BACHELOR THESIS

“CAN THE EYES OF A SUSPECT REVEAL THAT HE IS GUILTY OF A CRIME?

Solving crimes with eye-tracking technology

by

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ABSTRACT

The current research deals with the question whether people who possess guilty knowledge differ in their eye-movement patterns (i.e. fixation duration and fixation counts) in comparison to innocent people who do not possess guilty knowledge. In addition, eyewitnesses were also taken into account. Therefore, a between-subjects design with three conditions: guilty, eye-witness and innocent was used. Participants watched a First Person Perspective (FPP) video in which guilty knowledge in the guilty and eyewitness condition was manipulated. Then a Guilty Knowledge Test was conducted in which participants viewed four pictures of different guns and were asked whether they have seen one of these in relation to this investigation. While participants looked at the pictures of the guns, their eyes were tracked with a wearable eye-tracker. The results of the current study showed that guilty participants reveal their guilty knowledge by different fixation behavior in comparison to eyewitnesses and innocent participants. Further, the manipulation of guilty knowledge and inducement of feeling of guilt on innocent participants who have not committed a crime worked successfully. Future research should investigate further eye-tracking metrics.

1) INTRODUCTION

Being able to discriminate between deceit and truth is a challenge in a variety of situations, for various kinds of people and could destroy numerous innocents' lives. In fact, human's ability to tell whether somebody is lying or telling the truth is not greater than chance (Kraut, 1980; Vrij, 2004). Reasons why people fail to detect lies is the lack of overlap between the cues people believe to be associated with deception (subjective cues to deception) and the cues research has shown to be associated with deception (objective cues to deception) (Hartwig, Granhag, Stromwall, & Vrij, 2004). It is well known that nonverbal behaviors like being tensed, making fewer leg/foot and hand/arm movements are associated with deception (Vrij, 2008). Next to these cues, liars tend to have higher pitched voices and make longer pauses than truth tellers (Hartwig et al., 2004). Nevertheless, these cues are not a reliable source to distinguish deception from truth.

Especially, environments such as border crossings, job interviews, flight passenger screenings, and police interviews are in high demand for such detection skills (Derrick et al., 2010). Still, even those who are being trained to investigate suspects, do not possess a greater ability in detecting deception than lay people (Hartwig et al., 2004). This shows that the judicial system has flaws and this could potentially lead to a wrongful conviction of innocents. The created demand for intelligent monitoring systems that provide reliable and objective assessments has a long history and lasts until today (Derrick et al., 2010; Grubin, 2010).

Early attempts to detect lies by physiological measurements traces back to the end of the 19 th century. In 1895, Cesare Lombroso measured volume changes of hand using modified hydro sphygmograph during a forensic interrogation (Rosenfeld, 2018). Later on, Vittorio Benussi first used respiration measurement to tell truth from lies in 1914. From breathing recordings he calculated inspiration and expiration time and used them as deception indicators (Rosenfeld, 2018). In the 1920s, the polygraph was developed to record changes in respiration, cardiovascular activity and sweat gland activity (Grubin, 2010). A recently used method which also uses physiological measurements is the Concealed Information Tests (CIT).

The Concealed Information Test (CIT), originally called Guilty Knowledge Test (GKT) aims at differentiating 'guilty' subjects purposefully denying their crime-related knowledge from 'innocent' subjects truthfully denying knowledge (Lykken, 1959). It compares a subject's physiological responses towards a number of presented items. The traditional GKT researched by Lykken (1959) was conducted with skin conductance responses. Even though, psychological research delivered extensive evidence that the GKT is able to successfully detect crime-related

knowledge, the admissibility of deception detection devices in courts is not accepted universally (Peth, Suchotzki, & Gamer, 2016). Besides, GKT is not yet used in the justice system.

Nevertheless, interest remains in measures that can be acquired unobtrusively (Peth, Kim & Gamer, 2013). Eye-tracking technology is one of those measurements, since it was considered a suitable alternative technique (Derrick, Moffit, & Nunamaker, 2011). Previous research could proof that eye tracking technology was a successful alternative for discovering the possession of guilty knowledge (Derrick, et al., 2011). Derrick et al. (2011) developed a scenario in which guilty participants constructed an explosive device and innocent participants did not. Later, participants got to see an altered image of this device. It was expected that guilty participants recognized the modification in contrast to the innocent participants. The study showed that participants with guilty knowledge had longer fixation duration on the altered area in comparison to the participants without guilty knowledge (Derrick, et al., 2011). Furthermore, Derrick et al. (2011) could distinguish with 100% accuracy between participants possessing guilty knowledge from participants not possessing guilty knowledge. These results seem ideal, however the study only consisted of 11 participants. For this reason, this study will expand Derrick et al. (2011) study.

The aim of the current study is as mentioned before to further investigate whether eye-tracking is a suitable method for the GKT. Particularly, the effects of guilty knowledge on fixation through an eye-tracker will be researched. Furthermore, the study considers eyewitnesses who possess guilty knowledge but are not guilty of the criminal event.

2) THEORETICAL FRAMEWORK

2.1 Guilty Knowledge Test

The method to detect concealed knowledge was designed by Hugo Münsterberg in 1908. Later, Lykken (1959) was the one who introduced GKT into psychology. The GKT is a method of forensic physiology used to detect concealed knowledge to specific items (Gamer et al., 2006). The GKT follows the approach that physiological responses are linked to and correlated with mental processes. Therefore, observable or measurable bodily functions can allow for drawing inferences about particular mental processes such as recognition (Toglia, Don Read, Ross, & Lindsay, 2017). The test utilizes a series of multiple-choice questions using information that can be known only by the guilty suspect (Toglia et al., 2017). Before GKT can be used for a suspect interview, a series of questions are prepared. One of these items (probe) is crime relevant and the other items equally plausible consist of crime irrelevant details which are used as (distractors or controls) (Gamer et al., 2006). A possible GKT question could be *"Where did*

you hide the gun?" The answer options "*Shelf, **desk**, cupboard, bed"* are examples for crime relevant and crime irrelevant items. It is important to choose the control items in such a way that innocent suspects would not be able to discriminate the crime irrelevant items from the relevant once. During GKT, suspects physiological responses to each item are measured. It is assumed that suspects aware of crime-relevant information will be physiologically more reactive to the crime relevant items than to the crime irrelevant items. Innocent suspects physiological responses should be similar towards all alternatives because all items are equally plausible to them (Toglia et al., 2017). Finally, GKT is a good deception detection procedure to protect the innocent and make it hard for the guilty. Moreover, false positives are less likely. A false positive is a result that indicates that a given condition exists. For example finds a suspect guilty, even though he is innocent (Meijer, Selle, Elber, & Ben-Shakhar, 2014). This feature is the main strength of the GKT.

2.2 Guilty Knowledge Test in relation with eye-tracking

GKT traditionally was used in relation with autonomic physiological responses (Peth et al., 2013). More recently GKT studies use measures such as event-related potentials or reaction times (Peth et al, 2013). Unobtrusive respiration measures were also successfully applied to the GKT (Peth et al., 2013). Also, previous Lie-detector literature suggested that eye movements can detect deceptive behavior because humans find deception stressful and cognitively difficult (Wang, Spezio, & Camerer, 2009).The use of eye tracking is not yet that much researched, however existing studies demonstrate that eye movements such as gaze behaviors reflect major properties, such as personality, emotional state, and cognitive process (Nahari et al., 2019). This is no surprise since the eyes of a human are known as the window to the inner world (Nahari et al, 2019). Therefore, eye-tracking is a tool to read the eyes humans and get access to the encoded information which could not be translated until now.

The study by Ryan, Hannula and Cohen (2007) on eye movements showed that memory can be detected along different stimulus groups such as faces, buildings, scenes and objects. These studies found a decrease in sampling behavior (e.g., fewer fixations, fewer regions viewed, and increased fixation durations) for familiar stimuli compared to unfamiliar stimuli (Ryan et al., 2007). Another key point is that eye movements pose to be advantageous, since in comparison to other measures they are less susceptible to countermeasures. They are believed to be automatic and unaffected by voluntary control (Meijer et al., 2014). As a result guilty participants will be less able to manipulate and hide their guilty knowledge.

Besten (2017) additionally took another important suspect group into consideration. The eye witness who possess crime related information, but are innocent of the crime itself. This

approach will also be followed in this study. By observing the crime-scene, it is possible that these persons become familiar with crime-relevant items, yet, they are not guilty of the criminal event. Still, their eye movement patterns might show object recognition and then innocent people could be found guilty.

All in all eye-tracking poses potential to differentiate between participants possessing guilty knowledge from participants not possessing guilty knowledge and can be used as a method for the GKT.

*2.3 The E*ye-tracker

Since, it was pointed out that eye-tracking is a potential method to distinguish between truth and deceit, let us take a step back and understand what an eye-tracker is. An eye-tracker is a device for measuring eye positions and movements. Eye-tracking is a process of measuring either the point of gaze (where one is looking) or the motion of an eye relative to the head (iMotions, 2018). The measures obtained by an eye tracker are indirect behavioral measures of information processing which can be used for memory assessment (Peth, Kim & Gamer, 2013; Derrick et al., 2011). Eye trackers are used in research on the visual system, in psychology, psychology of language, marketing, as an input device from human-computer interaction, and in product design. Further, eye tracking technology in combination with guilty knowledge test could expose suspects who hide crime-related information and be useful tools for professional 'lie catchers' like police officers. There are a variety of different metrics used in eye tracking research, such as: Gaze points, fixation, Areas of Interest (AOI) and heatmaps. This study will take fixation (duration and count), AOI and heatmaps into account.

Eye fixation is used for object recall and can demonstrate the order of importance assigned to scene objects by people observing this scene (Farnsworth, 2018). An eye fixation is formed when various gaze points are very close, in time and space. The gaze points will then form a gaze cluster and this cluster is often called a fixation (iMotions, 2018). A fixation is a period in which our eyes are locked towards a specific object and fixation duration is typically 100-300 milliseconds (iMotions, 2018). Peth et al., (2013) found that guilty participants showed fewer, but longer fixations in comparison to innocent participants. Further, studies on eye tracking reported a decrease in fixations and regions viewed for familiar stimuli compared to unfamiliar stimuli. However, an increase in fixation duration was found (Peth et al, 2013). Fixation will be used in this study, as it seems suitable because the GKT consists of four static pictures of guns.

AOI is a tool to select regions of a selected stimulus and to obtain metrics for this specified region (iMotions, 2018). In this study two AOI were set. One AOI was set on the

picture of the gun and the other AOI was set on the whole picture including background. With the first AOI we wanted to check if guilty participants will recognize the modified gun and spot the blue dot.

A heatmap is a static representation which shows the distribution of gaze points (iMotions, 2018). In these representations hot zones are marked with red dots, where the participant gazed with higher frequency. Moderate and less frequent gazing is represented with yellow and green. With such a tool this study will use heatmaps to visualize where participants fixated with most frequencies. Furthermore, heatmaps will show directly whether guilty participants viewed on the modified AOI in comparison to the eyewitnesses.

2.4 The current study

In this study we examined whether eye fixations are suitable measurements for the detection of guilty knowledge. We used a mock crime scenario and divided the participants into three conditions: guilty, eyewitness and innocent. All three conditions saw a video and read a scenario story. The guilty condition watched a first person perspective (FPP) video where someone hid a weapon. The eyewitness condition watched the guilty person hiding the gun. Eyewitnesses were not able to spot the gun and thus were not aware of the blue dot. And the innocent condition walked into a room to sit at a lap top and study. During the GKT, eye fixations were recorded to assess recognition.

During the GKT the examiner showed four pictures of guns. Three of them were crime-unrelated, one gun was the same participants in the guilty condition saw and participants in the eye-witness condition only saw superficially. However, the crime-related gun was modified and showed no blue dot anymore in comparison to the video the guilty participants watched. By making this distinction we wanted to see whether eye movements differ between guilty and eyewitnesses who possess partly guilty knowledge in relation to the guilty participants. As mentioned previously Peth et al., 2013, demonstrated that participants who are familiar with a crime-relevant object tend to fixate for longer time on crime details than participants who are not familiar with that object. Therefore, we expected that guilty participants have a longer fixation duration on the altered area of the gun in comparison to innocent participants. Moreover, we also expect this for participants in the eyewitness condition. Namely, participants in the eyewitness condition have a longer fixation duration on the altered area of the gun in comparison to the innocent participants. Due to these expectations the following hypotheses were made:

Hypotheses 1: Participants in the guilty condition have longer fixation duration on AOI 1 (blue dot) than participants in the eyewitness condition. Participants in the eyewitness condition in

turn have a longer fixation duration on AOI 1 than participants in the innocent condition.

Hypotheses 2: Participants in the innocent condition will have higher fixation counts on AOI 2 than participants in the eyewitness condition. Participants in the eyewitness condition will have a higher fixation count than participants in the guilty condition.

2.5 Explorative variables

With the GKT approach, guilty knowledge is imposed on innocent participants. In order to increase involvement and empathy a post-questionnaire assessed how guilty participants felt.

Guilt

Guilt is an interpersonal emotion which means that is mostly felt when wronging another person (Cryder, Springer, & Morewedge, 2011). Guilts effects on interpersonal behaviors is targeted toward remediating relationships that were harmed by guilt-inducing acts (Cryder et al., 2011). Guilt is a member of negative self-conscious emotions which include shame, regret and embarrassment (Cryder et al., 2011). Simply exposing innocent participants to items will not lead to an increased responsiveness on the GKT (Bradley & Warfield, 1984). Emotional associations with the items will play a role in increasing responsiveness (Bradley & Warfield, 1984).

Hypotheses 3: Participants in the guilty condition will score higher on the scale of guilt than participants in the eyewitness condition. Participants in eyewitness condition will score higher on the scale of guilt than participants in the innocent condition.

Interviewer effect

The so called Interviewer effect is a distortion of responses in a personal interview which results from differential reactions to the social style and personality of interviewers or the presentation of questions. While participants being interviewed possible bias are probable to occur. Therefore, it is necessary to make sure that the found effects are not due to the interviewer effect.

3) METHODS

3.1 Participants

A total of 38 participants took part in the study (female = 19; male = 19). Their age ranged from 20 to 55 with a mean age of 24 years (*SD* = 5,924). The participants in the sample were Dutch (3), German (28), and other than that Greek, Ukrainian, Ecuadorian, Cypriot, Syrian, Hungarian and Spanish (7). One participant had to be excluded because no data has been recorded during the experiment, thus a total 37 participants were used for statistical analysis.

3.2 Research design

The current study used a completely randomized, between-subject design with one experimental manipulation: guilty knowledge. The experiment consisted of three conditions: guilty (N=13), eyewitness (N=13) and innocent (N=12). Participants in both guilty and eyewitness condition saw a video in which a gun was displayed, thus were exposed to guilty knowledge since they were both familiar with the appearance of that specific gun. Participants in the innocent condition, did not see a weapon in the video, thus were not exposed to guilty knowledge. The dependent variable was total fixation duration at one specific region. The explorative dependent variable was participants' guilt, and perceived competence, warmth and coldness of the GKT examiner.

3.3 Materials

Tobi Pro lab

Pro Lab is an eye tracking software designed for conducting experimental research with Tobi Pro hardware. The program's analysis and visualization tools allowed to process and prepare eye-tracking data for comparison, interpretation and presentation. Likewise it enabled to calculate a variety of eye-tracking metrics and create visual representations of data. By the same token it facilitated to obtain an overview of the data and report the findings

Eye-Tracker

Participants' eye behavior was recorded using a wearable Tobii eye tracker (see Figure 1). The system simultaneously tracked both eyes, to a rated accuracy of 0.5 degrees, sampled at 100Hz. The attention filter was used and contained a threshold of 100 degrees per second, a I-VT classifier and a minimum (fixation) duration of 60 milliseconds.

Figure 1. Wearable Tobi eye-tracker glasses

Informed Consent

An informed consent was given to every participant as the first step of the every experiment. Participants read through the informed consent and confirmed with a signature, that they affirm to participate in the study.

Post-questionnaire

A post-questionnaire was filled out by each participant on the lap top of the researcher at the end of every experiment. The questionnaire had 17 questions and measured variables like guilt, competence, warmth and coldness.

3.4 Procedure

After the experiment was ethically approved by the Ethics-Committee of faculty BMS, the experiment was set up in a room on the University of Twente campus. The sample consisted of participants from within the researchers environment, students who voluntarily participated and students who signed in on a platform named Sona-system. Depending on nationality, the experiment was conducted in English or in German. Participants were tested individually and each session took approximately 15 minutes. Two experimenters were present, one giving instructions and setting up the experiment and the other playing the role of the police interrogator in the GKT. The roles were not fixed since they were depending on the personal relationship to the participants.

The researcher first obtained informed consent (see Appendix A). Then, the eye tracker was placed and calibrated, supposing to create the impression their eye behavior is already being conducted which was not the case. In general, the experiment consisted of three parts: 1) the scenario story and FPP video, 2) the GKT and 3) the post-experiment questionnaire. In the first part, guilty knowledge was manipulated. Participants in each of the three conditions watched a different Powerpoint with a different scenario story and a different FPP Video (Appendix B). (a) Participants in the guilty condition read a story in which they were responsible for a shooting that took place at the Ravelijn building on the Campus of the University of Twente. The participants were told that they fled the crime scene and are currently in the Cubicus building trying to find a spot where they can hide the gun. After reading the scenario, the guilty participants watched a video in the FPP, in which they hid a gun and saw the gun in all its details including a blue dot. (b) Participants in the eye witness condition were told that they are heading to a tutorial in the Cubicus building on the University Campus. While walking in the hallway, they were being told that a shooting has taken place in the Ravelijn building, a few minutes ago. As they got closer to the tutorial in the Cubicus building, they suddenly spotted someone holding a gun. They followed the shooter and saw the spot where

the gun was hidden. The eyewitness watched a video from the perspective of an eye witness. The video showed the suspect of the shooting hiding a gun, however the eye witness who watched the video did not see the gun in detail, more specific the blue dot on the gun. Hence, participants in the eyewitness condition possessed guilty knowledge, but less detailed information than the guilty condition. (c) Participants in the innocent condition read a story in which they were walking out of a study area at the Cubicus building on the university campus. The video participants watched in the innocent condition, was from a perspective of a person walking down a hallway into a room. The person opened the door and sat down to a lap top. Participants in the innocent condition did not see a gun at all and thus did not possess guilty knowledge. They received information that a shooting had taken place minutes ago at the Ravelijn building and that the suspected shooter ran into the Cubicus building. Where the police ran around and questioned everybody in the building, including the innocent participant.

In the second part, the examiner explained to the participants that he/she was a suspect in this case and will now been asked some questions relating to the shooting that had taken place. Then the police interrogator asked 7 questions (see Appendix C) to pressure and confuses the participants. Also the impression of a real interrogation should be created. After that the police interrogator instructed the participants in all three conditions to look at four images of weapons: three crime irrelevant (control) images and one crime-relevant image. The first, second and fourth image shown to the participants were control images (see Appendix D). The third image shown was the crime-relevant image. The third image showed the weapon that was used in the FPP video and was familiar to the participants in the guilty and eye-witness condition. Participants in the guilty condition were shown a modified version of the gun used in the FPP video. The blue dot which they saw in the video was not present in the picture during the GKT. Each image was presented on the screen for 10 seconds (see Appendix D). In this specific moment, measuring eye movement was the data of interest. These 10 seconds were based on the research by Derrick et al. (2011) who suggested 12 seconds. After pilot testing the duration was minimized for two seconds, due to personal tryouts by the researcher. At the end of each picture the interrogator asked the participant if that particular object had recently been seen. Participants had to answer with yes or no. When all images were shown, the participants were asked to take off the glasses and fill out the questionnaire.

The post-experiment questionnaire elaborated the variables: guilt, stress, competence, warmth and coldness. The questionnaire consisted of 17 items and was about the participants experiences during the experiment (see Appendix E and dependent measures). After completing the questionnaire, a final debriefing was carried out in which participants were told that the

information they received during the experiment was not real and solely for the purpose of this research. Participants who had questions were answered and motivated to get back to researcher if further questions would arise.

3.5 Dependent Variable

Total fixation duration. To investigate the total fixation duration, two specific regions have been determined, which are called Area of interest (AOI). A particular Area of Interests (AOI) was set on the picture of the gun. AOI's are a tool that enables one to select regions of a displayed stimulus, in this case the picture, where the metrics of fixation duration can be calculated. With the use of the AOI's it is possible to evaluate the performance of two or more areas in the same picture, and groups can be compared (iMotions, 2018). The first area of interest (AOI 1) was assigned to the blue dot on the butt of the weapon (see Figure 2). It will be examined whether participants in the guilty condition will have longer fixation duration on the altered gun butt than participants in the eye-witness condition an innocent condition. AOI 2 has been assigned to the picture of the gun including background (see Figure 3).

Figure 2. AOI 1

Figure 3. AOI 2

Explorative variables

The following dependent variables were measured in a questionnaire: guilt, stress and perceived competence and warmth of the GKT examiner.

First, guilt was measured with 5 items on a scale ranging from 1 strongly disagree to 5 strongly agree in five categories. The items were adapted from Leith and Baumeister (1998). An example Item is *"When I think back to the video, I feel guilty"* used to measure guilt. Cronbach's alpha was conducted to check the reliability. The construct guilt ($\alpha = 0.888$) was found reliable enough to use.

Then, ten items measured the perceived behavior of the GKT examiner (warm, friendly, confident, dominant, cold, competent, intimidating, kind, likeable, and intelligent). These items

could be rated on a scale from 0 to 100. A score of 0 rating the interviewer as not warm and a score of 100 as very warm. The items were adapted from the study by Fiske, Cuddy, Xu, & Glick, (1999). The factor analysis showed three components instead of one and the construct competence ($\alpha = 0.419$), which was considered not high enough. Therefore, three constructs were created warmth, cold and competence. The construct warmth ($\alpha = 0.957$), cold ($\alpha = 0.829$) and competence ($\alpha = 0.713$).

3.6 Analyses

The participants' eye movements were tracked while they were watching the four pictures of guns with the wearable Tobii eye-tracking device. Subsequently, the gathered data was put together into a data set. The data was analyzed with the Tobii Pro Lab (x64).

During the analysis of the data in Tobii-Software, the researchers became aware that an error during or after the calibration occurred when measuring the eye-movements of some of the participants. For instance, when it was expected that a participant looked exactly on the gun, their focus point on screen may have varied from the actual focus point. Which means that the actual focus point was three centimeters underneath the expected focus point, the blue dot on the gun butt. Even small calibration errors could have devastating effects on the interpretation of experimental data (Street, Beesley, & Shanks, 2015). If left unresolved, the results could have represented false focus points. Therefore, it was decided to perform manual correction in the cases where these errors were expected to have taken place. Before the manual correction, there were three points chosen that would determine the distance between the false focus points and the expected focus points. The first point was the blue dot on the gun butt, the second point was the trigger and the third point was on the barrel. These points were chosen, because it is assumed that participants attention will be caught to these points naturally. In the end, of the 38 participants, the manual correction has been executed on 15 participants.

Furthermore, heatmaps have been created in order to visualize the data and to show the general distribution of visual attention (iMotions, 2018). These heatmaps can be viewed in Appendix E. The red color areas stand for a high number of fixation points, which can imply a high level of interest. Yellow and green areas show fewer fixation points, which may imply a low level of interest. Areas that do not show any color at all are likely not to have been attended to (iMotions, 2018). The data was then transferred from Tobii to Excel using the export option and from there to SPSS version 24 to analyze the data.

4) RESULTS

The variable fixation was checked for normality with the Shapiro-Wilk Test. For the first AOI, the data was not normally distributed ($p = 0.001$). Consequently, a non-parametric test: Kruskal-Wallis H Test was used. For the second AOI, the data was neither normally distributed ($p = 0.006$). Therefore, a Kruskal-Wallis H Test was conducted.

Hypotheses 1. To investigate whether participants in the guilty condition had longer fixation duration at AOI1 in comparison to participants in the eye-witness and innocent condition, a Kruskal-Wallis was conducted with the total fixation duration at the altered area. The test showed a statistically significant difference in the total fixation duration at the altered area between the groups, $\chi 2\ (2) = 7.688$, $p = 0.021$, with a mean rank score of $M = 24.73$ for the guilty condition, $M = 15.19$ for the eyewitness condition and $M = 18.50$ for the innocent condition. Since, a statistically significant difference could be found, a further post-hoc test namely Tukey HSD test was conducted, in order to investigate which of the three groups showed statistically significant differences. The post-hoc test found a statistically significant difference for the guilty condition in comparison to the eye-witness and innocent condition. Guilty participants showed longer fixation duration on AOI 1 ($M = 0.432$, $SD = 0.135$, $p = 0.008$) in comparison to the eyewitness condition. The guilty condition also fixated significantly longer on AOI 1 than the innocent condition ($M = 0.345$, $SD = 0.135$, $p = 0.04$) . Thus, hypothesis 1 has been partly confirmed.

Hypotheses 2. Investigated whether participants in the innocent condition will have higher fixation count on AOI 2 than participants in the eyewitness condition and participants in the eyewitness condition will have a higher fixation count than participants in the guilty condition. The conducted Kruskal-Wallis H Test revealed that there were no statistically significant differences between the groups, $\chi 2\ (2) = 0.094$, $p = 0.954$, with a mean rank score of $M = 19.5$ for the guilty condition, $M = 18.27$ for the eyewitness condition and $M = 19.29$ for the innocent condition. Thus, hypothesis 2 has not been confirmed.

4.1 Additional analyses

The explorative variables checked to see whether the three conditions differed for the variables guilt, competence, warmth and coldness. First, the data of all variables were checked for normality with the Shapiro-Wilk Test. The data of guilt were not normally distributed ($p = 0.016$). Therefore, a Kruskal-Wallis H Test was applied. The data of the three variables competence ($p = 0.105$), warmth ($p = 0.244$), and coldness ($p = 0.105$) were normally distributed. For these variables an ANOVA was executed.

Hypotheses 3. To investigate whether participants in the guilty condition will score higher on the scale of guilt than participants in the eyewitness condition. And participants in the eyewitness condition score higher on the scale of guilt than participants in the innocent condition a Kruskal-Wallis Test was conducted. There was statistically significant difference between the groups, $\chi 2$ (2) = 12.689, p = 0.002, with a mean rank score of (M = 25.35) for the guilty condition, (M = 22.12) for the eyewitness condition and (M = 10.33) for the innocent condition. The Tukey post-hoc test revealed that guilty participants scored higher on the scale of guilt in relation to innocent participants (M = 7.14, SD = 1.80, p = 0.001).

Furthermore, eyewitnesses scored scored higher on guilt than innocent participants (M = 5.98, SD = 1.80, p = 0.006). Thus, hypothesis 3 has been confirmed.

Interviewer effect

For the variables competence, warmth and coldness an ANOVA was conducted. Since we have three conditions, it is not clear between which conditions differences exist if theses occur, therefore the post-hoc test namely the Tukey HSD test was applied.

There was a statistically significant difference found for competence, F (2, 35) = 3,613, p = 0.037. The post-hoc test revealed that eyewitnesses rated the interviewer as less competent in comparison to innocent participants (M = -18.81, SD = 7.00, p = 0.029). For warmth no statistically significant difference was found, F (2, 35) = 3,201, p = 0.053. However, the post-hoc-test test revealed a statistically significant difference. Again eyewitnesses rated the interviewer as less warm than innocent participants (M = -27.23, SD = 10.76, p = 0.04). Finally for coldness no statistically significant difference was found F (2, 35) = 1,447, p = 0.249. The post-hoc test also showed no statistically significant difference within the three conditions.

Heatmaps

Below the heatmaps of the three groups are shown. The colors green, yellow and red stand for the fixation intensity. Green standing for fewer fixations, yellow for moderate fixations and red for increased fixations. Identically the heatmaps in all three conditions show the color yellow and red at the trigger. As expected the guilty condition additionally shows red areas towards the gun butt the blue dot (AOI 1) in comparison to participants in the eye-witness and innocent condition who did not possess information about AOI1.

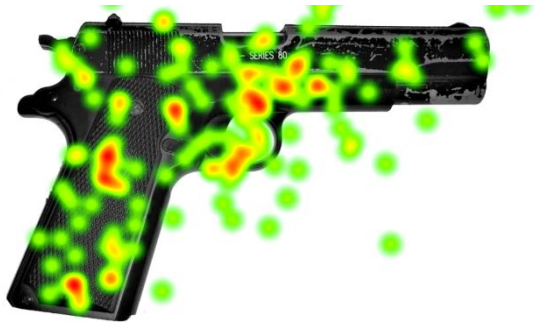

Figure 4. Heatmap of participants in the guilty condition

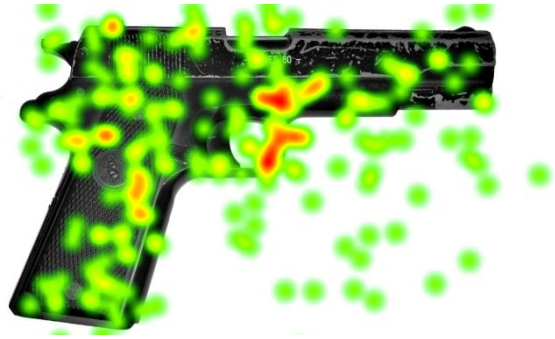

Figure 5. Heatmap of participants in the eyewitness condition

Figure 6. Heatmap of participants in innocent condition

5) DISCUSSION

The current study investigated whether people who possess guilty knowledge differ in their eye behavior (i.e. fixation duration and fixation count) in comparison to people who do not possess guilty knowledge. Further, a third group was taken into account: the eyewitnesses, who possessed some crime related knowledge, but were innocent. Participants watched a video and read a scenario and subsequently a GKT was conducted.

The outcomes showed that guilty participants fixated on the blue dot on the gun in the video which was missing on the picture shown during the interrogation when their eyes were tracked, indicating that they recognized something was missing. Further, as expected, guilty

participants fixated longer on AOI 1 in comparison to the eye witness and innocent participants. This result is consistent with previous studies on eye tracking. Peth et al., (2013) found that guilty participants showed longer fixations to crime relevant objects in comparison to innocent participants. These results represent the eye behavior of participants possessing guilty knowledge in comparison to participants not possessing guilty knowledge. The results confirmed that eyewitnesses were not aware of the AOI 1 and thus did not differentiate from the innocent in this aspect.

Further, it was expected that eyewitnesses who possess crime related knowledge, but are innocent of the crime itself would differ from the innocent condition. Since they possessed crime-related information eyewitnesses might have explored the gun more in comparison to innocent participants. The eyewitness condition could spot the gun from a further distance, which made us assume that a certain level of familiarity was reached. These expectations could not be proven. Even though Derrick et al., (2011) found that people would have a longer fixation towards an altered object when the object was already familiar to them, this study could not prove this. This is not surprising since the eyewitnesses in this study did not actually see the gun.

Furthermore, it was expected that guilty participants would explore the crime related image less and thus have fewer fixation points on AOI 2. Yet, these outcomes are not confirmed. This finding is in contrast with the study of Peth et al., (2013), who claimed that persons with crime-related knowledge would show less exploration which means fewer fixations on the weapon. One possible explanation for this could be that participants intentionally tried to not explore the gun a lot as they knew their eyes have been tracked in this study. An increased exploration of the crime-related item would come together with suspicious behaviors or body reactions and expose the suspects familiarity to the item. Participants hiding guilty knowledge might find it hard to hide familiarity when looking at the crime-related item and therefore, avoid it altogether. Furthermore, this study prioritized only the crime related weapon and did not look at the outcomes on the other three weapons shown in the GKT into account. Therefore, it would be interesting to investigate how the eyes of the three conditions behaved on the other three pictures of the gun. It would provide a comparison example of fixation behavior on crime-unrelated items, because now only fixation behavior on the crime-related item is investigated. Then it would be possible to compare fixations between crime-related items and crime-unrelated items.

Lastly, the variables guilt, competence, warmth and coldness additionally checked whether participants in the three conditions were influenced by characteristics belonging to the

interviewer. As expected, participants in the guilty condition proved that they felt more guilty in relation to the participants in the other two conditions. This finding is in line with studies assuming that mere exposure to crime related items and exposure to emotional manipulation will lead to actual feelings of guilt (Bradley & Warfield, 1984). Participants in the eyewitness and innocent condition scored lower on the scale of guilt because they either only saw someone committing a crime or saw nothing in relation to crimes. Interestingly eyewitnesses scored higher on guilt than innocent participants. This manipulation facilitated inducing guilty knowledge to participants who never committed a crime. Furthermore, when replicating this study with real offenders, these findings can lead investigators and give first guidelines.

5.1 Limitations

Since the eye-tracking technology is still in its infancy and especially eye-tracking in relation to GKT, this topic still needs a lot of exploration. That is why the current study experienced multiple flaws and still has room for improvements. However, eye-tracking technology has potential and with further research will evolve. Nevertheless, the following limitations shall be guidance for future research in this field.

First, the manipulation of guilty knowledge might have not been strong enough. The mock crime stories might have been misunderstood or not convincing or real enough for participants to empathize into the story. One possible reason is that most participants probably never experienced a real shooting, therefore imagining one is open for interpretation for each participant. Additionally, the videos were shown with the researchers present in the study which might led to a less realistic story for the participants. Showing a real offender might facilitate better empathy for participants. However, participants never really committed a crime and thus their eye behavior might differ from the one of real suspects all together.

Second, manual correction on eye-tracking data was necessary on 15 of 38 cases, because of possible errors that occurred during or after the calibration. Even though, the manual mapping was done as cautious and accurate as possible, it could be the case that the conducted fixation data were modified afterwards. In future, it is recommendable to always keep track on the eye behavior meanwhile participants are being tested.

Third, the environmental conditions in which the experiment was conducted was not optimal. The experiment was not always executed in the same room and the room often had windows, which might have distracted the participants and consequently have influenced fixations and thus on the results. Future research should make sure to conduct the experiment in always the same room and in a room without a lot of windows.

Fourth and accompanied with the third limitation, the experimenter who was supposed to play the police interrogator was present from the very start. Because the experiment was conducted in a room inside the library. It would have created too many noises when the door had to be opened many times. This could pose difficulties for participants to imagine their role properly and also take the role of the police investigator serious and thus hinder participants to experience feelings like guilt.

Lastly, a question in the post-questionnaire asked whether participants have noticed a change on the weapon. This question should indicate whether guilty participants recognized the altered spot on the gun. However, this question was misunderstood by many and should be reframed in replications.

5.2 Strong Points/ Conclusion

Eye tracking technology is advantageous in various aspects. First of all, it provides measures which cannot easily be eradicated. Fingerprints for example can be avoided by simply wearing gloves. Eye movements contrarily are involuntary and hard to control. Furthermore, the GKT is robust to false positives.

In conclusion, this study could prove that eye tracking has potential to detect deceit in the eyes of suspects. It should further be investigated, especially different eye-tracking metrics should be investigated. Important to realize is that a machine telling that a person is lying or telling the truth is unrealistic, however a machine guiding professional 'lie catcher' and helping understand the complex human being is more realistic. Lastly, it is recommendable to take the calibration error into account, thus further studies will not stumble over this again.

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7) APPENDICES

Appendix A. Informed Consent

'I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research. My questions have been answered to my satisfaction. I agree with my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time. I am also aware of the fact that my personal data will be made completely anonymous. If I request further information about the research, now or in the future, I may contact Rebecca Amui or Clara Bütner (r.l.o.amui@student.utwente.nl; c.buttner@student.utwente.nl).' If you have any complaints about this research, please direct them to the secretary of the Ethics Committee of the Faculty of Behavioural Sciences at the University of Twente, Drs. L. Kamphuis-Blikman P.O. Box 217, 7500 AE Enschede (NL), telephone: +31 (0)53 489 3399; email: l.j.m.blikman@utwente.nl

Signed in duplicate:

…… ……

Name subject Signature

I have provided explanatory notes about the research. I declare myself willing to answer to the best of my ability any questions which may still arise about the research.'

…… ……

Name researcher Signature

Appendix B. Mock Crime Stories

Story for the guilty condition:

You are at the University of Twente and you are responsible for a shooting that took place minutes ago at the Ravelijn building on the University Campus. You fled the crime scene and are currently in the Cubicus building trying to find a spot where you can hide your gun.

Instructions after the video and before the GKT/interrogation:

You were able to hide the gun but on your way out you run into the police. They received information that the suspected shooter ran into the Cubicus building. In order to catch the person responsible for the shooting, they want to question everybody in the building and each of you remains a suspect until proven innocent. Therefore, they take you into a room for interrogation. Of course, it is in your best interest to not say anything about the shooting and the gun. So, your intention is to not let them show you know something about that and just behave naturally. Is this clear?

(Adapted from Bradley, M. T., & Warfield, J. F. (1984). Innocence, information, and the guilty knowledge test in the detection of deception. *Psychophysiology*, *21*(6), 683–689. doi:10.1111/j.1469-8986.1984.tb00257.x)

Story for eye-witness condition:

You are at the University of Twente and you are heading to your next tutorial in the Cubicus building on the University Campus. When you are walking down the hallway, you are being told that a shooting has taken place minutes ago at the Ravelijn building. In the next hallway, you unexpectedly spot someone carrying a gun. In a split second, you decide to follow the suspected shooter from a close distance.

Instructions after the video and before the GKT/interrogation:

You were able to run away without the shooter noticing you and, on your way out, you run into the police. They received information that the suspected shooter ran into the Cubicus building. In order to catch the person responsible for the shooting, they want to question everybody in the building and each of you remains a suspect until proven innocent. Therefore, they take you into a room for interrogation. Of course, it is in your best interest to let them know you have nothing to do with this. So, your intention is to let them know you don't know anything about that and just behave naturally. Is this clear?

(Adapted from Bradley, M. T., & Warfield, J. F. (1984). Innocence, information, and the guilty knowledge test in the detection of deception. *Psychophysiology*, *21*(6), 683–689. doi:10.1111/j.1469-8986.1984.tb00257.x)

Story for innocent condition:

You are at the University of Twente and you are heading to your next tutorial in the Cubicus building on the University Campus. When you are walking down the hallway, you come across the new study areas. You stop and decide to take a look insight.

Instructions after the video and before the GKT/interrogation:

When you are walking out of the study area, you are being told that a shooting has taken place minutes ago at the Ravelijn building and that police is outside the Cubicus building. They received information that the suspected shooter ran into the Cubicus building. In order to catch the person responsible for the shooting, they want to question everybody in the building and each of you remains a suspect until proven innocent. Therefore, they take you into a room for interrogation. Of course, it is in your best interest to let them know you have nothing to do with this. So, your intention is to let them know you don't know anything about that and just behave naturally. Is this clear?

(Adapted from Bradley, M. T., & Warfield, J. F. (1984). Innocence, information, and the guilty knowledge test in the detection of deception. *Psychophysiology*, *21*(6), 683–689. doi:10.1111/j.1469-8986.1984.tb00257.x)

Appendix C. Interrogation Interview

Questions investigator asked the participant during the interview:

1. Please state your full name.
2. Please state your date of birth.
3. What is your country and place of birth?
4. How long have you been living in the Netherlands?
5. When was the last time you have travelled abroad?
6. Where did you go to?
7. What did you do last night as of 8 p.m.?

The investigator explained the next part of the interview. Figure 2 to 5 were then displayed for 12 seconds each. After each image is shown, the investigator asked the participant: “Have you seen this particular object recently?”. Participants were instructed to answer with yes or no.

Appendix D. Weapon Collage

Appendix E. Questionnaire

Start of Block: Default Question Block

Q1.1 Participant number (filled in by researcher)

_____

Q1.2 What is your age?

_____

Q1.3 What is your gender?

o Male (1)

o Female (2)

o Other (4)

Q1.4 What is your nationality?

o Dutch (1)

o German (2)

o Other, namely: (3) _____

Q1.5 What is your highest level of education?

o MAVO (7)

o HAVO (3)

o VWO (2)

o German Abitur (1)

o Bachelor (4)

o Master (5)

o PhD (6)

o Other, namely: (8) _____

Q1.6 What is your occupation?

o Working (1)

o Student (2)

o Other (3)

End of Block: Default Question Block

Start of Block: Block 1

Q2.1 The following questions will focus on the **first part** of the experiment: **the video** *(first person perspective)*

Q2.2 Clearly describe what you did/saw in the video:

_____

_____

_____

_____

_____

Q2.3 Please indicate to what extent you agree/disagree with the following statements

	Strongly disagree (20)	Somewhat disagree (21)	Neither agree nor disagree (22)	Somewhat agree (23)	Strongly agree (24)
When I think back to the video, I feel guilty (1)					

When I think back to the video, I feel tense (2)	
When I think back to the video, I feel regret (3)	
When I think back to the video, I feel bad (4)	
When I think back to the video, I want to apologize (5)	

End of Block: Block 1

Start of Block: Block 2

Q3.1 The following questions will focus on the **second part** of the experiment: **the interrogation**

Q3.2 Please indicate to what extent you agree/disagree with the following statements

	Strongly disagree (16)	Somewhat disagree (17)	Neither agree nor disagree (18)	Somewhat agree (19)	Strongly agree (20)

When I think back to the interrogation, I feel stressed (1)	
When I think back to the interrogation, I feel nervous (2)	
When I think back to the interrogation, I feel aroused/tensed (3)	
When I think back to the interrogation, I feel pressured (4)	
During the interrogation, I felt an increased heartbeat (5)	
During the interrogation, I felt I could cope with all the things going on (6)	
During the experiment, I felt confident with my ability to handle my instruction successfully (7)	

End of Block: Block 2

Start of Block: Block 3

Q4.1 During the interrogation, I found the interviewer to be...

0 10 20 30 40 50 60 70 80 90 100

Warm ()	
Friendly ()	
Confident ()	
Dominant ()	
Cold ()	
Competent ()	
Intimidating ()	
Kind ()	
Likeable ()	
Intelligent ()	

End of Block: Block 3

Start of Block: Block 4

Q5.1 During the interrogation, four images were presented:

Image 1: Kalashnikov (long, brown)

Image 2: Hunting Rifle (long, black)

Image 3: Handgun (black)

Image 4: Revolver (silver)

Q5.2 Did you notice some sort of change in one of these pictures?

- o Yes (1)
- o No (2)

End of Block: Block 4

Start of Block: Block 5

Display This Question:

If Did you notice some sort of change in one of these pictures? = Yes

Q6.1 Reminder on four images:

Image 1: Kalashnikov (long, brown)

Image 2: Hunting Rifle (long, black)

Image 3: Handgun (black)

Image 4: Revolver (silver)

Display This Question:

If Did you notice some sort of change in one of these pictures? = Yes

Q6.2 In which image did you notice a change?

- o Image 1 (1)
- o Image 2 (2)
- o Image 3 (3)
- o Image 4 (4)

Display This Question:

If Did you notice some sort of change in one of these pictures? = Yes

Q6.3 What exactly caught your attention in this picture?

_____

_____

_____

_____

_____