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Using eye-tracking to understand user behavior in deception detection system interaction

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USING EYE-TRACKING TO UNDERSTAND USER BEHAVIOR IN DECEPTION DETECTION SYSTEM INTERACTION

by

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ABSTRACT

This research presents the analysis of data collected using eye-tracking devices on user interaction with a deception detection system. The differences between two groups of subjects, namely Innocent and Guilty, were compared, where Innocent subjects did not carry any explosive and hence, had nothing to hide in declaring objects that they were carrying whereas Guilty subjects had to lie to deceive the system. The results indicate that there is no significant difference in pupil dilation between the Innocent and Guilty subjects. However, the amount of fixations on the empty spaces of slides containing an explosive image can be used to identify Innocent versus Guilty subjects where subjects in the Guilty condition were more likely than subjects in the Innocent condition to focus on the empty spaces between the images of objects on those slides.

Keywords: Eye tracking, cognition, deception detection, visual behavior, data mining, iMotion attention tool.

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1. INTRODUCTION

Making accurate judgements is an important aspect of investigative interviewing (Raskin, Honts, & Kircher, 2013). Detection of deception is an important aspect for national and personal security (Deokar & Madhusudan, 2005). The recent Paris attack and shooting attack at a nightclub in Orlando, Florida show the importance of national and personal security. Are there ways to stop these attacks?

As Benjamin Franklin said, “An ounce of prevention is worth a pound of cure.” It is important to identify the threats in advance rather than waiting for attacks to happen. Hidden information by individuals is the most important cue and also the most difficult information to retrieve or detect as individuals may try to hide information intentionally (Twyman, Lowry, Burgoon, & Nunamaker Jr, 2014b). The lack of skill and control on procedures being followed as well as human errors are potential causes that make the retrieval of such information complex (Twyman, Elkins, Burgoon, & Nunamaker, 2014a).

Facial analysis, eye tracking, and concealed information online tests are a few of the technologies which can be used to detect deception (Twyman et al., 2014a). Eye gaze movements can be used to analyze user behavior in online environments (Klami, 2010). Visual attention depends on the task being performed by an individual (Gidlöf, Wallin, Dewhurst, & Holmqvist, 2013). The data collected by eye tracking devices can be used to analyze the visual behavior or characteristics of individuals in different conditions.

The objective of this research is to analyze the data collected by eye tracking to identify potential threats. In this research, the eye tracking data for a deception detection system collected by Twyman et al. (2014b) is used to analyze the visual behavior of individuals in different conditions (i.e., Innocent and Guilty). This exploratory research summarizes the analysis performed on the data.

This paper is organized in the following manner. A literature review is presented on research in eye tracking and the psychology of eye gaze. Different types of analysis were carried out on the data and the results are reported. The theoretical explanations underlying the results of the analysis are also provided. The thesis concludes with limitations and future scope for research.

2. LITERATURE REVIEW

Safeguarding of national security and personal tasks is a highly challenging task (Deokar & Madhusudan, 2005). Recent attacks in various countries, including the United States, show that there is not enough security in place and they warrant more research in the security field. Most commonly used techniques are behavioral analysis interviews (BAI), comparison question tests (CQT), and concealed information tests (CIT) (Vrij, 2008). Changes in the electric waves on the skin are used as measurement for CIT (Ambach, Bursch, Stark, & Vaitl, 2010). New tools to assist humans are developed continuously based on the research in this field (Vrij, 2008).

Various techniques are summarized in Table 2.1 along with their descriptions (Ambach et al., 2010; Masip, Herrero, Garrido, & Barba, 2011; Twyman et al., 2014b).

Table 2.1. Summary of techniques used for deception detection

Technique	**Measurement**
Comparison question test (CQT)	Changes in electric signals are measured to detect deception
Behavioral analysis interview (BAI)	Using behavior provoking questions to observe differences in verbal and non-verbal responses
Concealed information test(CIT)	Comparisons of response for relevant and irrelevant items

Although the above mentioned techniques are widely used, they are believed to lack accuracy because all the above techniques need human interventions (Masip et al., 2011). Some of the drawbacks are listed in the Table 2.2.

Table 2.2. Drawbacks of techniques used for deception detection

Technique	**Drawbacks**
Comparison question test (CQT)	Time consuming and low validity
Behavioral analysis interview (BAI)	Time consuming
Concealed information test (CIT)	Impact of counter-measures

The CQT theory states that guilty persons tend to react more to relevant questions whereas innocent persons tend to react to comparison questions (MacNeill, Bradley, Cullen, & Arsenault, 2014). A research study has shown that CQT is 90% accurate in identifying guilty and innocent persons but it is very time consuming to interview every person (Offe & Offe, 2007). However, the main criticism faced by CQT is the absence of relevant theory on individuals' behaviors (Ben-Shakhar, Gamer, Iacono, Meijer, & Verschuere, 2015).

The behavior of individuals based on their intention will change and in most of the cases, the guilty person or person in guilt tends to manipulate his or her behavior (Masip & Herrero, 2013). This can be identified through the use of behavioral analysis interviews (BAI). However, research shows that BAI may not be accurate (Vrij, Mann, & Fisher, 2006). The study by Vrij et al. (2006) shows us that guilty persons are more helpful than innocent persons which is opposite or contradictory to the BAI theory. In the study conducted by Masip et al. (2013), both Guilty and Innocent groups would tend to look innocent and the Guilty group even used countermeasures and were successful in convincing the interviewer that they were innocent. Much research is needed in this area to validate the BAI theory (Horvath, Blair, & Buckley, 2008) and better methods are needed for identification and evaluation.

Both CQT and BAI techniques depend heavily on the capability of the interviewer in identifying the culprit (Twyman et al., 2014b). There is a need for a technique which is less dependent on the interviewer and the concealed information test (CIT) is a possible solution for it (Twyman et al., 2014b). The CIT technique is considered a more valid approach when compared to CQT and BAI (Ben-Shakhar & Elaad, 2003; Iacono & Lykken, 1997). Japan uses the CIT approach widely in crime investigations (Ogawa, Matsuda, & Tsuneoka, 2015). This technique takes minimal time to complete the process and can be effective when used with invasive sensors (Twyman et al., 2014b). However, research on non-invasive sensors is also warranted. Twyman et al. (2014a, 2014b) conducted experiments combining CIT, eye tracking and facial analysis to analyze the behavior of guilty and innocent participants in a mock crime scenario.

Research shows that taking cognition into account will improve the accuracy of lie and truth detection (Granhag, Vrij, & Verschuere, 2015). One of the recent trending non-invasive technology is eye tracking. Eye tracking is one of numerous psychophysiological techniques (Pak & Zhou, 2013). The movement of an eye can be used to understand the cognitive process of an individual (Just & Carpenter, 1976). Visual attention depends on the task being performed by an individual (Gidlöf et al., 2013). Researchers advocate that there is a relationship between the cognitive process of what we see and our eye gaze movements (Fleisher & Gordon, 2010; Zulawski, Wicklander, Sturman, & Hoover, 2001). Measurements like pupil dilation, revisit time, response time etc. can be used in understanding the cognitive response of an individual.

Using infra-red camera on the eye tracking devices, the pupil dilation and gaze movements can be tracked (Bhuvaneswari & Satheesh Kumar, 2015). Stimuli is first processed by the peripheral attention (Twyman et al., 2014b). Eyes tend to move towards the stimuli if it is significant to an individual (Twyman et al., 2014b). Lying increases the cognitive load since it involves making up a story and remembering it through the test (Granhag et al., 2015). Innocents do not have to hide their inner feeling whereas guilty suspects have to hide their inner feelings (Granhag et al., 2015). According to the defensive responsive theory, guilty behavior tends to escape or avoid the situation (Gray, 1987).

Analysis of eye movements can uncover cognition in humans while performing any task (Merkley & Ansari, 2010). Study conducted by Twyman et al. (2014b) used CIT with eye tracking to assess the individuals' conditions. The results show that individuals, in the Guilty condition, tend to focus on a safety point when the stimuli contained relevant objects (Twyman et al., 2014b). The study also reported that defensive behavior is not affected by time (Twyman et al., 2014b). However, this could change with constant exposure to the stimuli. Lying takes a little more time when compared to truth telling

(Walczyk, Roper, Seemann, & Humphrey, 2003). The results of a study show that the Guilty participants responded quickly to the statements about a theft in which they were involved than to the neutral statements (Raskin, Honts, Kircher, & ebrary, 2014). However, the Innocent participants responded more quickly to all the statements when compared to the Guilty participants (Raskin et al., 2014).

3. RESEARCH METHODOLOGY

The experiment was conducted by Twyman et al. (2014b) and is described as follows.

3.1. EXPERIMENTAL DESIGN

The deception detection system was evaluated using a lab experiment. A building security screening context was chosen to simulate the experimental conditions. Students were recruited as participants for this study as finding individuals who have the intention to commit a crime was challenging.

3.2. EXPERIMENT PROCEDURES

The participants were divided into two conditions, namely Guilty and Innocent (I), with greater number of participants in the Guilty condition. The intention of having a greater number of participants in the Guilty condition is to further classify them into four groups with equal participants in each sub-group. Also, the number of participants in each sub-group is equal to the number of participants in the Innocent condition. The four sub-groups under the Guilty condition are: 1. Guilty with no training on countermeasure (G), 2. Guilty with training on mental countermeasure (CM), 3. Guilty with training on physical countermeasure (CP), and 4. Guilty with training on all, i.e., both mental and physical, countermeasures (CA). The participants were instructed to pack a bag with standard items such as books, clothes etc. and deliver it to another person, who is inside the building. The building is secured and the participant must pass through the security checkpoint to deliver it, since the contact is located in the safe part of the building. The participants in the Guilty condition constructed and packed a mock improvised explosive device (IED) in the bag along with the standard items which were common to all the participants. A room, as shown in the Figure 3.1, was chosen only for screening the participants and arrangements were made in such a way that there is no distraction for the participant.

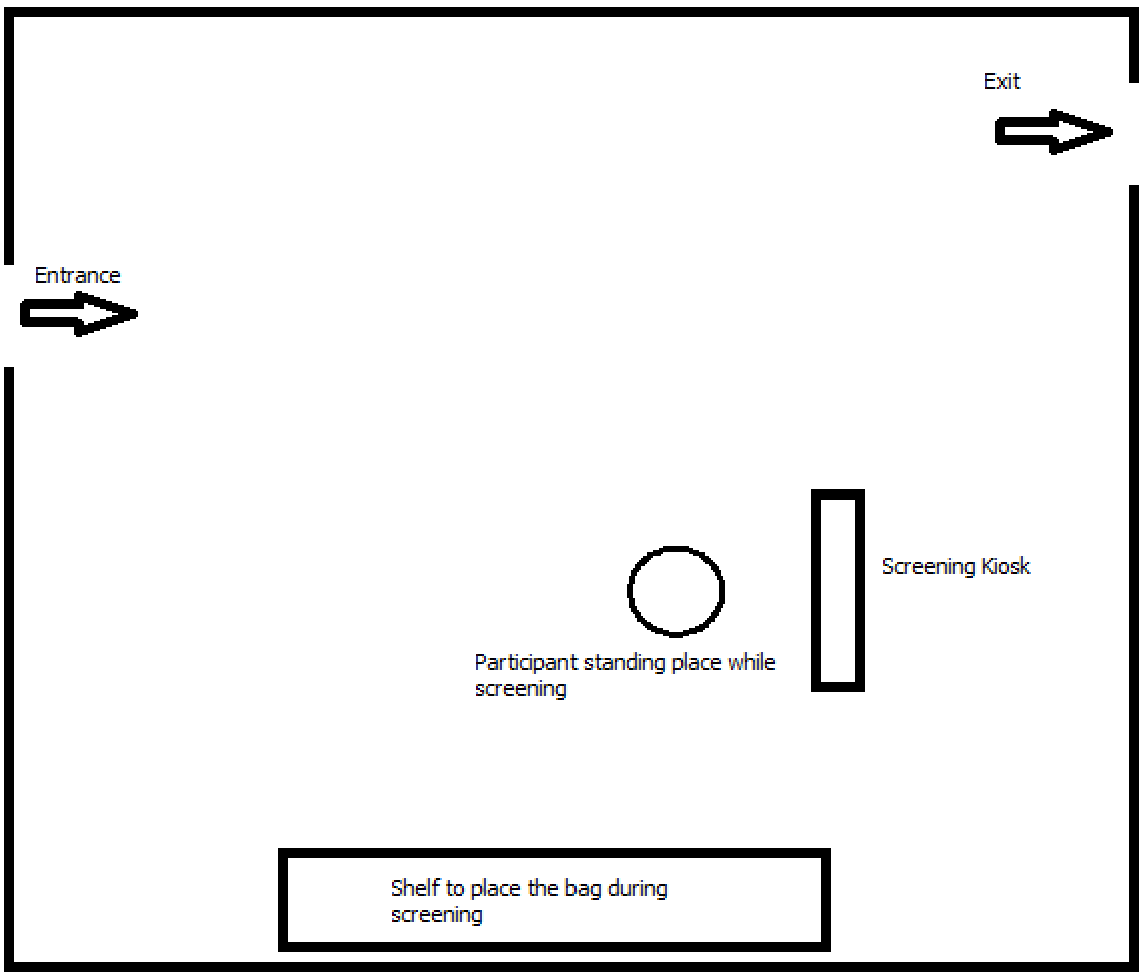
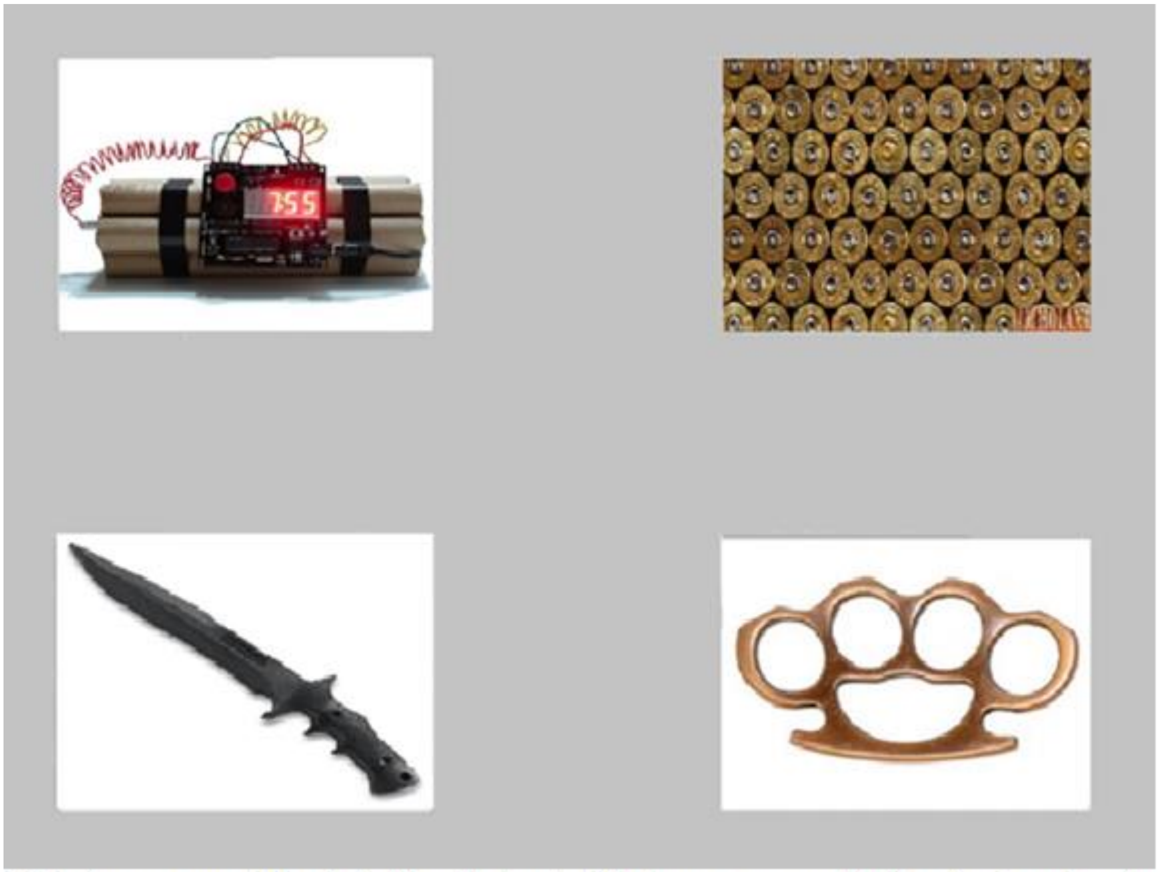


Figure 3.1. Screening room layout

To enter the safe part of the building, the participants must answer the questions verbally, with Yes or No, asked by the second-generation Automated Screening Kiosk (ASK). A brief introduction about the ASK is given to the participant during sign-up. The participants were also informed that if they pass through the screening room successfully without being caught, an amount of $20 is awarded. After the participants complete the screening process, they were instructed to answer the post-experiment survey. They were later explained that the whole task is just an experiment and they did not do any illegal activity during the experiment.

At the ASK, the interview proceeded as mentioned: When the participant stepped near the ASK system, voice instructions were given by the system and the individual was guided to undergo a 15-second process of calibration. Following this, an avatar would appear on the screen and asked “Are you carrying any of these items?” Immediately after the question, four banned items were displayed on the screen for a duration of five seconds. An example of the items displayed on the screen can be seen in Figure 3.2.

The questioning process was repeated five times and an IED was displayed only once on the screen. This sequence was repeated three more times with changes in the position of the images between different quadrants. On the whole, the question was asked 20 times and it took 4 minutes to complete the process. At the end, the participant was instructed to fill out the post experiment questionnaire and was told that this was just an experiment.



* The images are only for illustration. Black and white images were used in the actual experiment.

Figure 3.2. Sample screen

4. ANALYSIS METHOD

This research aims to analyze the data collected using eye tracking tools and various methods such as gaze patterns and heat maps. The study is limited to the analysis of the participants under the Guilty (G) and Innocent (I) conditions. Different measures based on the heat maps were used to analyze attention, respondent count, time spent on the area of interest, and the fixation sequence.

The data was saved in four data frames which were eye tracking data, participant mapping information, slide mapping information, and image mapping information. Eye tracking data contains the X and Y coordinates of each participant's gaze for each slide along with pupil diameters of the left and right eyes. The participant data frame stores information about the participant's condition (i.e., G or I), and the date of participation along with the rotation of slide sequence for each participant. The participant data frame also has information on whether the participant was disqualified and the reason for disqualification if so. Participant and eye tracking data can be mapped using the participant ID. Information about slide sequence for each rotation and critical slide (i.e., the slide that includes an explosive) is stored in the slide mapping data frame. The slide mapping data frame also stores information about the quadrant in which the image of an explosive is displayed in the critical slide. Slide number column maps the eye tracking data with slide mapping data frame. Image mapping data frame stores the information about the objects displayed on each slide. It also stores the quadrant in which the object was displayed in each slide. SlideID is used to map the image mapping data frame with the slide mapping data frame.

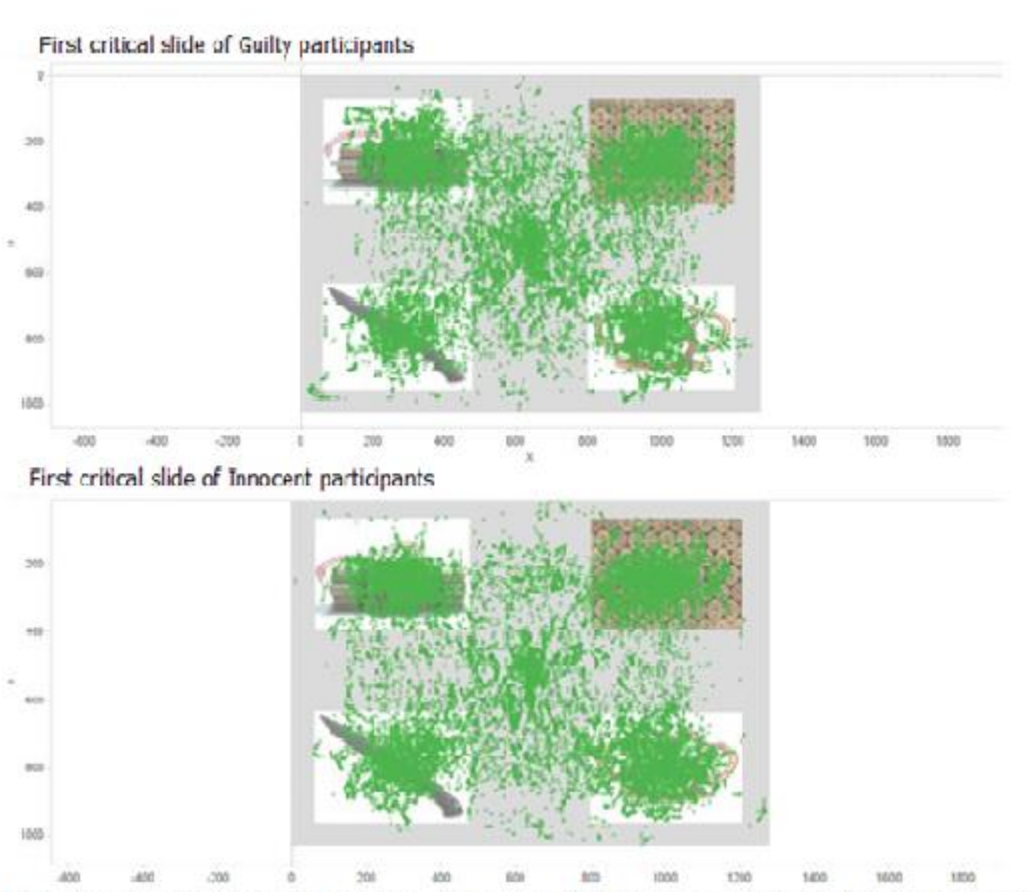
R was used to read the data and generate suitable subsets after the data was cleansed. The subsets were analyzed using the iMotions attention tool, IBM SPSS statistics, and tableau. The data was fed into the iMotion attention tool, a tool to analyze eye tracking data, and different measures like fixation points, area of interest, heat maps, respondent count, and time spent were compared and assessed. The raw data was taken and formatted into meaningful subsets using R programming. The subset data was then loaded into iMotions to generate metrics like fixation points, area of interest, heat maps, respondent count, and time spent.

5. ANALYSIS AND RESULTS

The raw data was loaded into the R Studio and suitable subsets were made. The outlying data points, which were lying outside the screen were filtered out. The next step was to remove the participants who were disqualified in the main study. 6 out of 71 participants in Guilty and Innocent conditions were disqualified. Some of the reasons for disqualifying participants include failure of eye tracking calibration, problems in following the experimental procedures, answering Yes when the bomb was displayed. The final data set contains 32 participants in the Guilty condition and 33 in the Innocent condition. The data comprising the disqualified participants was filtered out of the data set. In each rotation, the images displayed were the same but were placed in different quadrants. The data points were rotated in such a way that the placement of the images is the same in all rotations. The next step involves sub-setting the data based on the condition, rotation and sequence. Scatter plots were plotted using the X and Y coordinates of the eye gaze for each critical slide in each sequence. For each condition, four graphs are plotted as the critical slide was displayed four times. The images shown in this study were generated with the help of the slide and image mapping information from the secondary data. Figure 5.1 shows the scatter plots comparing data points on critical slide 1 for Innocent and Guilty conditions.

The scatter plots show that the number of data points between the images is higher for participants in the Guilty condition than for participants in the Innocent condition for all four critical slides, which refer to slides that display the image of an explosive. According to the spotlight theory of attention, objects on the screen can be recognized using the peripheral or covert attention i.e., through the corner of the eyes.

Previous research shows that an object or changes in an object can be detected with the help of our peripheral vision (Schall & Bergstrom, 2014; Vater, Kredel, & Hossner, 2016). Emotional information can be recognized with peripheral vision (Calvo, Avero, & Nummenmaa, 2011). The guilty participants identified the explosive displayed on the kiosk screen with their peripheral vision and hence, there are more data points near the images of the objects on the screen. This observation can be observed in all scatter plots comparing the Guilty condition and the Innocent condition.



* The images are only for illustration. Black and white images were used in the actual experiment.

Figure 5.1. Fixation plot for critical slide in the first sequence (G vs I)

Another reason for having more data points between the images could be due to the saccades. With a saccadic movement, a person can make easy recognition of an object (Dandekar, Ding, Privitera, Carney, & Klein, 2012). Higher number of data points between the images for participants in the Guilty condition could be due to saccadic movement of eyes. Research shows that the initial saccadic movement was not affected by the condition of the participant (Twyman et al., 2014b). The study also shows that after detecting the critical item in the foil, participants avoided looking at the object (Twyman et al., 2014b). However, scatter plots show that saccadic movements were made by the participants not only near the object of detection but also on the entire screen. Figures 5.2, 5.3 and 5.4 shows the scatter plots for critical slide 2, critical slide 3 and critical slide 4 respectively.

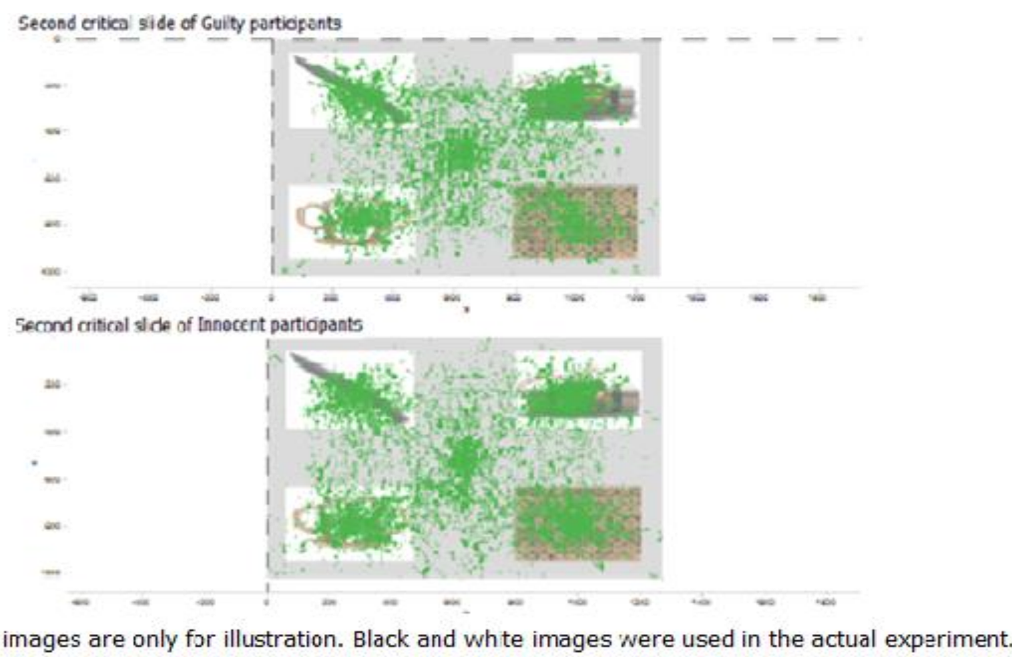
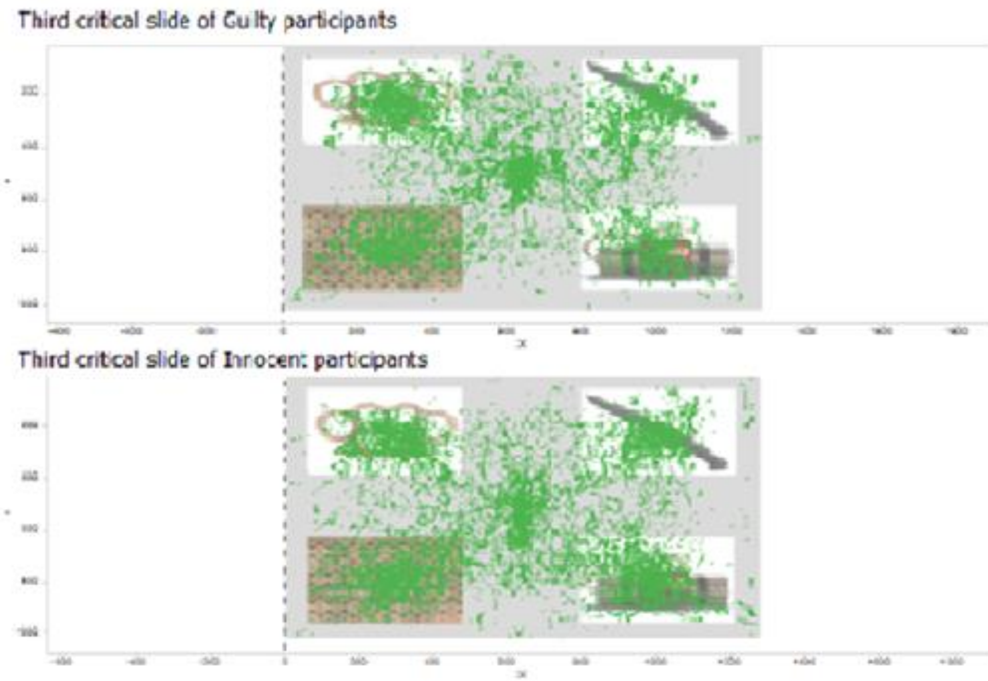


Figure 5.2. Fixation plot for critical slide in the second sequence (G vs I)



* The images are only for illustration. Black and white images were used in the actual experiment.

Figure 5.3. Fixation plot for critical slide in the third sequence (G vs I)

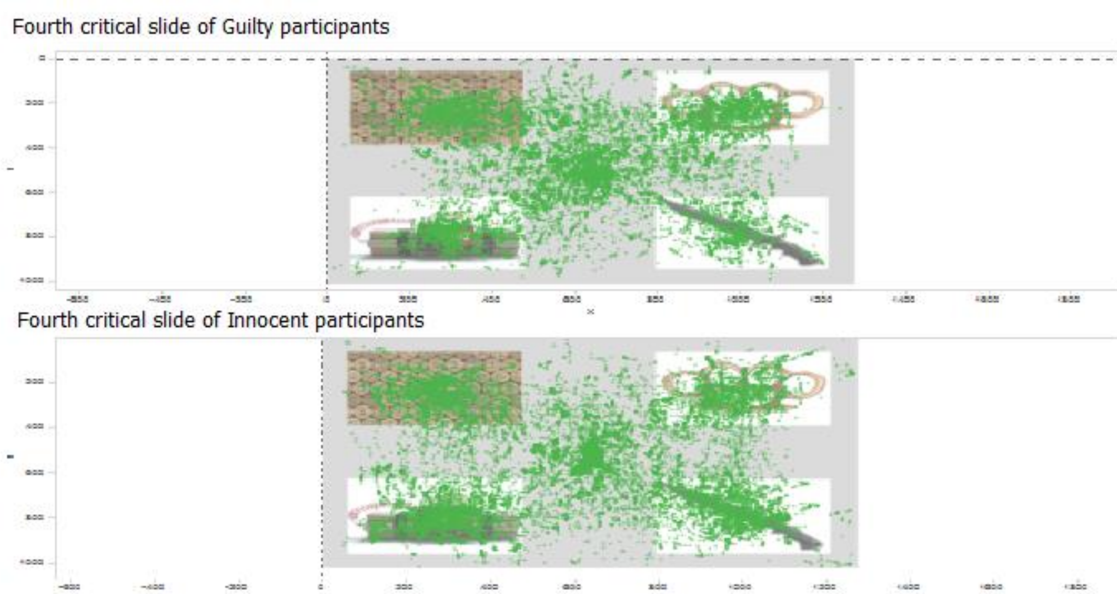
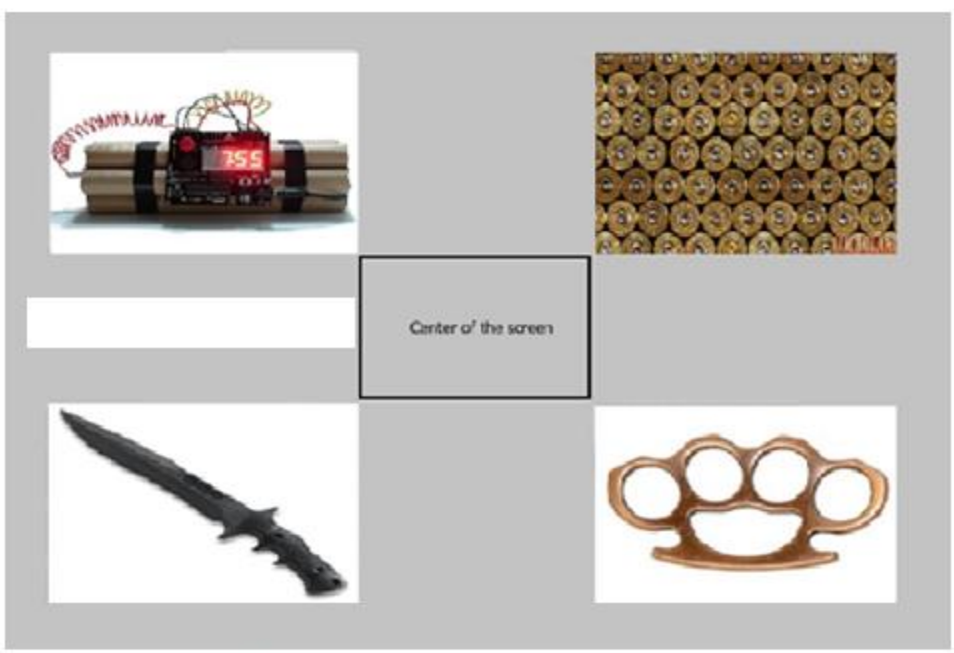


Figure 5.4. Fixation plot for critical slide in the fourth sequence (G vs I)

The next part of the analysis was performed using the eye tracking module in the iMotion attention tool. Data was prepared in a format which the module could accept and analyze. The center region (see Figure 5.5) is defined as the area in the center region of the screen which is equidistant from all the images on the screen. The software generates measures, such as fixation counts, after eliminating the saccades. The first assessment was to analyze the heat maps for all the critical slides for participants in the Guilty and Innocent conditions and compare them. Figure 5.6 show a comparison of all the critical slides in sequence for all the guilty participants. When the heat maps of critical slides for the guilty participants are compared to the heat maps of critical slides for the innocent participants (see Figure 5.7), it was observed that the Guilty participants tend to look at the center region of the screen more than the Innocent participants.



* The images are only for illustration. Black and white images were used in the actual experiment.

Figure 5.5. Slide showing the center of the screen

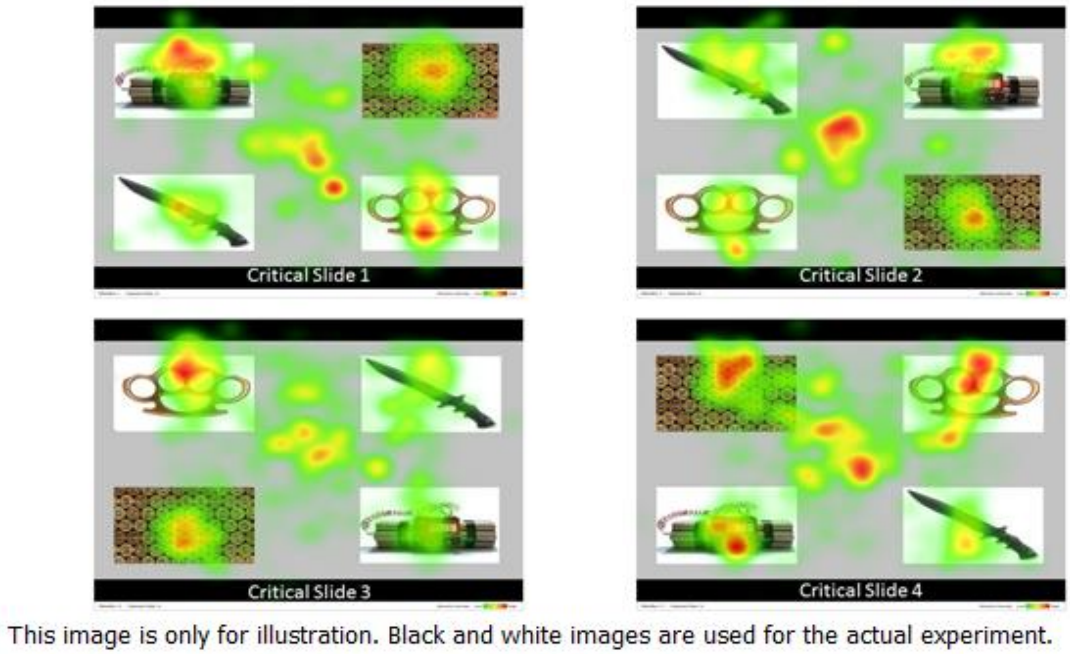


Figure 5.6. Heat maps of critical slides for Guilty participants

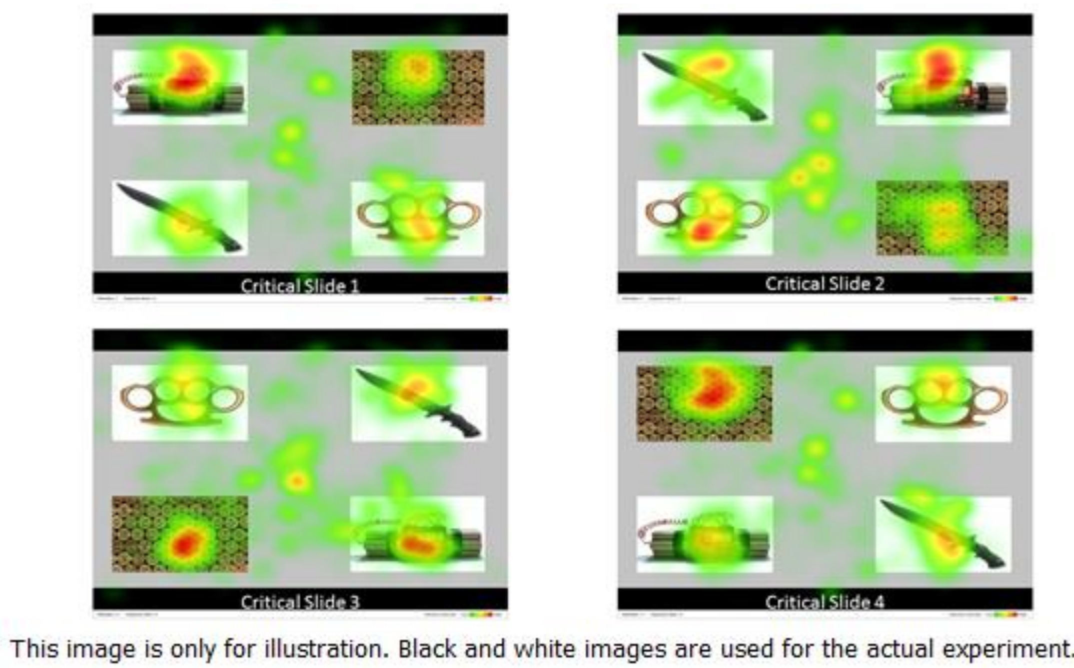


Figure 5.7. Heat maps of critical slides for innocent participants

Table 5.1 shows the counts of participants whose attention was at the center of the screen (i.e., second and third rows) and on the image of the explosive (i.e., fourth and fifth rows) in all the critical slides for participants in both the Guilty condition and the Innocent condition.

Table 5.1. Number of participants who focused at the center vs explosive

Area of Interest	Condition	Critical slide 1	Critical slide 2	Critical slide 3	Critical slide 4
Center	**G**	13	16	12	14
	I	3	7	5	4
Explosive	**G**	33	30	26	22
	I	31	30	28	31

A significant difference was found in the number of participants who focused on the center region of the screen in the Guilty condition and the Innocent condition. The results of the chi-square test that assessed whether there is a difference in the number of fixations at the center region of the screen between the Guilty and Innocent conditions are as follows: $\chi^2 = 8.706$; $p = 0.003$ (<0.05) for critical slide 1, $\chi^2 = 5.89$; $p = 0.015$ (<0.05) for critical slide 2, $\chi^2 = 4.20$; $p = 0.040$ (<0.05) for critical slide 3, and $\chi^2 = 8.12$; $p = 0.004$ (<0.05) for critical slide 4.

The same analysis was carried out to compare the number of participants who focused on the explosive in the Guilty condition and the Innocent condition, and no significant difference was found in the first three critical slides: $\chi^2 = 2.0$; $p = 0.157$ (>0.05) for critical slide 1, $\chi^2 = 0.185$; $p = 0.667$ (>0.05) for critical slide 2, and $\chi^2 = 0.15$; $p = 0.699$(>0.05) for critical slide 3. However, there is a significant difference in the fourth critical slide: $\chi^2 = 6.848$; $p = 0.009$ (<0.05) for critical slide 4. Table 5.2 shows the percentages of fixations at the center region of the screen for participants in the Guilty and Innocent conditions. When the percentages of fixations on the critical slides for all the participants in the Guilty and Innocent conditions were compared, it is observed that

Table 5.2. Summary of participant attention (center region)

Condition	**Percentage of fixations in the center region**			
	Critical slide 1	**Critical slide 2**	**Critical slide 3**	**Critical slide 4**
G	7.8 %	11.94 %	6.43 %	7.47 %
I	1.04 %	4.21 %	3.98 %	1.3 %

the percentage of fixations at the center region of screen is more than 6% of the total fixations in all the critical slides for guilty participants, whereas it is less than 5% of the total fixations in all the critical slides for innocent participants.

Empty space between the images is the space between the images displayed on the slide along with the center area of the slide as shown in Figure 5.8. Using the iMotions attention tool, the number of fixations on the center region of the screen and the empty spaces on the critical slides is generated for all participants. The number of fixations on the center region of the screen on all critical slides for participants in the guilty condition and the innocent condition is shown in Table 5.3.

Table 5.3. Number of fixations at the center of the screen

Condition	**Critical slide 1**	**Critical slide 2**	**Critical slide 3**	**Critical slide 4**
G	44	50	44	55
I	13	21	30	13

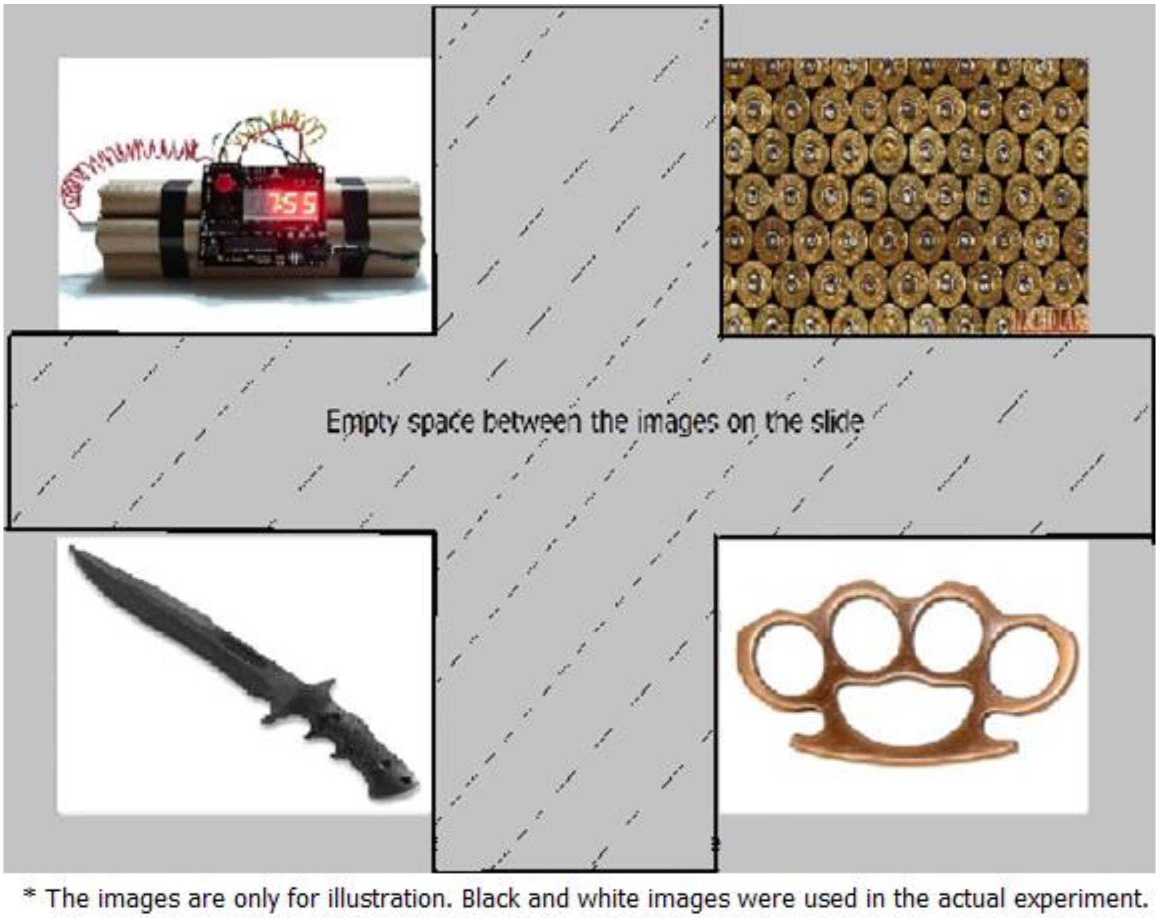


Figure 5.8. Slide showing the empty space between the images on the screen

The number of fixations in the empty space on the screen for all critical slides for participants in the Guilty condition and the Innocent condition is shown in Table 5.4.

Table 5.4. Number of fixations in the empty space of the screen

Condition	**Critical slide 1**	**Critical slide 2**	**Critical slide 3**	**Critical slide 4**
G	104	121	125	125
I	52	79	90	52

The fixation counts in Tables 5.3 and 5.4 are between-subject measures. Hence, the independent sample t-test was used to analyze the data in Table 5.3 and Table 5.4. A significant difference ($t = -5.98$; $p = 0.001 < 0.05$) was found between the number of fixations at the center region of the screen for participants in the Guilty condition and the Innocent condition. There is also a significant difference ($t = -4.64$; $p = 0.004 < 0.05$) between the number of fixations on the empty space of the screen for participants in the Guilty condition to and the Innocent condition.

The statistics from the independent-samples t-test and the chi-square test as well as the heat maps for critical slides suggest that participants in the Guilty condition tend to focus more on the empty space of the screen when compared to participants in the Innocent condition. The reason that there are less fixations on the empty space of the screen in the Innocent condition is that they were not exhibiting defensive behavior.

The chi-square test was performed on the number of participants who fixated on the explosive image in the Guilty condition versus the Innocent conditions and the results show that there is a significant difference only for the fourth critical slide. The χ^2 values for the critical slides with the explosive image as the area of interest are: $\chi^2 = 2.0$; $p = 0.157$ (>0.05) for critical slide 1, $\chi^2 = 0.185$; $p = 0.667$ (>0.05) for critical slide 2, and $\chi^2 = 0.15$; $p = 0.699$(>0.05) for critical slide 3, $\chi^2 = 6.848$; $p = 0.009$ (<0.05) for critical slide 4.

Pupil dilation was also compared by taking the average pupil diameters for comparisons.

- Paired sample t-test results for the pupil diameters of guilty participants with gazes on the explosive image versus outside the explosive image suggest there is no difference between them ($t = -0.357$; $p = 0.724 > 0.05$).
- Independent-sample t-test results for the pupil diameters of participants in the Guilty condition and the Innocent condition when gazing on the explosive image also yield no difference ($t = 0.204$; $p = 0.839 > 0.05$).
- Paired sample t-test results for the average pupil diameters of guilty participants when gazing on the critical slide, i.e., the slide on which the image of an explosive is displayed, versus on slides in which there is no explosive image also suggest there is no difference between them ($t = -1.263$; $p = 0.216 > 0.05$).

The analysis revealed that there is no significant difference in all the three cases. Hence, a conclusion is made that it may be difficult to use pupil dilations to detect deception.

The percentages of fixations on the explosive image by guilty participants decreased with repetitions of explosive in subsequent critical slides (see Table 5.5). The defensive responses of the participants made them avoid looking at the explosive stimuli (Twyman et al., 2014b). However, the percentage increased in the last or fourth critical slide.

Table 5.5. Fixation percentage on the explosive (G vs I)

Condition	**Percentage of fixations on the explosive**			
	Critical slide 1	**Critical slide 2**	**Critical slide 3**	**Critical slide 4**
G	30.65 %	21.94 %	14.4 %	19.2 %
I	36.1 %	27.72 %	30.1 %	18.75 %

6. CONCLUSION AND LIMITATIONS

The analysis results show that gaze fixations can be used as one of the non-invasive method to detect deception. Results show that the Guilty participants look more at the center and empty spaces between the images than the Innocent participants for all the critical slides. However, there is no significant difference in the number of participants who looked at the explosive in both conditions. The reason for having a greater number of participants in the Guilty condition gazing at the center and empty spaces could be due to recognition of the object images with their peripheral vision (Schall & Bergstrom, 2014; Vater et al., 2016) and the saccadic eye movement. The experiment conducted by Twyman et al. (2014b) show that significantly more amount of time was spent (4.5 % more than the Innocent participants) looking at the safety point (i.e., the center of the screen) by the Guilty participants. This was supported by the analysis performed in this thesis showing that there are greater number of fixations at the center region of the screen for the Guilty participants than the Innocent participants. When empty space between the images was taken into consideration, there were more fixations made by the Guilty participants in the empty space than the Innocent participants. The peripheral vision can be identified as one of the methods used for defensive behavior and the Guilty participants are motivated to exhibit defensive behavior.

There is no significant difference in the average pupil diameter of participants in the Guilty condition and the Innocent condition ($t = 0.204$; $p = 0.839 > 0.05$) which contradicts the results from the study conducted by Raskin et al. (2014). The Guilty participants spent less time reading the statement which were answered deceptively than

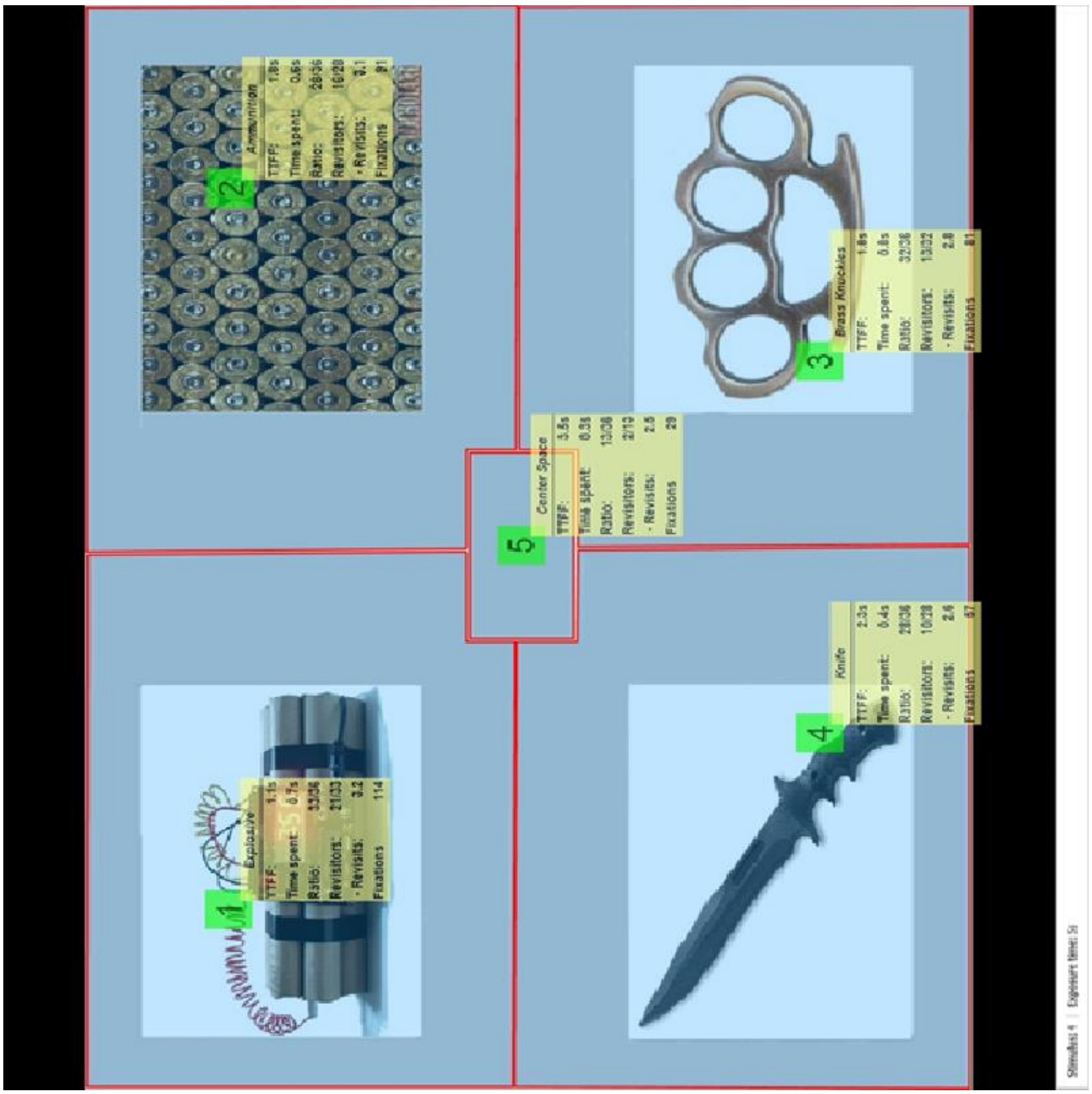
Innocent participants (Raskin et al., 2014). There was a greater increase in pupil diameters when they were reading those statements (Raskin et al., 2014). The reason for the somewhat contradicting results in the current analysis could be due to the time constraint and the measurement of pupil diameters when participants were reading the statement. Since the time taken by the participants to say No was not measured and the time of exposure of the slide was constant throughout the experiment, there was no significant difference in the pupil diameter. Another reason for having no significant difference in the average pupil diameter for participants in the Guilty condition and Innocent condition could be due to countermeasures, i.e., the action performed by the Guilty participants to conceal information and manipulate the response (Dehais, Causse, & Tremblay, 2011).

Future research can be carried out to analyze the data collected for participants in the three countermeasure conditions, i.e., mental countermeasure (CM), physical countermeasure (CP) and all countermeasure (CA) in the analysis. Techniques such as stress inoculation training has been shown to improve deceptive performance, even when one is under stress (Stetz et al., 2007). In other words, countermeasure techniques may assist individuals to conceal stress, deceive the system, and be successful in lying. Hence, analysis on countermeasures should be carried out in future studies. Another limitation for this study is that the accuracy of the device is not perfect. There is a possibility that the fixations lie slightly beside the point which was captured by the eye tracking device. However, there is vast development in eye tracking technology that will lead to improvements in accuracy in future studies.

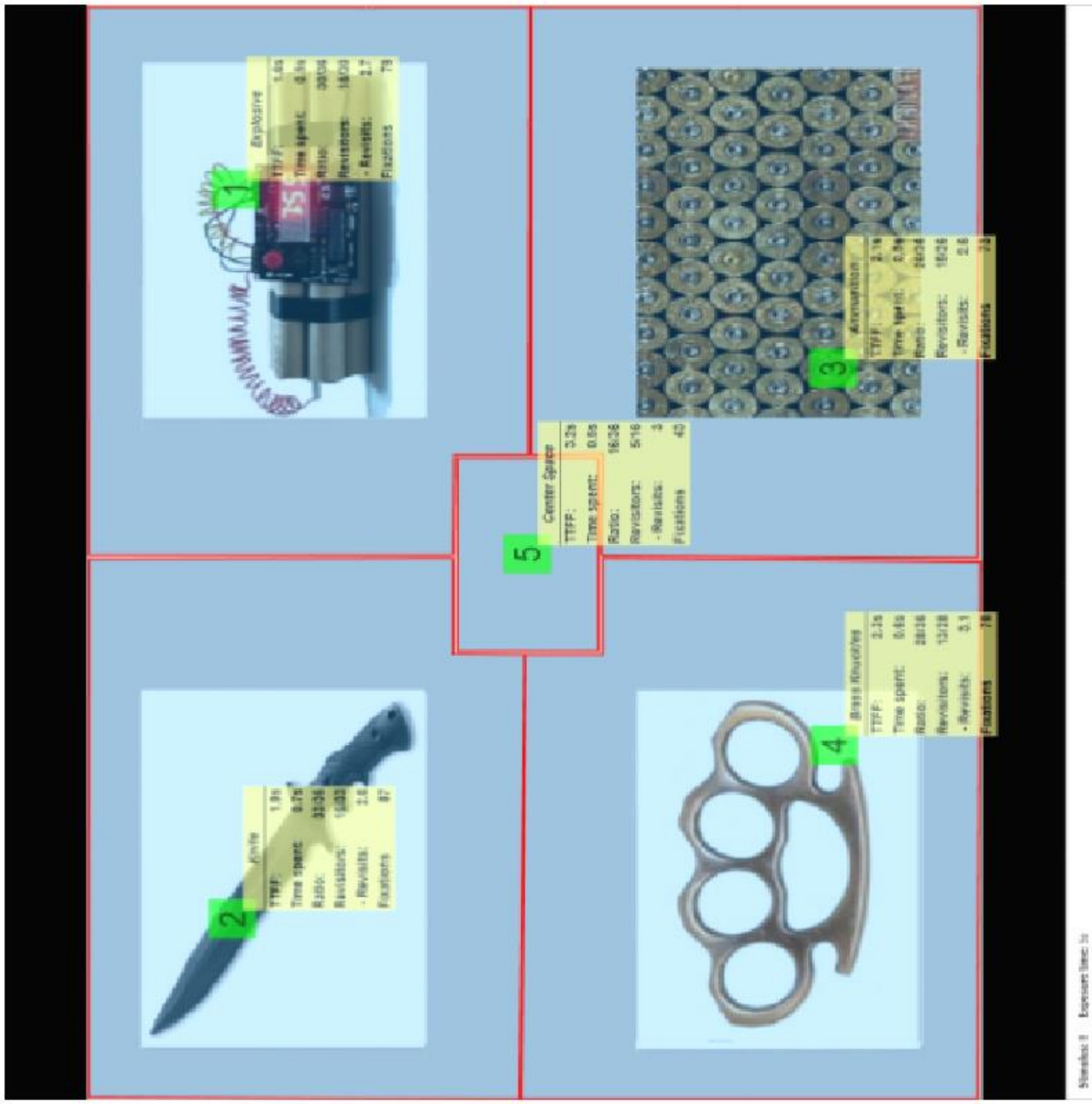
APPENDIX

Area of Interest plots generated by iMotions eye tracking module

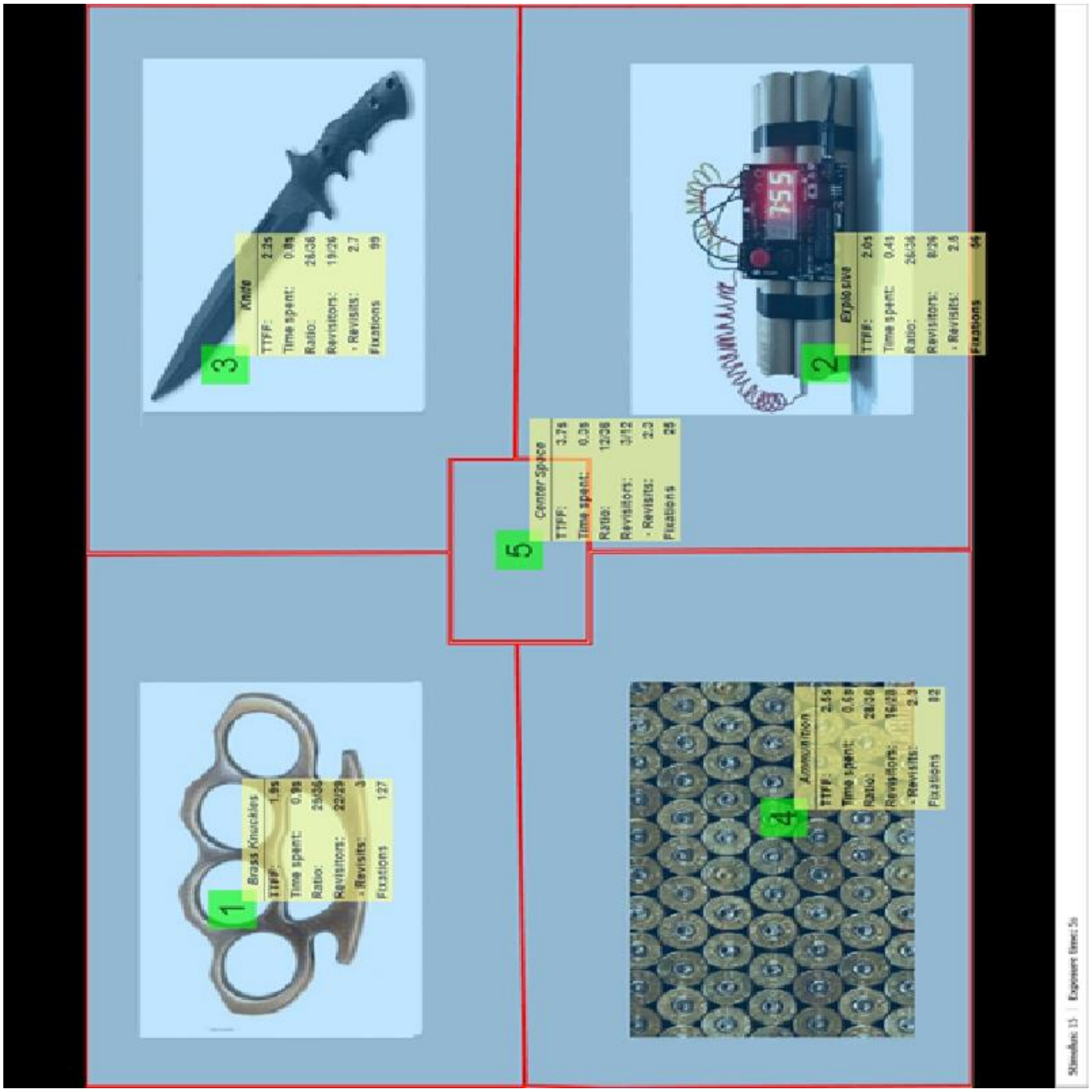
AOI Plot for the critical slide in sequence 1 for Guilt participant:



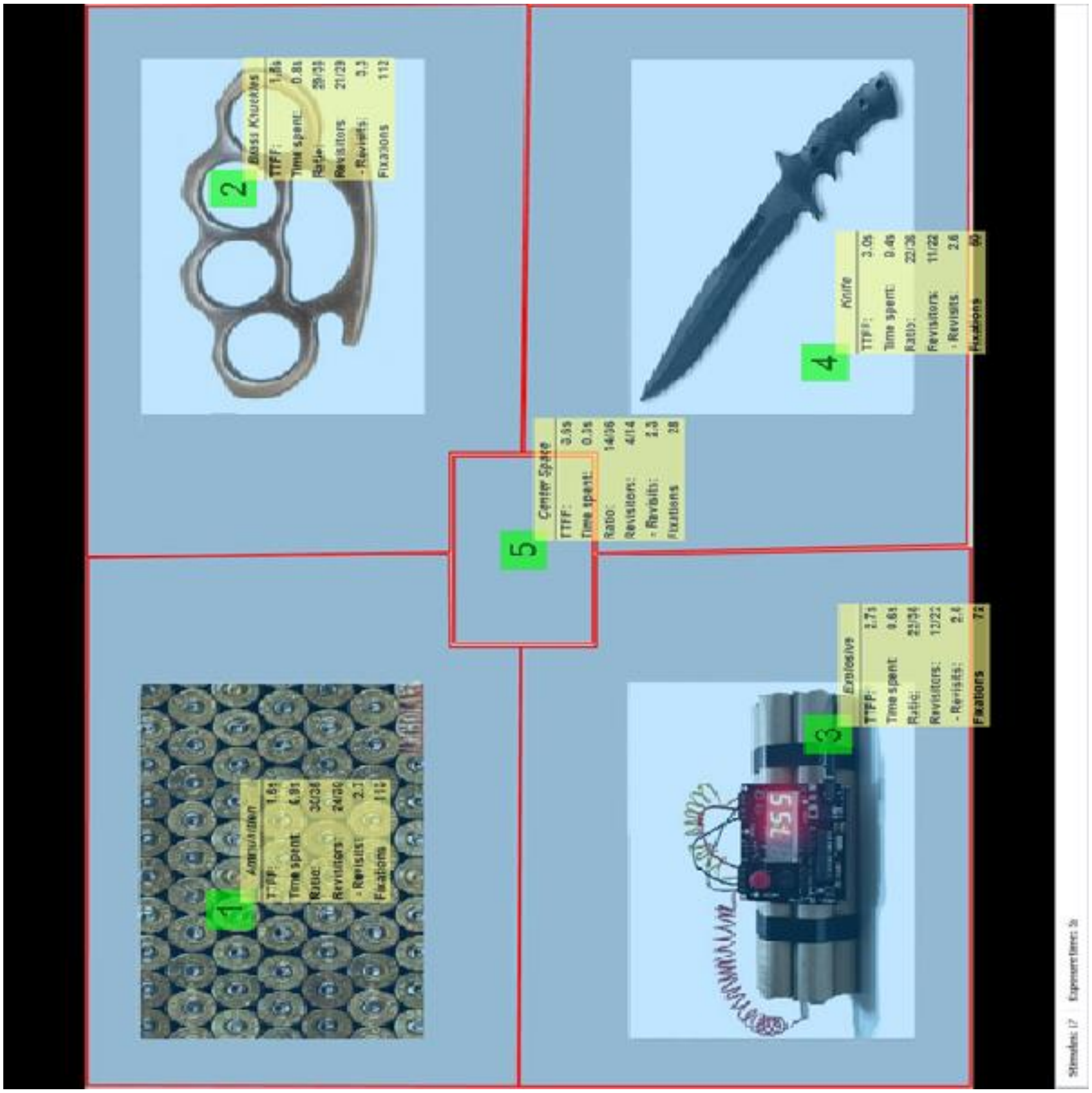
AOI Plot for the critical slide in sequence 2 for Guilt participant:



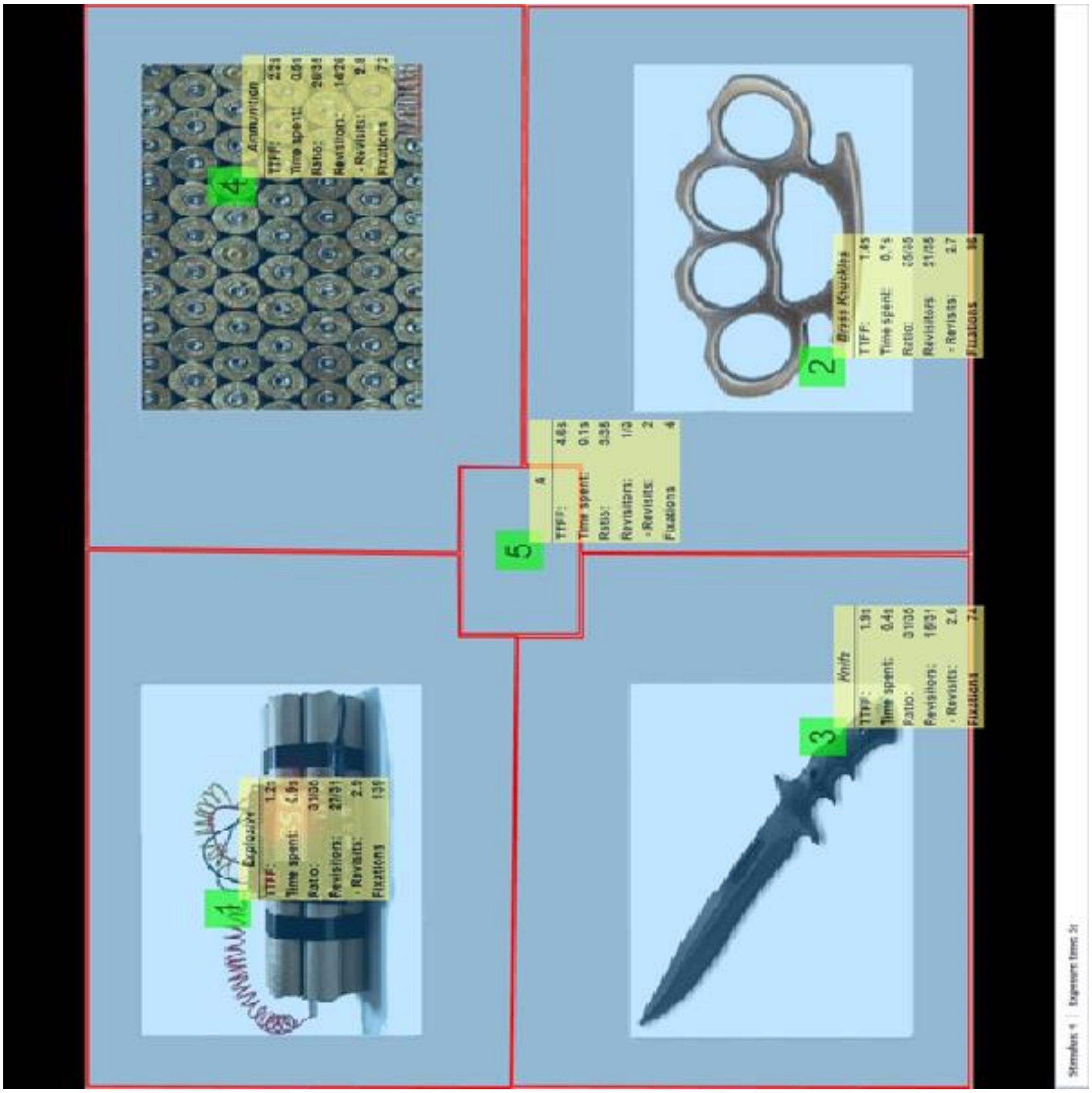
AOI Plot for the critical slide in sequence 3 for Guilt participant:



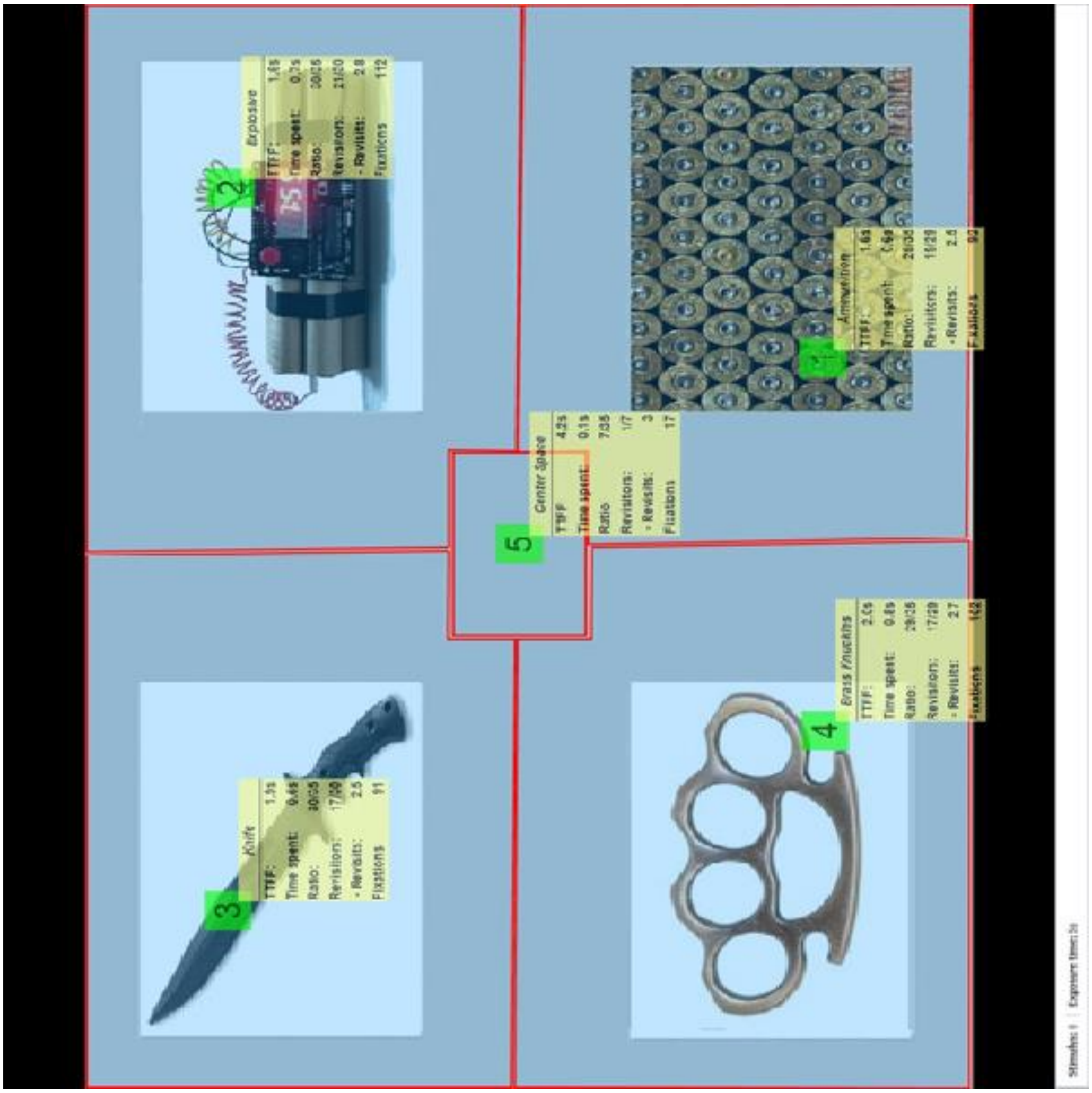
AOI Plot for the critical slide in sequence 4 for Guilt participant:



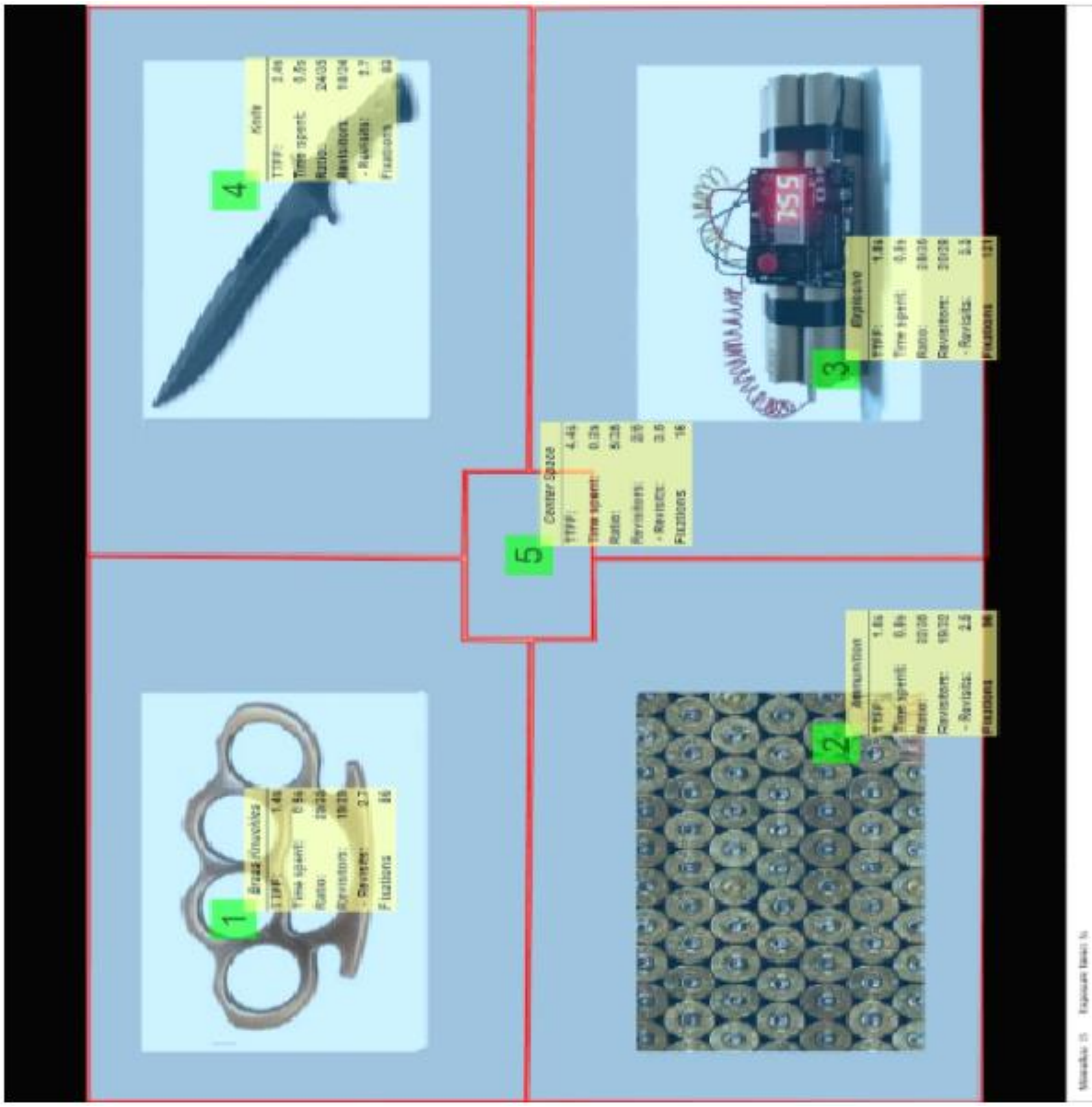
AOI Plot for the critical slide in sequence 1 for Innocent participant:



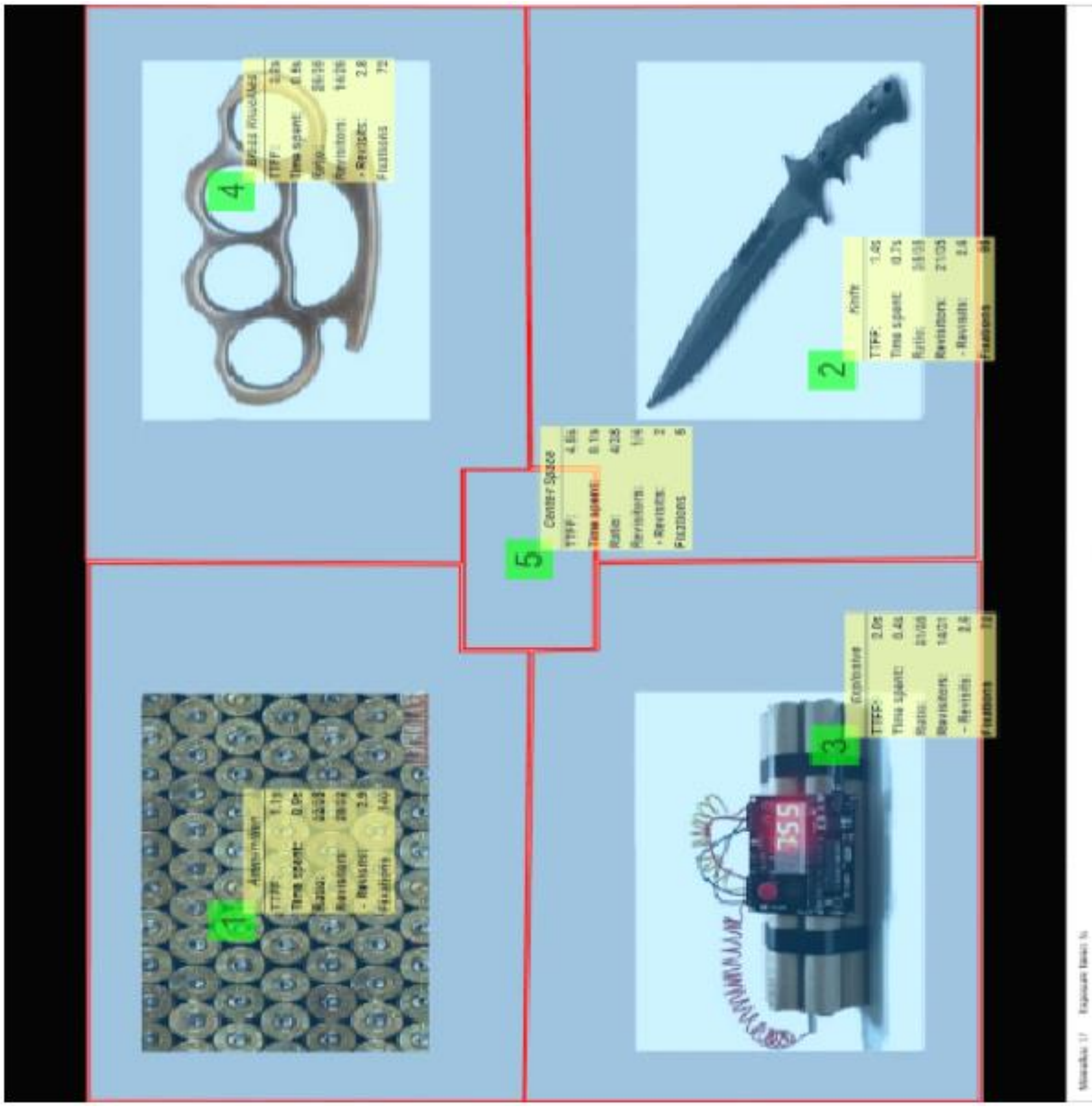
AOI Plot for the critical slide in sequence 2 for Innocent participant:



AOI Plot for the critical slide in sequence 3 for Innocent participant:



AOI Plot for the critical slide in sequence 4 for Innocent participant:



BIBLIOGRAPHY

Ambach, W., Bursch, S., Stark, R., & Vaitl, D. (2010). A Concealed Information Test with multimodal measurement. International Journal of Psychophysiology, 75(3), 258-267.

Ben-Shakhar, G., & Elaad, E. (2003). The validity of psychophysiological detection of information with the Guilty Knowledge Test: a meta-analytic review. Journal of Applied Psychology, 88(1), 131.

Ben-Shakhar, G., Gamer, M., Iacono, W., Meijer, E., & Verschuere, B. (2015). Preliminary process theory does not validate the comparison question test: A comment on Palmatier and Rovner (2015). International Journal of Psychophysiology, 95(1), 16-19.

Bhuvaneswari, P., & Satheesh Kumar, J. (2015). A note on methods used for deception analysis and influence of thinking stimulus in deception detection. International Journal of Engineering and Technology, 7(1), 109-116.

Calvo, M. G., Avero, P., & Nummenmaa, L. (2011). Primacy of emotional vs. semantic scene recognition in peripheral vision. Cognition & emotion, 25(8), 1358-1375.

Dandekar, S., Ding, J., Privitera, C., Carney, T., & Klein, S. A. (2012). The fixation and saccade p3. PloS one, 7(11), e48761.

Dehais, F., Causse, M., & Tremblay, S. (2011). Mitigation of conflicts with automation use of cognitive countermeasures. Human Factors: The Journal of the Human Factors and Ergonomics Society, 53(5), 448-460.

Deokar, A., & Madhusudan, T. (2005). Developing Group Decision Support Systems for Deception Detection. Paper presented at the Proceedings of the 38th Annual Hawaii International Conference on System Sciences.

Fleisher, W. L., & Gordon, N. J. (2010). Effective interviewing and interrogation techniques: Academic Press.

Gidlöf, K., Wallin, A., Dewhurst, R., & Holmqvist, K. (2013). Using eye tracking to trace a cognitive process: Gaze behaviour during decision making in a natural environment. Journal of Eye Movement Research, 6(1).

Granhag, P. A., Vrij, A., & Verschuere, B. (2015). Detecting deception: Current challenges and cognitive approaches: John Wiley & Sons.

Gray, J. A. (1987). The psychology of fear and stress (Vol. 5): CUP Archive.

Horvath, F., Blair, J., & Buckley, J. P. (2008). The behavioural analysis interview: clarifying the practice, theory and understanding of its use and effectiveness. International Journal of Police Science & Management, 10(1), 101-118.

Iacono, W. G., & Lykken, D. T. (1997). The validity of the lie detector: Two surveys of scientific opinion. Journal of Applied Psychology, 82(3), 426.

Just, M. A., & Carpenter, P. A. (1976). Eye fixations and cognitive processes. Cognitive psychology, 8(4), 441-480.

Klami, A. (2010). Inferring task-relevant image regions from gaze data. Paper presented at the 2010 IEEE International Workshop on Machine Learning for Signal Processing.

MacNeill, A. L., Bradley, M., Cullen, M., & Arsenault, A. M. (2014). Cognitive and emotional reactions to questions in the comparison question test. Perceptual and motor skills, 118(2), 429-445.

Masip, J., & Herrero, C. (2013). 'What Would You Say if You Were Guilty?'Suspects' Strategies During a Hypothetical Behavior Analysis Interview Concerning a Serious Crime. Applied cognitive psychology, 27(1), 60-70.

Masip, J., Herrero, C., Garrido, E., & Barba, A. (2011). Is the behaviour analysis interview just common sense? Applied Cognitive Psychology, 25(4), 593-604.

Merkley, R., & Ansari, D. (2010). Using eye tracking to study numerical cognition: the case of the ratio effect. Experimental brain research, 206(4), 455-460.

Offe, H., & Offe, S. (2007). The comparison question test: Does it work and if so how? Law and human behavior, 31(3), 291-303.

Ogawa, T., Matsuda, I., & Tsuneoka, M. (2015). The comparison question test versus the concealed information test? That was the question in Japan: a comment on Palmatier and Rovner (2015). International Journal of Psychophysiology, 95(1), 29-30.

Pak, J., & Zhou, L. (2013). Eye gazing behaviors in online deception.

Raskin, D. C., Honts, C. R., Kircher, J. C., & ebrary, I. (2014). Credibility assessment: scientific research and applications. Oxford: Academic Press.

Schall, A., & Bergstrom, J. (2014). Eye tracking in user experience design. Sl Morgan Kaufmann Publisher.

Stetz, M. C., Thomas, M. L., Russo, M. B., Stetz, T. A., Wildzunas, R. M., McDonald, J. J., . . . Romano, J. A. (2007). Stress, mental health, and cognition: a brief review of relationships and countermeasures. Aviation, space, and environmental medicine, 78(Supplement 1), B252-B260.

Twyman, N. W., Elkins, A. C., Burgoon, J. K., & Nunamaker, J. F. (2014a). A rigidity detection system for automated credibility assessment. Journal of Management Information Systems, 31(1), 173-202.

Twyman, N. W., Lowry, P. B., Burgoon, J. K., & Nunamaker Jr, J. F. (2014b). Autonomous scientifically controlled screening systems for detecting information purposely concealed by individuals. Journal of Management Information Systems, 31(3), 106-137.

Vater, C., Kredel, R., & Hossner, E.-J. (2016). Detecting single-target changes in multiple object tracking: The case of peripheral vision. Attention, Perception, & Psychophysics, 78(4), 1004-1019.

Vrij, A. (2008). Detecting lies and deceit: Pitfalls and opportunities: John Wiley & Sons.

Vrij, A., Mann, S., & Fisher, R. P. (2006). An empirical test of the behaviour analysis interview. Law and human behavior, 30(3), 329-345.

Walczyk, J. J., Roper, K. S., Seemann, E., & Humphrey, A. M. (2003). Cognitive mechanisms underlying lying to questions: Response time as a cue to deception. Applied Cognitive Psychology, 17(7), 755-774.

Zulawski, D. E., Wicklander, D. E., Sturman, S. G., & Hoover, L. W. (2001). Practical aspects of interview and interrogation: CRC press.

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