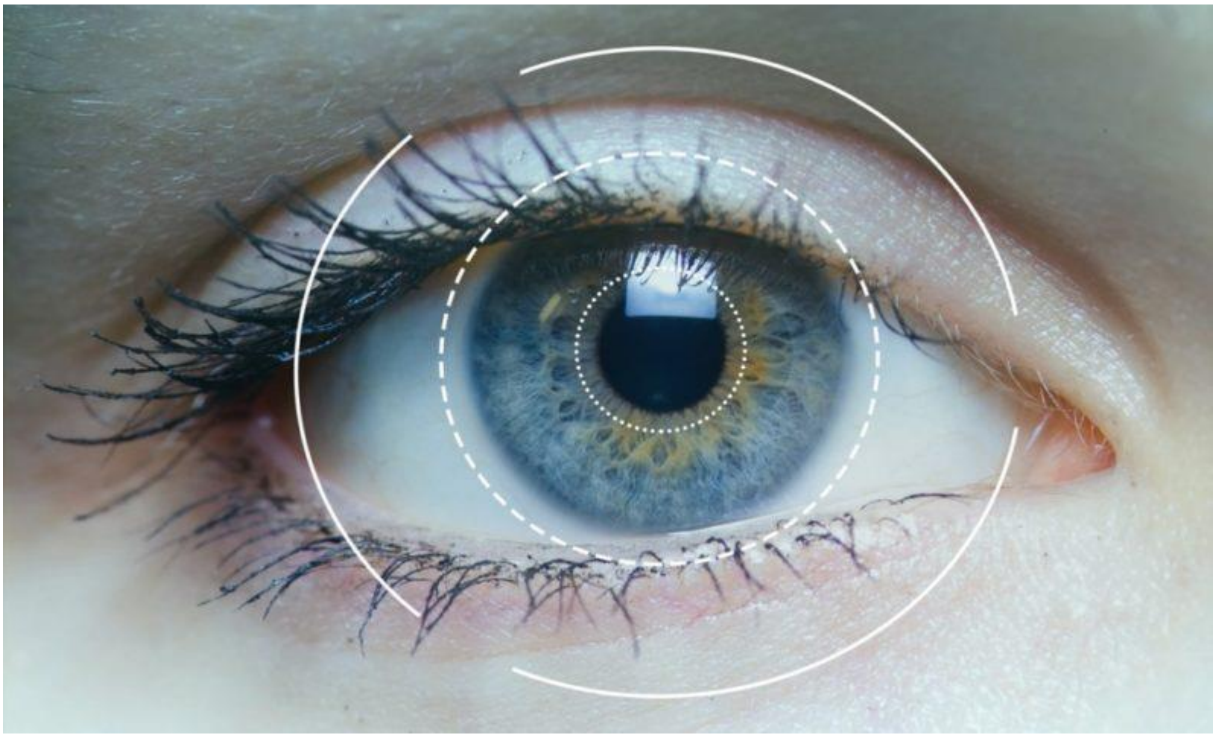
Truth (or) lies within the eyes

Examining the effects of guilty knowledge with eye-tracking



Master thesis

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Abstract

The current study made use of eye-tracking technology to gain insight into the effects of guilty knowledge on eye movement. In addition, the study adds to existing literature by examining participants who possess guilty knowledge but are not guilty of the criminal event. The study used a completely randomized, between-subject design and consisted of three conditions: the bomb-building, the bomb-observing, and the puzzling condition. An experiment was conducted in which guilty knowledge was manipulated and required both bomb-building and bomb-observing participants to lie about recognizing an explosive device during a new version of Guilty Knowledge Test (GKT). Our findings show that it is possible to differentiate between guilty participants possessing guilty knowledge and participants without guilty knowledge by both eye gaze and fixation duration. Yet, it remains difficult to distinguish participants possessing guilty knowledge without being guilty from participants possessing guilty knowledge due to committing the crime. These findings are worrying with regards to false-positive outcomes. Future research should therefore start focusing on the eye movements of observers.

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On September 21st in 2001, Lofti Raissi was the first person to be arrested for the 9/11 attacks. He was under suspicion of training pilots who flew an aircraft into the Pentagon. After interrogation, Raissi was sent to Belmarsh high-security prison in South-East London awaiting extradition to the US. In prison, Raissi became known as the "Bin Man", named after Osama bin Laden, and was stabbed twice. After five months in prison, the court concluded Raissi had no association with the attacks and had been wrongfully convicted.

Especially in high impact situations such as terrorist attacks, detection of those responsible is of the utmost importance. Still, research found that most people cannot accurately distinguish between truthful and deceptive statements of suspects and witnesses (Granhag, Andersson, Stromwall, & Hartwig, 2004). Multiple studies have shown that the accuracy rates fall below 60% (Kraut, 1980; Vrij, 2000). Even police officers have failed to detect deception better than chance (Hartwig, Granhag, Stomwall, & Vrij, 2004). So, the ability of people as lie-detectors is weak. The forensic field has therefore started to actively look for other, more objective indicators of deception, most notably using physiological response measurements. One promising new method includes eye-tracking technology (Kovaled, Luniakova, & Menshikove, 2016), which is the focus of the current study.

Specifically, eye-tracking technology will be researched as a potential technique to conduct a new version of the Guilty Knowledge Test (GKT). The purpose of the GKT is to detect the presence of guilty knowledge by measuring physiological responses (Gamer, Rill, Vossel, & Gödert, 2006). Originally, the GKT was described by Lykken (1959) who used skin conductance responses as the dependent measure. Until now, this measure received the most attention in GKT research and has shown high accuracy rates for differentiating guilty from innocent suspects (Meijer & Verschuere, 2015). Yet, a recent study by Derrick, Moffit, and Nunamaker (2011) suggests that eye-tracking technology can also be an efficient measurement for the GKT. In their study, they measured eye gaze behaviour by infrared light sources to determine if an individual possessed guilty knowledge of an explosive device. In order to examine this, they discriminated between two groups: participants familiar with the explosive device (i.e. participants who were instructed to assemble the device) and participants unfamiliar with the explosive device (i.e. participants without instruction). The eye behaviour based GKT yielded 100% accuracy in discriminating between those who had to assemble the explosive device and those who had not.

Although the results of this pilot study are promising, only 11 participants were part of the sample. This seems to be a sufficient reason for further research into eye-tracking technology for discrimination between the guilty and the innocent. The current research will therefore build upon the study by Derrick et al. (2011). First, the GKT and its accuracy will be explained. Subsequently, we will elaborate more on eye-tracking technology as a measurement for the GKT. Finally, the present study will be described, and specific hypotheses will be formulated.

Guilty Knowledge Test

Detecting deception by physiological response measures, also known as psychophysiological detection of deception (PDD), has a long history in psychological science (Lombroso, 1895). PDD methods measure physiological changes such as facial expression, voice frequency, heart rate, breathing patterns, skin conductance, and changes within the brain (Andreassi, 2000). One PDD method that is often found to discriminate between the guilty and the innocent is the GKT, also referred to as Concealed Information Test (CIT; Verschuere, Ben-Shakhar, & Meijer, 2011). The GKT utilizes a series of multiple-choice questions using information that can be known only to the guilty suspects (Ben-Shakhar & Elaad, 2002). The following case is an example of a (hypothetical) crime that could be properly investigated with the GKT (Ben-Shakhar, Bar-Hillel & Kremnitzer, 2002).

> On May 12 of 2017 at 4 p.m., an explosive device went off in Rome, close to a packed post office and United Nations building. The explosive device was placed between two vehicles in the post office car park. One blast heard and likely to have been the result of a rudimentary homemade bomb filled with termite. One car was badly damaged, however, there were no injuries. Two suspects fled the crime scene in a stolen red Ford Fiesta.

Before the GKT can be used for a suspect interview, a series of questions is prepared. Each question contains one crime-relevant item and several similar but crime-irrelevant items. The crime-relevant item contains a detail of the crime that is known only to the police and the person(s) closely familiar with the crime (Meijer & Verschuere, 2015). The crime-irrelevant items are referred to as distractors or controls (Meixner, & Rosenfeld, 2011). Based on the case presented above, a typical GKT question could be: “Which explosive substance was used for the homemade bomb? (a) Black powder, (b) Ball bearings, (c) Termite, (d) Iron pallets, (e) Flammable liquid." The answer option "Termite" is an example of a crime-relevant item. The control items are potentially explosive substances such as "Ball bearing", "Iron pallets". 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 (Lykken, 1998).

During the GKT, suspects' physiological responses to each item are measured. The suspects are usually instructed to say "no" to all items presented to them. Yet, there are also procedures in which the suspect is also allowed to remain silent or repeat the item (Ben-Shakhar, Bar-Hillel, & Kremnitzer, 2002). The GKT proposes that suspects aware of crime-relevant information will be physiologically more reactive to the crime-relevant items than to the crime-irrelevant items (Bradley & Rettinger, 1992). So, involvement can be inferred when a suspect shows consistently larger responses to the correct intimate details of the crime under investigation.

On the other hand, for an innocent suspect, the physiological responses should be similar because all alternatives are equally plausible (Meijer & Verschuere, 2015). If the crime-relevant information has not been revealed to the general public and is still only known by the criminal, the chance that an innocent suspect will physiologically be more aroused regarding the key items compared to the control items depends on the amount of questions and the amount of control items per questions (Ben-Shakhar & Elaad, 2003). In this way, the false-positive test outcomes can be controlled for by the examiner, providing maximal protection of the innocent (Meijer & Verschuere, 2015). This is seen as a main advantage of the GKT. Another advantage is the broad range of physical response measures that can be used for the GKT.

Accuracy of well-known physiological response measures

Originally, the GKT uses skin conductance responses as measure and previous research has shown to accurately discriminate between the guilty and the innocent. For example, Ben-Shakhar and Furedy (1990) showed in their meta-analysis of 10 GKT laboratory experiments that 84% of the participants with concealed knowledge and 94% of those without were correctly classified. Further, laboratory studies estimate that 76-84% of guilty participants and 83-99% of the innocent ones are correctly classified (Elaad, 1998; Ben-Shakhar & Elaad, 2003; Vrij, 2008). Besides this, only two field studies have been published to date, both using skin conductance response as measure. The results of the innocent participants were very high, with 98% and 94% of them being correctly classified.

The results for participants with guilty knowledge were less impressive. In one field study, a reasonable accuracy rate (76%) of guilty participants was found, however in the other field study the percentage (42%) of guilty participants who were correctly classified was much lower (Elaad, 1990; Elaad, Ginton, & Jungman, 1992).

Alongside the original skin conductance response measure, other physiological response measures for the GKT have been researched (Matsuda, Nittono, & Allen, 2013; Meijer, Selle, & Ben-shakhar, 2014). For example, Wang et al. (2013) found an accuracy rate of 95% in recognizing guilty knowledge with a single electroencephalography (EEG) electrode. Furthermore, electrodermal, respiratory, and cardiovascular measures were also able to successfully (above 90%) discriminate between guilty and innocent participants. Yet, voice stress analysis showed that vocal measures are invalid for the detection of guilty knowledge (Gamer, Rill, Vossel, & Gödert, 2006). Although some of these measures have already shown to work for the GKT, new measurements are still being developed and researched.

Recently, technological development made it possible to track eye movement in a very precise matter and research suggested that eye movement can be used as makers of memory during concealed recognition (Millen, Hope, Hillstrom, & Vrij, 2017). Therefore, the current research seeks to determine whether eye-tracking technology can be seen as potential technique to conduct a new version of the GKT.

Introducing eye-tracking measures for the Guilty Knowledge Test

Multiple studies have researched the detection of deception with eye tracking before and two main concepts, eye fixation and gaze behaviour, are most commonly measured (Althoff & Cohen, 1999; Derrick et al., 2011; Schwedes & Wentura, 2016). First, eye fixation, is used for object recall and can demonstrate the order of ‘importance’ assigned to scene objects by people observing this scene (Spain & Perona, 2008). 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. A fixation is a period where the eyes are locked towards an object (“7 most used eye tracking metrics”, 2015). Peth, Kim and Gamer (2013) examined whether eye fixations could be allowed for the detection of guilty knowledge. They used a mock crime procedure with a manipulation of arousal and measured eye fixations during a GKT. Results showed that guilty participants fixated for significantly more time on central crime details compared to innocent participants. These results indicate that eye fixation can be used for object recognition and is therefore a suitable measure for the detection of deception.

The second concept, gaze behaviour, is generally used to help examine how stimuli are processed. Gaze behaviour can demonstrate which elements of a stimulus the eyes are looking at and can show where a person's attention is drawn to (Frischen, Bayliss, & Tipper, 2007). Whereas a fixation is formed by gaze points only, eye gaze behaviour consists of both eye gaze points and saccades, which are the eye movements between the fixation. Boraston and Blakemore (2007) researched gaze behaviour in an autism study and reported: "the idea behind gaze behaviour is that when a person looks directly at an object, its image falls on the fovea, the part of the retina specialized for detailed visual processing". Recordings of people's gaze behaviour can therefore give an indication of where in an object people are seeking detailed information. For detection of deception with eye tracking, this is valuable information.

Guilty suspects might be gazing at different detailed information on a familiar object (e.g. the weapon used to commit murder) in comparison to innocent suspects who are unfamiliar with the object. So, the gazing patterns of participants might provide information to what extend they are recognizing the crime-relevant object. Derrick et al. (2011) researched object recognition during a GKT by measuring eye gaze behaviour of guilty and innocent participants. Instead of just recognizing a familiar object, they examined a more complex form of recognition. In particular, guilty participants had to recognize that a detailed part of a familiar object was missing. Results showed that the guilty participants, who had to assemble an explosive device, gazed more time at the missing part of the explosive device than the innocent participants, who were unfamiliar with the explosive device. They were able to distinguish guilty from innocent participants with 100% accuracy. These outcomes indicate that, next to eye fixation, eye gaze behaviour is also a suitable measure for the detection of deception.

Although all the above-mentioned findings look promising for the use of eye tracking, they might have overlooked the eye movements of one important group. When a crime is committed, there is a possibility that other people are present at the crime-scene, such as eye-witnesses and bystanders. Especially with the rising acts of terrorism, this is often the case. 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. It is therefore of great relevance to see how the eye movement patterns of this group differs from the guilty ones. So, participants who are familiar with the crime-relevant object but are not guilty of the criminal event need to be included. These outcomes can provide crucial information concerning false-positive test outcomes.

All in all, both eye fixation and gaze behaviour can be used as measures for the differentiation between guilty and innocent participant in a new version of the GKT. Additionally, the current study will take ‘observers’ into account to see if their eye movements differ from guilty participants. Hopefully, we can provide clarification regarding possible false-positive test outcomes.

The present study

The current study will examine whether eye tracking technology can be used as a potential technique to conduct a new type of GKT. In addition, the present experiment will systematically manipulate guilty knowledge and requires some participants to lie about recognizing a concealed object during a version of the GKT with an examiner. During the test, eye gaze behaviour and eye fixations are recorded to assess recognition. To manipulate guilty knowledge, a scenario in which participants have to complete an operational task is created. Some participants are asked to assemble or observe an explosive device, while others should complete a jigsaw puzzle.

In particular, the current experiment consists of two main conditions: no bomb-familiarity and bomb-familiarity. The no bomb-familiarity condition consists of one group: puzzlers. Participants in this condition are innocent and do not possess guilty knowledge. The bomb-familiarity condition consisted of two groups: bomb-builders and bomb-observers. In the bomb-builders condition, participants are guilty of assembling an explosive device and thus possess guilty knowledge. However, in the bomb-observing condition, participants only observe the explosive device. So, they are not guilty of assembling the explosive device, yet they do possess guilty knowledge. By making this distinction, we want to examine whether eye movement of guilty participants differs from “innocent” participant who do possess guilty knowledge.

In the GKT, the examiner will show four images of objects to the participants, one of which is the crime-relevant object, i.e. the explosive device. However, the explosive device is incomplete because one crucial part (i.e. the electronic device) has been modified. This part is also referred to as the altered area. As a consequence, only one of the two crucial parts is still visible on the explosive device (i.e. the battery device). This part is also referred to as the non-altered area. According to the study by Peth et al. (2013), participants who are familiar with a crime-relevant object tend to fixate for more time on central crime details than participants who are unfamiliar with that object. Based on these findings, we expect that the bomb-familiarity participants will show longer eye movements (both gaze and fixation) to the non-altered area of the explosive device compared to the no bomb-familiarity participants. We also expect this effect to be stronger for the bomb-builders compared to the bomb-observers. This leads up to the following hypothesis:

H1: Bomb-familiarity participants spend more time gazing at the non-altered area where the battery device is visible in comparison with no bomb-familiarity participants; this effect is stronger for bomb-builders than bomb-observers.

H2: Bomb-familiarity participants spend more time fixating on the non-altered area where the battery device is visible in comparison with no bomb-familiarity participants; this effect is stronger for bomb-builders than bomb-observers.

The research by Derrick et al. (2011) showed that guilty participants, who were familiar with the explosive device, gazed more time at the missing part of the explosive device than the innocent participants, who were unfamiliar with the explosive device. Therefore, in the current study, it is also expected that the bomb-familiarity participants will show longer eye movements (both gaze and fixation) to the altered area of the explosive device compared to the no bomb-familiarity participants. Furthermore, we expect the bomb-builders to show more time gazing and fixating at the altered area compared to the bomb-observers. Taking the above-mentioned information into account, the following hypotheses are formulated:

H3: Bomb-familiarity participants spend more time gazing at the altered area where the electronic device is missing in comparison with no bomb-familiarity participants; this effect is stronger for bomb-builders than bomb-observers.

H4: Bomb-familiarity participants spend more time fixating on the altered area where the electronic device is missing in comparison with no bomb-familiarity participants; this effect is stronger for bomb-builders than bomb-observers.

Explorative variables

In addition, we would like to explore some additional variables that might play a role in the experiment. We are mainly interested in participants' feelings with regards to the operational task they performed and the GKT they participated in. The following five variables will be measured in a post-experiment questionnaire: participants' affective response, guilt, stress and cognitive load, task performance, and perceived competence and warmth of the GKT examiner.

First, we are interested in the three variables (i.e. participants' affective response, guilt, stress and cognitive load) that might be affected by the manipulation of guilty knowledge. With regards to affective response, it is conceivable that participants in the bomb-familiarity condition are likely to perceive more negative feelings during the performance of the operational task compared to the no bomb-familiarity participants. Also, it is likely that the bomb-builders will perceive more negative feelings than the bomb-observers. From the second variable, guilt, it is imaginable that bomb-familiarity participants will have stronger feelings of guilt during the task performance and the GKT than the no bomb-familiarity participants. Furthermore, it is likely that the bomb-builders will have stronger feelings of guilt than the bomb-observers. Regarding cognitive load and stress, participants in the bomb-familiarity condition are likely to perceive higher levels of stress and cognitive load during the GKT in comparison with the no bomb-familiarity participants. Again, it is likely that the bomb-builders will perceive higher levels of stress and cognitive load than the bomb-observers.

Second, the two other variables (i.e. participants' task performance and perceived competence and warmth of the GKT examiner) are not an intended part of the study and might add noise to the relationship of interest. To make sure that these variables will not account for the effects found in the study, we will take them into consideration.

Method

Participants

A total of 72 people participated in the experiment on voluntarily basis. Four participants were excluded due to technological failure (3) and bad trackable pupil movement (1). So, a total of 68 participants were eventually used for statistical analyses (34 women, 34 men; mean age = 22.8 years; *SD* = 2.4; range 18-32 years). The sample consisted of participants with different nationalities: 88.2% Dutch, 5.9% German, 3.0% British, 1.5% Scottish and 1.5% Bulgarian. Most of the participants were students within the field of psychology, technical medicine and biomedical technology. All participants had normal or corrected-to-normal vision. We reported all data exclusions, all manipulations, and all measures in the study.

Research design

The current study used a completely randomized, between-subject design with one experimental manipulation: guilty knowledge. The experiment consisted of three conditions: the bomb-building condition (N = 23), the bomb-observing condition (N = 22), and the puzzling condition (N = 22). Participants in both bomb-building and bomb-observing condition were exposed to guilty knowledge and were also referred to as bomb-familiarity participants. Participants in the puzzle (control) condition were not exposed to guilty knowledge and were also referred to as no bomb-familiarity participants. The dependent variables were total gazing duration at specific regions, i.e. area of interests (AOI’s) and total fixation duration on the AOI’s. The explorative dependent variables were participants’ affective response, task performance, guilt, stress and cognitive load, and perceived competence and warmth of the GKT examiner.

Procedure and Materials

After receiving ethical permission, the experiment was set up in a university building on campus and participants were recruited for participation via the researcher’ social network. Depending on nationality, the experiment was conducted in Dutch (63) or in English (5). Participants were tested individually, each session lasted for about 10 to 15 minutes. Two experimenters were present: the main researcher and a research associate, who also played the role of examiner in the Guilty Knowledge Test (GKT). The researcher first obtained informed consent (see appendix A). Then, the eye tracker was placed and calibrated. Participants’ eye behaviour 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 degree per second, a I-VT classifier and a minimum (fixation) duration of 60 milliseconds.

Figure 1. Wearable Tobii eye tracker

After the placement of the Tobii eye tracker, the experiment consisted of two main parts: (1) the manipulation of guilty knowledge and (2) the GKT. In the first part, guilty knowledge was manipulated by an operational task. The instruction diverged depending on the condition to which a participant was randomly assigned. (a) In the bomb-building condition, participants were instructed to assemble an explosive device using a straightforward protocol and materials (see figure 2 and appendix B1 and B2). (b) In the bomb-observing condition, participants were instructed to observe the researcher while the researcher was assembling the same explosive device used in the bomb-building condition. Participants used an observation form (see appendix C1 and C2) to observe the researcher, who was sitting across the table. By observing the bomb-building process, participants became familiar with the explosive device and as such possessed guilty knowledge. However, they were not guilty of assembling the explosive device. (c) In the puzzle condition, participants were instructed to complete a basic jigsaw puzzle of 50 pieces (see appendix D). Hence, participants in this condition were not familiar with the explosive device and thus did not possess guilty knowledge.

After participants completed their task, they received a message from the researcher. The researcher told the participants that an intelligence agency received information about a future bombing at the university campus and wanted to briefly talk to the participant. Then the researcher indicated all participants that it was important (and in their own interest) to let the intelligence agency know they had nothing to do with it and act as naturally as possible. The three participants who were most convincing (to be decided afterwards by the examiner) would receive a reward of €30. After all information was clearly understood by the participants, they followed the researcher to another room where the GKT examiner would wait for them. The participants were seated in front of a computer screen and across the examiner.

For the second part of the experiment, all guilty knowledge tests were standardized. The test started by the examiner asking participants seven questions about their background and travel history (see appendix E). These questions were asked to make the test setting more realistic. Then the examiner instructed the participants to look at four images: three crime-irrelevant (control) images and one crime-relevant image. The first, third and fourth image shown to the participants were control images (see appendix E). The second image shown was the crime-relevant image. This image was familiar to the bomb-familiarity participants and showed the concealed object i.e. the explosive device. This was the same explosive device presented to the bomb-builders and -observers in their operational task, however the electronic device and the connecting wires had been removed (see figure 3) to make the image novel to the bomb-familiar participants (Derrick et al., 2011).

Each image was presented to them on the computer screen for 10 seconds (see appendix E). The 10 seconds were based on the research by Derrick et al. (2011) and pilot tests. This is the most important part for measuring eye movement. Participants are asked to keep their heads in a straight position while looking at the screen. After each image was presented to the participants, the examiner asked them if they had recently seen this specific object. Participants were instructed to answer with yes or no. After all images were shown, the examiner told the participants the test ended and to meet the researcher outside.

The researcher then took off the eye-tracker device and asked the participants to fill in a post experiment questionnaire, consisting of 34 questions about participants' experiences during the experiment (see appendix F and dependent measures). After completing the questionnaire, a final debriefing was carried out.

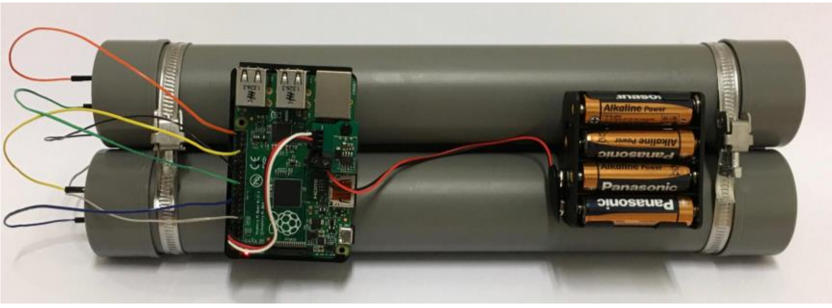

Figure 2. Explosive device (complete)

Figure 3. Explosive device (without battery device and wires)

Dependent variables

Total gaze and fixation time. To investigate gazing at and fixation to specific regions, area of interests (AOI) were designated to the area of the image we were interested in. AOI 1 is determined to the area where the battery device is visible (see figure 4). AOI 2 is determined to the altered area where the electronic device is missing (see figure 5). Tobii Pro Lab (x64) converted the data into seconds.

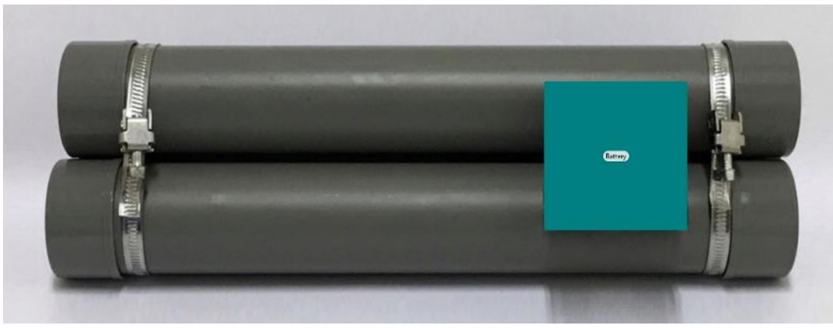

Figure 4. AOI 1 – Battery device

Figure 5. AOI 2 – Electronic device

Explorative dependent variables. The following five explorative dependent variables were measured in the post-experiment questionnaire: participants' affective response, task performance, guilt, stress and cognitive load, and perceived competence and warmth of the GKT examiner.

First, affective response during the operational task was measured using six items. Participants answered the items on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). The items are adapted from a study by ter Huurne and Gutteling (2008). Two examples of items are: "During the performance of the operational tasks I felt anxious" and "During the performance of the operational tasks I felt comfortable". Three items have been recorded in such a way that the construct measures positive emotions. Thus, the higher the score, the more positive emotions. Cronbach's alpha was conducted to check the reliability. The construct affective response ($\alpha = .84$) was found reliable enough to use.

Second, task performance was measured using four items. The answer options of the four items ranged from 1 (strongly disagree) to 5 (strongly agree). Two examples of items are: "Performing the operational task, I found interesting" and "Performing the operational task, I found difficult". The construct task performance (α = .63) was not found reliable to use.

Subsequently, stress and cognitive load during the GKT were measured using nine items on a scale ranging from 1 (strongly disagree) to 5 (strongly agree) and consist of two subscales. The items are adapted from a study by Ströfer, Noordzij, Ufkes, and Giebels (2013). An example of the four items used to measure stress is: "I felt nervous during, or directly after the interview". An example of the five items used to measure cognitive load is: "I thought the interview was mentally demanding". The subscale stress (α = .54) was not found reliable to use. Yet, the subscale cognitive load (α = .68) was found reliable to use.

Further, guilt during the operational task and the GKT was measured using two items on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). An example of an item is: "I felt guilty during, or directly after the interview". The construct guilt (α = .67) was found reliable enough to use.

Subsequently, perceived competence and warmth of the GKT examiner was measured regarding using six items on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). The items are adapted from a study by Fiske, Xu, Cuddy, and Glick (1999). Examples of items are: "During the interview, I found the examiner competent" and "During the interview, I found the examiner cold". Three items have been recoded in such a way that the construct measures positive thoughts about the examiner. Thus, the higher the score, the more positive the thoughts regarding the examiner. A factor analysis showed two components instead of one and therefore competence and warmth are examined as two separate constructs, both consisting of three items. Cronbach's alfa showed support to use both competence (α = .76) and warmth (α = .73) as components.

All in all, the following variables were found reliable enough to use: participants' affective response, guilt, cognitive load, and perceived competence and warmth of the GKT examiner.

Results

Hypotheses

With regards to the first area of interest (AOI), the data was normally distributed for both dependent measurements, i.e. total gazing duration and total fixation duration. For that reason, ANOVA tests have been executed. Regarding the second AOI, there was no normality in the data for both dependent variables, therefore Kruskal-Wallis tests have been executed.

Hypothesis 1. To investigate hypothesis 1, that the bomb-familiarity participants will spend more time gazing at the non-altered area where the battery device was visible in comparison with the no bomb-familiarity participants, a ANOVA was conducted with the total gazing duration (in seconds) at the battery device. There was a statistically significant difference between groups, $F(2, 68) = 4.50$, $p = .02$. A Tukey post hoc test revealed that the bomb-builders ($M = 3.76$, $SD = 2.47$, $p = .02$) gazed for significantly more time at the battery device in comparison with the puzzlers ($M = 1.93$, $SD = 1.80$). There was no statistically significant difference between the bomb-builders and the bomb-observers ($M = 3.49$, $SD = 2.39$, $p = .91$) and between the bomb-observers and the puzzlers ($p = .057$). Thus, hypothesis 1 not confirmed. In addition, the gazing count has been considered.[1]

Hypothesis 2. To investigate hypothesis 2, that the bomb-familiarity participants will spend more time fixating on the non-altered area where the battery device was visible in comparison with the no bomb-familiarity participants, a ANOVA was conducted with the total fixation duration (in seconds) on the battery device. There was a statistically significant difference between groups, $F(2, 68) = 4.56$, p = .01. A Tukey post hoc test revealed that the bomb-builders ($M = 3.50$, $SD = 2.13$, $p = .02$) and the bomb-observers ($M = 3.29$, $SD = 2.17$, $p = .05$) fixated for significantly more time on the battery device in comparison with the puzzlers ($M = 1.85$, $SD = 1.69$). There was no statistically significant difference between the bomb-builders and the bomb-observers ($p = .94$). Yet, hypothesis 2 is confirmed. Yet, the effect is not stronger for bomb-builders compared to bomb-observers. Figure 6 gives an overview of these findings. In addition, the gazing count has been considered.[2]

Hypothesis 3. To investigate hypothesis 3, that the bomb-familiarity participants will spend more time gazing at the altered area where the electronic device was missing in comparison with the no bomb-familiarity participants, a Kruskal-Wallis was conducted with the total gazing duration (in seconds) at the altered area. The test showed there was no statistically significant difference in the total gazing duration at the altered area between the three groups, $\chi^2(2) = .64$, $p = .73$, with a mean rank score of 37.00 ($M = 0.51$) for the bomb-builders, 33.48 ($M = 0.26$) for the bomb-observers and 32.98 ($M = 0.35$) for the puzzlers. Thus, hypothesis 3 is not confirmed. In addition, the gazing count, i.e. how many times a participant gazed in the AOI, and several locations of AOI 1 were considered and showed the

[1] Gazing count: ANOVA, $F(2, 65) = 3.61$, $p = .03$
[2] Fixation count: ANOVA, $F(2, 65) = 3.61$, $p = .02$

same findings. [3] [4]

Hypothesis 4. To investigate hypothesis 4, that the bomb-familiarity participants will spend more time fixating on the altered area where the electronic device was missing in comparison with the no bomb-familiarity participants, a Kruskal-Wallis was conducted with the total fixation duration on the altered area. The test showed there was no statistically significant difference in the total fixation duration (in seconds) at the electronic device between the three groups, $\chi^2(2) = .65$, $p = .72$, with a mean rank score of 37.00 ($M = 0.50$) for the bomb-builders, 33.52 ($M = 0.26$) for the bomb-observers and 32.91 ($M = 0.34$) for the puzzlers. Thus, hypothesis 4 is not confirmed. In addition, the fixation count and several locations of AOI 1 were considered and showed the same findings.[5] [6]

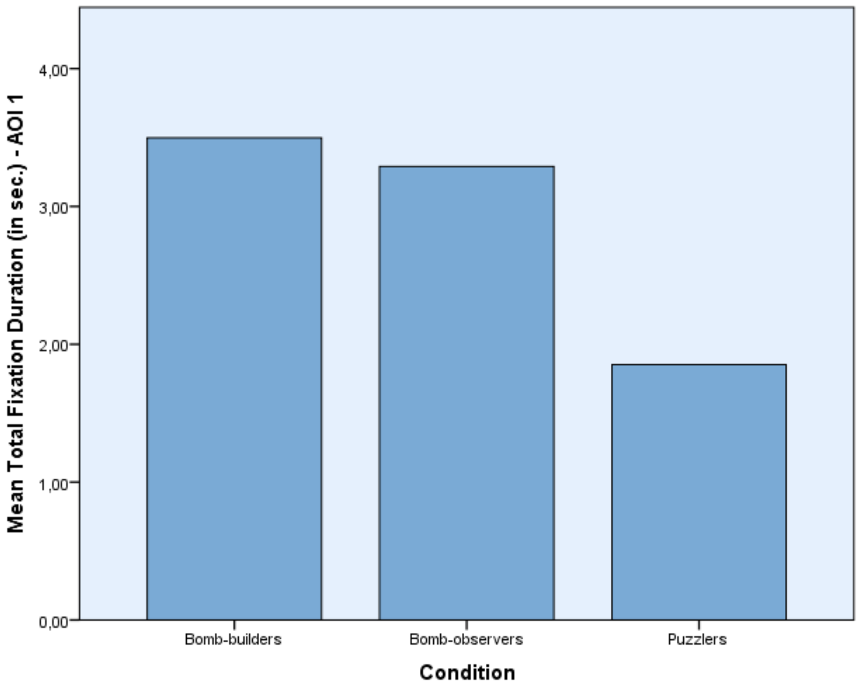

Figure 6. Total fixation duration at non-altered area (AOI 1) per condition

Additional analyses

Explorative dependent variables. The data of the post-experiment questionnaire is examined and the following five explorative variables were found reliable to use: participants'

[3] Gazing count: Kruskal-Wallis H, $\chi^2(2) = .11$, $p = .95$.
[4] AOI includes electronic device and connecting wires (without shiny silver wire that ties the pipe system together): Kruskal-Wallis H, $\chi^2(2) = 1.71$, $p = .43$.
AOI includes electronic device, connecting wires and silver wire: Kruskal-Wallis H, $\chi^2(2) = .18$, $p = .91$.
[5] Fixation count: Kruskal-Wallis H, $\chi^2(2) = .09$, $p = .96$.
[6] AOI includes electronic device and connecting wires: Kruskal-Wallis H, $\chi^2(2) = 1.57$, $p = .45$.
AOI includes electronic device, connecting wires and silver wire: Kruskal-Wallis H, $\chi^2(2) = .13$, $p = .94$.

affective response, guilt, cognitive load, and perceived competence and warmth of the GKT examiner. Table 1 shows the mean scores and standard deviations of the variables within the three groups. Furthermore, five separate ANOVA's were conducted.

First, we examined the three variables (i.e. participants' affective response, guilt, and cognitive load) that might be influenced by the independent groups. Results showed a statistically significant effect for affective response, $F(2, 68) = 3.24$, $p = .046$. A Tukey post hoc test revealed that the bomb-observers showed significantly more negative emotions with regards to the operational task than the puzzlers ($p = .047$). Yet, there was no statistically significant difference between the bomb-builders and the puzzlers ($p = .16$) and between the bomb-observers and the bomb-builders ($p = .83$). Second, the results showed a statistically significant effect for guilt, $F(2, 68) = 3.72$, $p = .03$. A Tukey post hoc test revealed that the bomb-observers showed significantly stronger feelings of guilt in comparison with the puzzlers ($p = .02$). There was no statistically significant difference between the bomb-observers and the bomb-builders ($p = .49$) and between the bomb-builders and the puzzlers ($p = .26$). Third, there were no statistically significant effects found for cognitive load, $F(2, 68) = .21$, $p = .82$.

Second, we examined the two variables (i.e. competence and warmth) that might have added noise to the relationship of interest. There were no statistically significant effects found for competence, $F(2, 68) = .72$, $p = .49$, and for warmth, $F(2, 68) = .15$, $p = .86$. Finally, a Wilks' Lambda test showed no statistically significant main effect for the manipulation of guilty knowledge on all independent variables, $F(2, 68) = .99$, $p = .46$.

Table 1

Mean scores affective response, guilt, cognitive load, competence, and warmth

		Affective response	Guilt	Cognitive load	Competence	Warmth
Bomb-builders	Mean	3.59[ab]	1.78[ab]	2.86	3.80	2.87
	SD	0.76	0.85	0.73	0.48	0.81
Bomb-observers	Mean	3.47[a]	2.07[a]	2.85	3.74	2.82
	SD	0.76	0.79	0.76	0.61	0.62
Puzzlers	Mean	3.99[b]	1.39[b]	2.75	3.62	2.94
	SD	0.61	0.87	0.40	0.41	0.81

Gazeplots and heatmaps. Below the heatmaps and gazeplots of the three groups are shown. In general, all three groups roughly show the same patterns and focused their attention on the same two points on the explosive device. Still, it is interestingly to see that the puzzlers have the biggest heat points on both sides of the explosive device and yet show the least total gaze and fixation duration.

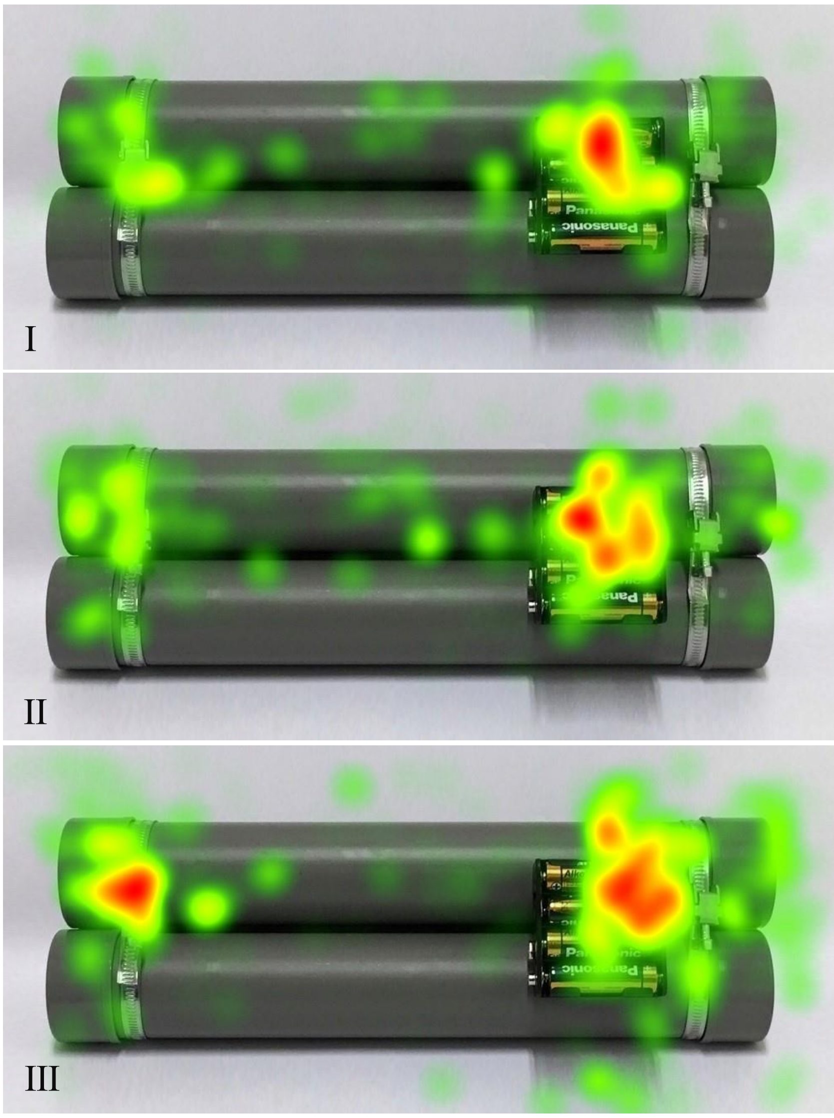

Figure 7. Heatmap bomb-builders (I), bomb-observers (II) and puzzlers (III)

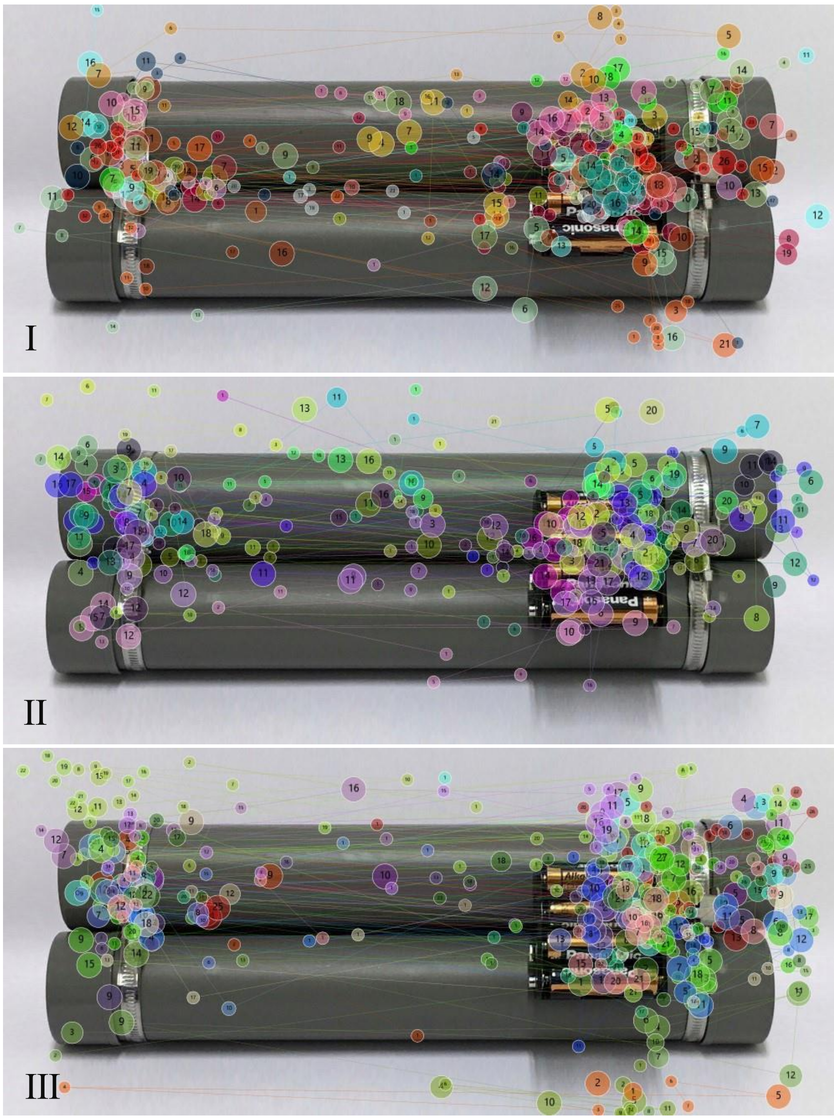

Figure 8. Gazeplots bomb-builders (I), bomb-observers (II) and puzzlers (III)

Discussion

The aim of the current study was to examine whether eye-tracking technology can become a potential new physiological measurement for the detection of deception. An experiment was conducted in which guilty knowledge was manipulated and required bomb-familiarity participants to lie about recognizing a crime-relevant object during a version of the Guilty Knowledge Test (GKT). During the GKT, both eye gaze and fixation duration were measured to assess recognition. Based on participants' eye movements, we investigated whether participants possessing guilty knowledge (bomb-familiarity participants) could be differentiated from participants without guilty knowledge (no bomb-familiarity participants). Furthermore, we were interested in the difference between possessing guilty knowledge with and without being guilty of the crime.

As expected, both bomb-builders and bomb-observers fixated for more time on the non-altered are where the battery device was visible (AOI 1) in comparison to the puzzlers. These results indicate that, by fixation duration, participants who possess guilty knowledge can be distinguished from participants without guilty knowledge. These findings are in line with the research by Peth et al. (2013). With regards to eye gaze duration, only bomb-builders gazed for more time at the non-altered area in comparison to the puzzlers. This outcome is also in line with our expectation and suggests that participants who possess guilty knowledge due to committing the crime can be differentiated from participants without guilty knowledge.

Bomb-observers did also differ from puzzlers on eye gaze duration regarding the non-altered area, but the difference was just not on a significant level. Interpretation must therefore be handled with caution. The finding suggests that participants possessing guilty knowledge without being guilty of the crime cannot be distinguished from participants without guilty knowledge. This effect is surprising because research suggests that eye gaze behaviour can be used for memory assessment and that people will seek longer at crucial object details when the object is already familiar to them (Boraston & Blakemore, 2007; Derrick et al., 2011). In contrast to the puzzlers, bomb-observers became familiar with the explosive device and therefore we expected bomb-observers to gaze for (significantly) more time at the non-altered area of the device. Yet, this was not the case. On the other hand, the effect might be not as surprising, when in fact, participants in both groups can be considered innocent. They both did not commit a crime. This suggests that only being familiar with the crime-relevant object, and not being guilty of the crime, is not enough to be distinguished from participants without guilty knowledge. It might be possible that feelings of guilt play a role here. In the current study, we only explored the influence of the guilty knowledge manipulation on guilt and we will elaborate on this later. Still, future research should investigate the possible mediating effect of participants' feelings of guilt on eye movement.

Contrary to our expectations, bomb-familiarity participants did not differ from no bomb-familiarity participants with regards to their gazing and fixation duration at the altered where the electronic device was missing (AOI 2). These findings indicate that participants possessing guilty knowledge do not spend more time gazing and fixating on an altered area of a crime-relevant object in comparison to participants without guilty knowledge. These findings are not in line with the recent findings of Derrick et al. (2011). In their study, they yielded 100% accuracy in discriminating between participants with and without guilty knowledge based on their eye gaze recordings at an altered area of an explosive device. There are several possible explanations for the contradicting findings.

First, the study of Derrick et al. (2011) was a pilot study in which 11 people participated. The sample size of the current study was 72. A bigger sample size might give a more representative view and in such a small sample as 11 participants, a sampling error or bias is more likely (Marshall, 1996). Furthermore, Derrick et al. (2011) used a 24% cut of line to determine the accuracy rates of the study. Yet, in the present study we try to distinguish based on group differences. It is possible that the difference in approach might cause a different effect. Also, Derrick et al. (2011) used an EyeTech TM3 eye tracker that was mounted directly below a computer monitor. In the current study, a wearable Tobii eye tracking device was used. The wearable eye tracker could have made participants more aware of the fact that their eye movements were being tracked. Consequently, bomb-familiarity participants might not have shown their instinctive eye movements during the GKT.

In addition, the feelings of stress and guilt in combination with the different experimental settings might also have influenced the outcomes. In the current study, the mean scores on the variables cognitive load and guilt were rather low, indicating that most participants did not have strong feelings of cognitive load and guilt. This might be due to the location and time of conductance. The present experiment was conducted in a university building during summer vacation. The university building, and the whole university campus, was very quiet and remote. In contrast, Derrick et al. (2011) conducted their experiment at a kiosk located in a high-volume pedestrian traffic environment. It is expected that while participants had to build the explosive device, a lot of pedestrians were passing by. Due to the crowded setting, bomb-builders might have been more aware of the harm the explosive device could cause compared to the bomb-familiarity participants in the remote university building. The setting in the study of Derrick et al. (2011) could therefore have evoked stronger feelings of stress and guilt and, consequently, showed more sincere eye movement behaviour than bomb-familiarity participants in the current experimental setting. The location and time of conductance can be seen as a weakness of the present study. In the future, the effect of difference in setting needs to be explored. It is interesting to repeat the study when both university building and campus are lively and busy and see how this differs. It is conceivable that the change in setting will increase feelings of cognitive load and guilt. Consequently, bomb-familiarity participants might act more like a real guilty person would.

Lastly, other noise variables might explain the difference in the current outcomes. We examined both competence and warmth of the GKT examiner perceived by participants. No effects were found on both explorative variables. We therefore have no indication that an interviewer effect could account for the effects obtained in our experiment and cannot explain the difference in findings with Derrick et al. (2011).

With regards to the other three explorative variables, we found that bomb-observers showed more negative feelings regarding the operational task in comparison to the puzzlers. We found no difference between the feelings of bomb-builders and both bomb-observers and puzzlers. We found no difference between the three groups with regards to participants' cognitive load indicating that the different conditions did not influence participants' cognitive load. We also found that bomb-observers showed stronger feelings of guilt during the task performance and the GKT compared to the puzzlers. Yet, bomb-builders did not differ in their feelings of guilt from both bomb-observers and puzzlers. This outcome is surprising because we assumed that participants assembling an explosive device would perceive the strongest feelings of guilt, followed by participants observing the assembling process.

Contrary to our expectations, bomb-builders did not differ from bomb-observers on both gaze and fixation duration and regarding both areas of interest. These findings indicate that it is difficult to differentiate between those possessing guilty knowledge without being guilty of the crime and those possessing guilty knowledge due to committing the crime. These findings provide crucial information in relation to false-positive test outcomes. A possible explanation for the unexpected findings lies in the performance of the operational task combined with participants' feelings during the task performance and the GKT. Before the start of the task, all participants were instructed to complete their task as quick as possible. Prior to the experiment, we expected participants in all conditions to be busy with performing their operational task until they were finished. During the experiment, participants in the bomb-building condition indeed started to assemble the explosive device straight away using a step-by-step protocol. Most bomb-builders looked very eager to finish their task quickly.

On the other hand, participants in the bomb-observing condition generally did not start filling in the observation directly. Most participants did not write down much information and only graded the performance after the experimenter was finished with assembling the device. Furthermore, it did not seem like the bomb-observers felt time-pressure since the experimenter was in charge of the time while assembling the device. Consequently, most bomb-observers had several minutes to become consciously aware of the situation they were in and this might have increased their negative feelings and feelings of guilt. Contrary, most bomb-builders were very busy completing the task and might have been less aware of what they were actually doing. It is conceivable that bomb-builders therefore did not perceive strong negative feelings, feelings of guilt, and cognitive load. Altogether, it is believable that the operational tasks of both bomb-builders and bomb-observers did not have the expected effect on participants' feelings during the task performance and GKT. These factors might have an opposite influence on the eye movements of both bomb-builders and bomb-observers. As above-mentioned, future research should critically investigate the possible (indirect) influence of participants' affective response, guilt and cognitive load on eye movement.

Although the outcomes regarding the difference between bomb-builders and bomb-observers are not satisfactory, the current study adds to existing literature by making this distinction in the first place. It is furthermore important to show that it is not (yet) possible to accurately distinguish between the innocent from the guilty. Future research should actively investigate the eye movements of observers, such as eye-witnesses and bystanders, and compare them to both innocent (not involved) participant and guilty participants. It is advisable to take participants' feelings of affective response, guilt, and cognitive load into account and look if these variables have a mediating effect on the eye movements of participants. Furthermore, it is advisable to also analyse the first-time gazing and first-time fixating on the areas of interest. Research into object recognition shows that a person is able to recognize a familiar object within 60 milliseconds (Doniger, Foxe, Murray, Higgins, & Javitt, 2002). It might be able to more accurately discriminate the groups by the first (or second) time gazing and fixating. Lastly, in the future, it might also be interesting to do a similar research but instead of removing a crucial item from a crime-relevant object, adding one to the object.

In sum, the current study examined eye-tracking technology as potential technique to conduct a new version of the GKT. With some caution, we can conclude eye-tracking technology can be used as potential physiological measurement for the discrimination between guilty people who possess guilty knowledge and people without guilty knowledge when examining a crucial part of a crime-relevant object that is visible for everyone but only familiar to participants possessing guilty knowledge. Yet, the present research also showed that eye-tracking technology is not able to discriminate between possessing guilty knowledge with and without being guilty of the crime. Society cannot afford more false-positive outcomes in the forensic practice. Therefore, further research is necessary to decide whether truth lies within the eyes. Lofti Raissi would have agreed.

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Appendix

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 of 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 Anouk den Besten (a.l.denbesten@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

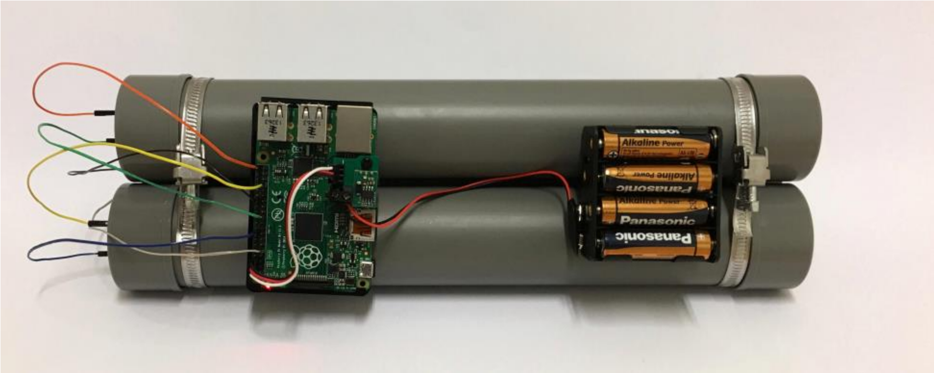
Appendix B1. Instructions for bombmaking condition

Operational task – explosive

On the internet, instructions can be found of how to build an explosive. We would like to know how difficult or easy it is to build one, using such an instruction and how people would do this. Therefore, we would like to ask you to build an explosive device. The instruction is to perform this task as good and as quick as possible.

On the table in front of you are an instruction form and some materials.

Appendix B2. Instruction form for assembling explosive device



[After following all steps carefully, the device should look like the image shown above]

Materials list

- Set of 3 pre-assembled pipes with electronic device holder
- Electronic device with pre-attached wires
- Batteryholder
- 8 x AA-battery
- 6 x Jumperwire (black, grey, blue, green, orange and yellow)
- 2 x Sticky gum

Step-by-step protocol

Step 1. Attach the six jumperwires to the GPIO pins on the electronic device using the following instruction. Make sure to use the open side, not the pin side, at the end of all jumperwires.

1a. Attach the grey jumperwire to pin no. 9

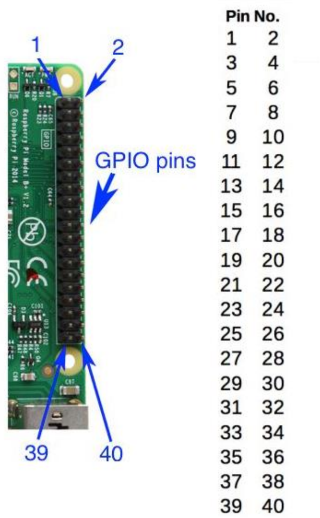
1b. Attach the blue jumperwire to pin no. 16

1c. Attach the green jumperwire to pin no. 21

1d. Attach the black jumperwire to pin no. 28

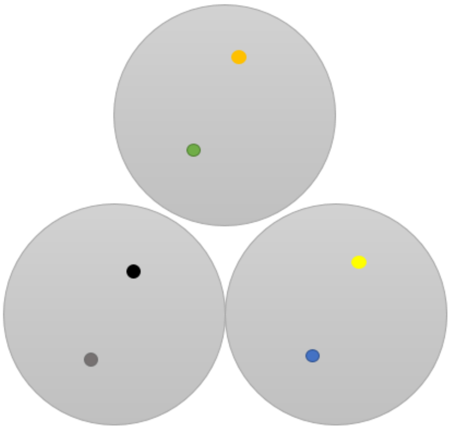
1e. Attach the yellow jumperwire to pin no. 33

1f. Attach the orange jumperwire to pin no. 40



Step 2. Click the electronic device into the pre-assembled electronic device holder, as is showed on the image above. Make sure the part of the electronic device with the jumperwires is at the left hand side of the device holder.

Step 3. Attach the six jumperwires to the left hand end of the pipes into six small gapes. Make sure the jumperwires are set at the correct place as is showed in the image bellow.



Step 4. Click the 8 AA-batteries into the battery holder.

Step 5. Attach the battery holder to the right hand side of the pipes, next to the silver wire, using the 2 sticky gums. Make sure the two silver points on the battery holder are facing towards the electronic device. Make sure the battery holder is pressed strongly against the bomb, however do not break the battery holder by pressing too hard.

Step 6. Connect the pre-attached wire from the electronic device onto the silver points on the battery holder. Now the bomb is ready.

Appendix C1. Instructions for bomb observing condition

Operational task – observation

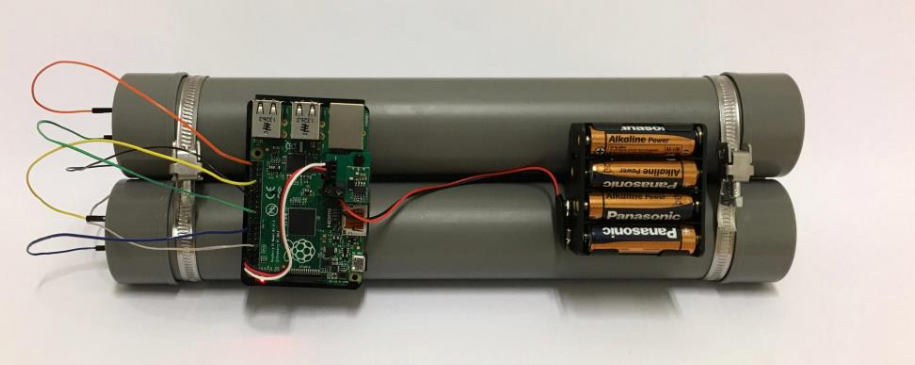
On the internet, instructions can be found of how people build an explosive. We would like to know how difficult or easy it is to build one and how other people would look at this. Therefore, we would like to ask you to observe the researcher that is building an explosive device. The instruction is to perform this task as good as possible.

On the table in front of you are an observation form and a watch.

Appendix C2. Observation form

Please fill in this form while observing the researcher.

The explosive device that the researcher will build, using an instruction form, has to look like the image below.



<u>Feedback</u>	<u>Score: 1 (low) – 10 (high)</u>
How is the position of the researcher? (think of: physical appearance e.g. straight back, neck)	
How concentrated is the researcher?	
How fast is the researcher? - How fast is the researcher finished? …. Minutes …. Seconds	

How precise is the researcher?	

Appendix D. Instructions for no bomb familiarity condition

Operational task – jigsaw puzzle

On the internet, different types of jigsaw puzzles can be found. We would like to know how difficult or easy it is to put one together and how other people would do this. Therefore, we would like to ask you to put together a puzzle. The instruction is to perform this task as good and as quick as possible.

On the table in front of you are the puzzle pieces and the puzzle example.

Figure 8. Example of jigsaw puzzle used in the experiment

Appendix E. Investigative interview

Questions investigator asked to 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 traveled 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 showed, the investigator asked the participant: *"Have you seen this particular object recently?".* Participants were instructed to answer with yes or no.

Figure 9. First Image Shown to Participants – Phone

Figure 10. Second Image Shown to Participants – Familiar bomb

Figure 11. Third Image Shown to Participants – Car

Figure 12. Forth Image Shown to Participants – Unfamiliar bomb

After all images had been shown, participants are being told the interview has come to an end and they can see the researcher outside.

Appendix F. Post-experiment survey

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Fill in the participant number (by researcher).

What is your gender?

- Male
- Female
- Other

What is your age?

What is your nationality?

- Dutch
- German
- Other, namely:

\>>

We are interested in your experiences during the experiment. Therefore, we would like to ask you some questions.

\>>

The following questions will focus on the **first part** of the experiment: **the operational task**.

Please read the questions carefully.

\>>

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What **operational task** did you perform?

In general, the instructions to perform this task were...

- Clear
- Unclear

Indicate to what extent do you agree with the following statements:

During the performance of the **operational task**, I felt...

	Strongly disagree	Disagree	Undecided	Agree	Stongly agree
Anxious					
Worried					
Comfortable					
Tensed					
Relaxed					
Guilty					
Satisfied					

Indicate to what extent do you agree with the following statements:

Perfoming the **operational task,** i found...

	Strongly disagree	Disagree	Undecided	Agree	Stongly agree
Interesting					
Difficult					
Enjoyable					
Exciting					

>>

The following questions will focus on the **second part** of the experiment: **the interview with someone from intelligence office**.

Please read the questions carefully.

>>

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Indicate to what extent do you agree with the following statements:

	Strongly disagree	Disagree	Undecided	Agree	Stongly agree
I felt upset during, or directly after the interview.	○	○	○	○	○
I felt that the stress during, or directly after, the interview increased to such high levels that I could not let go of it.	○	○	○	○	○
I felt nervous during, or directly after the interview.	○	○	○	○	○
I felt tension during, or directly after the interview.	○	○	○	○	○
I felt guilty during, or directly after the interview.	○	○	○	○	○

Indicate to what extent do you agree with the following statements:

	Strongly disagree	Disagree	Undecided	Agree	Stongly agree
I had to concentrate during the interview.	○	○	○	○	○
The interview was mentally demanding.	○	○	○	○	○
The interview required much mental effort.	○	○	○	○	○
I had to think about the answers of the questions.	○	○	○	○	○
The interview was difficult.	○	○	○	○	○
The interview was enjoyable.	○	○	○	○	○
The interview was interesting.	○	○	○	○	○

Indicate to what extent do you agree with the following statements:

During the interview, i found the interviewer...

	Strongly disagree	Disagree	Undecided	Agree	Stongly agree
Friendly	○	○	○	○	○
Competent	○	○	○	○	○
Dominant	○	○	○	○	○
Cold	○	○	○	○	○
Intelligent	○	○	○	○	○
Confident	○	○	○	○	○

>>

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During the interview with someone from intelligence office, four pictures were presented:

Picture 1: Car
Picture 2: Explosive Device (grey)
Picture 3: Mobile phone
Picture 4: Explosive Device (brown)

Did you notice something with one of these pictures?

- Yes
- No

>>

Only if answered 'Yes':

Which picture caught your attention?

- Picture 1
- Picture 2
- Picture 3
- Picture 4

What exactly caught your attention to this picture?

>>

The questionnaire has almost come to an end.
Do you like to stay informed about this research? If yes, fill in your name and email below.

>>

This is the end of the questionnaire. Thank you for your response.
Please inform the researcher that you are ready.