32	0.30	7.80	6.78
O3	2.11	2.17	1.28	1.42	0.23	0.24	8.00	9.22

Table 3: AOIs in Group 3: TFD, AFD, FFD and FC of the criminal group and innocent group.

	TFD (s)		TFF (s)		FFD (s)		FC (freq)	
	Criminal	Innocent	Criminal	Innocent	Criminal	Innocent	Criminal	Innocent
F	2.79	4.42	0.77	0.60	0.35	0.25	8.90	15.40
S1	2.94	2.42	1.41	1.43	0.25	0.25	8.80	9.44
S2	2.61	2.16	1.49	1.66	0.23	0.21	6.50	8.00
S3	2.59	2.21	0.71	0.73	0.22	0.18	7.70	9.44

Table 4:AAS of the criminal group and innocent group

	Criminal	Innocent
AAS (deg)	6.03	6.82

4. Discussion

This research aims to investigate the differences in gaze behaviors between criminals and innocents when viewing crime-related and non-crime-related images. The eye-tracking results could reveal individuals' attention bias among suspects with different identities. This study could facilitate the understanding of suspects' psychological activities and enrich methods for detecting more clues in criminal cases. Eye-tracking parameters, including Total Fixation Duration (TFD), First Fixation Duration (FFD), Fixation Count (FC), Time to First Fixation (TFF), and Average Amplitude of Saccade (AAS), were used for analyses. TFD and FC indicate the overall attention allocation, while FFD shows the initial attention. TFF reveals how quickly the subjects notice the corresponding AOI, and AAS reflects the subjects' psychological load. Statistical analyses were conducted among AOIs based on the above eye-tracking parameters.

The results of within-group ANOVA analyses showed that all subjects had longer attention to V (victim) and F (footprint) compared to other pictures in the same group. The reason why subjects paid more attention to the victim is because both groups are familiar with the victim and were informed a case happened. Hence both groups are sensitive to this AOI. Additionally, they had already accepted the background setting of "a murder has occurred" before viewing the material, triggering their top-down processing. This involved associations with past suspenseful movies, crime news, and clues related to the murder. While browsing through the material, when stimuli were the same or similar to their associative scenarios, they spent more time verifying the plausibility of their conjectures and attempting to obtain more clues or evidence from them. Hence, they also paid more attention to the footprints.

The first fixation duration (FFD) reflects the subjects' early processing stage[10]. Between-group analyses revealed that subjects in the crime group had significantly higher FFD for V (victim), F (footprint), and K (knife) compared to those in the innocent group. This suggests that the crime group experienced greater difficulty in early processing and engaged in more complex mental activities when viewing pictures related to the case cues. The time to first fixation duration (TFF) indicates the degree of attraction of the stimulus material to the subject or the subject's alertness level. The crime group exhibited a shorter TFF for V when viewing the first set of materials, indicating early attentional alertness to the target pictures. Given their involvement in the victim's death, the crime group naturally displayed a high

ISSN 2616-5783 Vol.7, Issue 6: 189-194, DOI: 10.25236/AJHSS.2024.070630

level of vigilance for victim-related information, a finding consistent with prior research[11] .

The total fixation duration (TFD) and fixation counts (FC) of the criminal group for pictures V, F, and K were significantly smaller than those of the innocent group, showing statistical differences in the T-tests of FC. In conjunction with the longer First Fixation Duration (FFD) of the criminal group, it is evident that subjects in this group recognized the crime-related nature of the pictures upon initial gaze, at the early response stage. Consequently, they deliberately ignored these pictures in the later response phase, leading to a much smaller FC. This suggests that the criminal group consciously avoided cue stimuli relevant to the case. These findings are consistent with those obtained by Kim et al. in the field of Concealed Information Test (CIT) involving Simulated Theft Scenarios[12]. The criminal group, motivated to avoid detection, refrained from devoting excessive attention to crime-related item information, while the innocent group, not implicated in the crime, displayed broader attention and did not avoid viewing crime-related information.

Furthermore, the analysis of the Average Amplitude of Saccades (AAS) using between-group t-tests indicates a significant difference between participants in the criminal group and the innocent group. Participants in the criminal group had significantly smaller saccade amplitudes than those in the innocent group. AAS reflects an individual's cognitive complexity and state of tension[13]. The criminal group, having accepted their identity as 'criminals' before the experiment began, was instructed to avoid being caught as much as possible during the experiment. Consequently, participants in the criminal group experienced a greater psychological burden and cognitive load, resulting in shorter AAS.

This study has limitations that could be addressed in future research. As a preliminary study, only 19 participants were involved. In future studies, recruiting more participants could yield more representative results. Participants in this study were recruited from Shanghai and represented a wide age range and diverse backgrounds. Further research could explore the impact of factors such as age, culture, and occupation, as a detailed breakdown could provide more specific insights. Finally, to enhance the participants' immersion in their assigned identities, future studies could incorporate VR or audio elements.

5. Conclusion

This present research investigated the difference in attention when viewing crime related and non-crime related images between criminals and innocent people. The participants of two groups were asked to view three groups of pictures. In each group, there was one crime related image and three non-crime related images. An eye tracker recorded participants' gazing behaviors during the process to identify their attention bias. The crime group showed longer FFD and shorter TFF, TFD, and FC to the crime-related stimuli in the experiment, indicating that they showed attentional vigilance and deliberate avoidance to these materials. In addition, the shorter AAS indicated a tense psychological state in the crime group subjects. This study provides new experimental design ideas for scholars who are constrained by the experimental environment in this field, and at the same time also providing a certain theoretical basis for the application of actual cases in the future.

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