



The added value of behavioural information in crime scene investigations

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ABSTRACT

Forensic and behavioural science are often seen as two different disciplines. However, there is a growing realization that the two disciplines should be more strongly integrated. Incorporating psychological theories on human behaviour in forensic science could help solving investigative problems, especially at the crime scene. At the crime scene it is not just about applying scientific methods to analyse traces; these traces must first be perceived and categorized as relevant. At the crime scene, the behavioural perspective of an investigative psychologist could play an important role. In this study, we examine to what extent (1) investigative psychologists detect deviant behavioural cues compared to forensic examiners when investigating a crime scene, (2) forensic examiners can find the relevant traces that can be associated with this behaviour and (3) the availability of a psychological report highlighting these behavioural cues helps forensic examiners in finding more relevant traces. To this end, a total of 14 investigative psychologists and 40 forensic examiners investigated a virtual 3D mock crime scene. The results of this study show that investigative psychologists see significantly more deviant behavioural cues than forensic examiners, and that forensic examiners who receive a psychological report on these cues recognize and collect significantly more traces that can be linked to deviant behaviour and have a high evidential value than examiners who did not receive this information. However, the study also demonstrates that behavioural information is likely to be ignored when it contradicts existing beliefs.

1. Introduction

Crime scene investigators are responsible for recognizing potential evidence at the crime scene and for selecting and collecting pieces of evidence for the purpose of documentation and further analysis. Differentiating between relevant and irrelevant traces is a complex, cognitive process, and is crucial to the success of criminal investigations. Understanding behaviors of offenders, victims and other people involved guides the search for and interpretation of traces. Therefore, knowledge from behavioural sciences should be integrated into crime scene investigation (CSI) to improve the quality of the investigation. In some districts in the Netherlands investigative psychologists advise crime scene examiners during investigations at crime scenes, yet, the presumed added value has never been investigated. In the present paper we studied the influence of introducing an investigative psychologist into the CSI.

1.1. Crime scene investigations

During the investigation of a crime scene, information is obtained about the actions that have taken place at a scene [1–3]. The main goal of crime scene examiners, those responsible for the CSI, is to collect evidence that can be used during the investigation – for instance, to reconstruct what may have happened or to identify a suspect – and can further be used as evidence in court [2]. Generally, a CSI consists of several steps: recognition, documentation, collection and preservation of evidence¹. For the latter three steps strict standards and protocols [4, 5] are set and constantly improved [6,7] to ensure that evidence will be accepted when presented in the courtroom [3,4,6,8–11]. However, before these standardized steps can take place, forensic examiners first have to perceive the traces or trace items and determine their relevance. This process is less standardized, and during this phase of the CSI forensic examiners apply a more dynamic approach to develop

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¹ See figure G.1. for a visual of the current steps of a forensic investigation and a simplification of the interaction at the crime scene between the search for traces and scenario construction.

hypotheses of what may have happened at the crime scene and to recognize potential evidence [12]. It should be emphasized that the recognition and selection of evidence is highly complex and is primarily a cognitive process. The study of Earwaker et al. (2020) emphasizes that a more structured and evidence-based process is needed for the creation and examination of hypotheses at the crime scene [13], especially since decisions made at the crime scene play a key role throughout the further forensic reconstruction and legal processes [7,13,14]. When evidence is not recognized, it will not be secured and examined, and thus be lost forever [2,3,12]. Therefore, recognizing potentially relevant traces or trace items is of the uttermost importance, and, unlike the technical steps that follow, this process is difficult to capture in rules and guidelines and is under-studied [12,13].

1.2. Human factors during CSI

As with all human decision making, the process of recognizing and interpreting (latent) traces is susceptible to errors in reasoning [15,16]. The selection and interpretation of traces at the crime scene involves differentiating between crime-related and unrelated traces and weighing their potential quality², which is especially complex, as crime scenes are often ambiguous and observations at a crime scene may usually be attributed to multiple explanations [17,18]. For example, a bloodstain on a sink could be crime-related but could also be the result of a small shaving accident unrelated to the crime. Crime scene examiners should consider these different explanations to create multiple scenarios that guide the search for and selection of relevant traces. Prior information that crime scene examiners receive before they enter a crime scene and expectations they hold based on earlier experience may influence their interpretation of traces [19,20]. When prior information or expectations are correct, this will help the crime scene examiners, but when they are incorrect, this could lead to wrongful interpretations and conclusions. The more ambiguous the crime scene, the greater the chance expectancy effects will affect the results [19,21].

Crime scene examiners must determine whether a crime was committed at all, considering not all scenes are crime scenes. They have to formulate hypotheses based on the available information and their observations to create plausible scenarios that suit the observed traces [17]. Traces that are left behind after a crime can provide information on an activity that took place and may point in the direction of a perpetrator, while unrelated traces can create bias and point crime scene examiners in the wrong direction. Based on their hypothesized scenarios, crime scene examiners will value the traces they perceive and select the evidence that is submitted for further examination [1,2,7,12,17,22].

Santtila et al. (2004) and Lee (2001) state that the skill of recognizing crucial evidence is acquired through experience and training [3,23]. However, substantiation for this statement is lacking support and literature is contradictory [16]. Compared to novice forensic examiners, experienced crime scene examiners can perform their CSI more efficiently as they are able to rely on schemas based on trace patterns often found during crime scene investigations [12,23,24]. An example of this is creating schemas based on observations of behavioural patterns of burglars that can be derived from traces left behind at burglary crime scenes. It is important to note, however, that the same schemas can degrade the evaluative performance of the CSI as they can restrict an expert's imagination and flexibility, causing the experts to ignore, or even miss, important information if it does not match their expectations. This expectancy bias can cause tunnel vision³ and makes experts less open-minded towards alternative, less likely scenarios [16,25]. In

² The chance that e.g. a trace would produce a good fingerprint or DNA profile.

³ Perceiving all information from one assumed correct hypothesis, thereby overlooking other explanations.

addition, research has shown that there are large differences among crime scene examiners when it comes to their selection of traces, and that important traces can be easily missed [22].

1.3. Knowledge from behavioural sciences in CSI

Clearly, recognition and selection of relevant traces is extremely difficult. Therefore, knowledge from different disciplines could help to enhance the quality of the crime scene investigation [2,26]. In particular, as crime scenes are the result of criminal behaviour, knowledge from behavioural sciences such as investigative psychology and criminology might help in interpreting the crime scene and its traces and building possible scenarios at the scene. It might also supplement our understanding of the crime scene investigators' decision making [2,27,28]. Criminology focuses, among other things, on behaviour in general and in particular on working methods and activities of perpetrators [29]. Investigative psychology aims to gain insight into both perpetrator behaviour as well as the perception, choice behaviour and decision-making behaviour of professionals in the criminal justice system. They aid in suspect prioritization, geographical profiling, linking crimes and crime scenes, the interviewing process and risk assessment of offenders [30]. They develop awareness of biases and pitfalls arising from these human factors in criminal investigations, including forensic investigations [15,16,31]. Forensic science and behavioural science are often seen as two different disciplines. However, a new mindset is emerging with the proposition that the two disciplines ought to be bridged. Rossy et al.'s (2018) handbook proposes that the next step in the development of this new mindset would be the crossover of the two disciplines achieved through learning from each other's expertise and exploring new opportunities for improving evidence recognition at a crime scene [2]. This principle is emphasized in the influential paper 'the Sydney declaration' by Roux et al. (2022) stating that interdisciplinary interactions between forensic practice and (among others) scientific disciplines such as criminology can improve knowledge of deviant and criminal behaviour, allowing for a better understanding of traces [7].

Nowadays, crime scene examiners try to understand the environment of a crime scene by 'thinking as an offender' [14]. However, to do so, they rely on their own experience, as criminology and the psychology of criminal behaviour are barely included in their training programs [2,28]. Stark (1987), Rossy et al. (2018) and Roux et al. (2022) state that criminologists understand the ecology of a crime and thus have a substantial ability to decipher peculiarities of a scene which they could use as a guide in search for traces [2,7,32]. It is hypothesized that incorporating psychological knowledge of human behaviour into the investigative stage of a crime scene could lead to the consideration of more relevant hypotheses and therefore could also improve the recognition of evidence, which would ultimately improve the investigation process.

Incorporating psychological theories on behaviour in forensic investigations is emerging in several countries around the world [2,33]. As a result, direct involvement of psychologists at crime scenes is also emerging [2,30]. In the Netherlands, nowadays, most investigative psychologists provide recommendations on interrogations or other investigative strategies and assist in offender profiling [33,34]. Interestingly, in some districts in the Netherlands, investigative psychologists may also advise crime scene examiners during investigations at crime scenes by pointing out peculiarities at the scene. Investigative psychologists base their observations and interpretations of a crime scene on a behavioural perspective. Some claim to recognize deviant (behavioural)⁴ cues, which might be missed by forensic experts [33,35]. As mentioned efficacious in the paper of Alison et al. (2011) the developing field of behavioural investigative advice is broadening to provide

⁴ The term deviant behaviour encompasses behaviour that deviates from established social norms, rules, standards or expectations.

investigative recommendations, which have to be based on replicable, transparent, and valid knowledge and research [30,33]. However, empirical studies have yet to assess the effects of this psychological perspective.

Although knowledge from behavioural sciences is likely to help broadening the view at the crime scene, incorporating investigative psychologists also entails risk. The biggest risk is causing bias. It is known that additional information is prone to cause bias in decision making, and therefore any additional information must be well managed to minimize the risk of cognitive bias [13,16,19,20]. As suggested by Dror et al. (2021), van den Eeden (2018) and de Gruijter et al. (2017) the moment and order in which information is added to an investigation is important [20,36,37]. This also applies to information provided by an investigative psychologist. If behavioural knowledge would contribute to improving the quality of the CSI, it is essential to consider how and when this information should be added. To the best of our knowledge, it has not yet been investigated whether the investigative psychologist's advice has an influence on the recognition and selection of evidence by a crime scene examiner.

1.4. The present study

The aim of this study is to investigate whether crime scene examiners would detect deviant (behavioural) cues in a case concerning a deceased person at-home based on their experience, or whether they would possibly detect these cues only after receiving the report of an investigative psychologist. Therefore, the primary research question of this paper is: "Does the report of an investigative psychologist influence the decisions of a crime scene examiner during the investigation of a deceased person in a home?". We examine to what extent (1) investigative psychologists detect deviant behavioural⁴ cues compared to forensic examiners when investigating a crime scene, (2) forensic examiners are able to find the relevant traces that can be associated with these deviant behavioural cues and (3) the availability of a psychological report drawing attention to these behavioural aspects helps forensic examiners in finding more relevant traces.

We expect that the process of forming hypotheses, and searching for and securing traces can be improved with knowledge from different disciplines, such as forensic science and behavioural sciences. Furthermore, this study will provide insight into CSI decision-making in general. Together, this knowledge is critical in improving CSI.

2. Method

2.1. Mock crime scene

This study uses a virtual 3D mock crime scene staged in a 'real' house and had a similar study setup as the study of de Gruijter et al. (2017) [17]. The mock crime scene was ambiguous and was designed specifically for this study. Noticing the presence of specific cues would lead the participants toward the ground truth: domestic homicide. Other aspects could lead them towards a second possible alternative interpretation of the scene: suicide. The crime scene concerned the victim's home, so participants could get an idea of the victim's persona and lifestyle (who is the victim, how does she live, what are her daily activities and preferences). Deviant cues are elements present at the crime scene indicating behaviour that did not fit that image of the victim. These cues were labelled as deviant behavioural cues. To make the scene as realistic as possible, the deviant behavioural cues were discussed with two crime scene examiners from the Netherlands Forensic Institute and two crime scene examiners from the Dutch Police. With their input a realistic scenario was created based on aspects of real cases. In this scenario deviant behavioural cues were embedded. Together with two scientists experienced in the creation of mock crime scenes (from the University of Amsterdam and the VU University) the final scenario was created. An in-depth description of the ground truth scenario and the

alternative scenario, and the way the virtual crime scene was constructed can be found in Appendix A. Fig. 1 shows some photos of the scene.

There were 15 pre-determined forensic traces/items present, multiple forensic examinations could be performed on each trace. Furthermore, there were 24 behavioural cues integrated into the scene, leading to 10 traces that are likely to be only found when a participant notices the deviant behavioural cues (e.g. a messy bathroom, while the rest of the house was tightly cleaned, leading to the towels on the floor that could be a possible trace). These 10 traces are called 'the deviant behaviour' traces (for more information see Appendix B and C). Within these 25 collectable traces, a distinction was made between traces with a 'high' and a 'low' evidential value (for more information see Appendix C)⁵. The division was based on the link between the trace and the perpetrator. For example, a DNA sample from the used gun had a 'high' evidential value as this could link a suspect to the crime, while a DNA sample from the blood pool found under the victim had a 'low' evidential value as this would not link a potential suspect to the crime. It should be noted that a 'low' value trace is not necessarily unhelpful and still possibly contributes to solving a crime as it helps to reconstruct the event. The classification of the traces on the forensic/deviant behaviour and 'high'/'low' categories was performed by three assessors having substantial agreement (interrater reliability, $\kappa = 0.68$ ($p < 0.001$) [38]. Traces that were rated differently were re-evaluated until an agreement was reached.

2.2. Participants

2.2.1. Crime scene examiners

A total of 40 crime scene examiners from six different police regions participated in this study. The participants were recruited via police management whereafter they could voluntarily sign up for the study. The group consisted of 27 men and 13 women within an age range of 28–66 years ($M = 44$, $SD = 11$) and experience range of 2–38 years ($M = 13$, $SD = 9$).

2.2.2. Investigative psychologists

14 investigative psychologists (nine females and five males) participated in this study. The age range was 29–62 ($M = 39$, $SD = 9$) with 1–19 years of experience ($M = 7$, $SD = 5.7$). Among this group, six participants had experience with deceased person cases.

2.3. Design

The design required two phases in the study. In the first phase, investigative psychologists and crime scene examiners examined the same virtual 3D mock crime scene providing the data to examine the first research question [1] to what extent are investigative psychologists able to detect deviant behavioural cues compared to forensic examiners when investigating a crime scene and second research question, [2] to what extent are forensic examiners able to find the relevant traces that can be associated with deviant behaviour. Both groups received the same prior information⁶ and investigated the same crime scene.

In the second phase, the forensic examiners were split into two groups, the experimental and the control condition, to answer the third research question [3] to what extent does the availability of a psychological report drawing attention to these behavioural aspects help forensic examiners in finding more relevant traces. Participants in the experimental condition were presented with extra information in the form of a behavioural

⁵ During the experiment, participants were not aware of the distinction the researchers made between the forensic and 'deviant behaviour' traces as well as the high and low evidential values of these traces.

⁶ Crime scene examiners helped in creating realistic 'prior information' for more information see Appendix D.



Fig. 1. A selection of photos of the scene of the mock crime scene.

report halfway through the experiment regarding deviant behavioural cues that were present in the virtual crime scene. The behavioural report was composed for this research and was written by two investigative psychologists (who did not participate in this study) and partially based on literature [39,40]. Crime scene examiners in the control condition only received general forensic information based on the virtual crime scene halfway through the experiment. The general forensic information gave no advantage over the experimental group. We chose this design over a design with a control group that receives no information at all, in order to keep the experiment as uniform as possible for all groups. The forensic information had no substantive value. In our opinion, it is more important to make sure both control and experimental group have an 'intervention', as participants who receive information may have the idea that they should do something with it.

The experimental group consisted of 21 participants and the control group of 15 participants⁷. There was no significant difference in age, region, education, sex, and experience between the two groups.

2.4. Procedure

At the start of the experiment, with the aid of an intake

⁷ Four participants were excluded from the analysis because they based their conclusion on (strong) misinterpretations of the virtual crime scene. Therefore their results could not be compared to those from the other participants, e.g. one participant stated that the scenario had to be domestic homicide as he/she thought the cartridge case was from a revolver, while the gun next to the victim was a 0.22 mm, concluding that there had to be another person involved), causing their results to be no longer useable. However, it is quite interesting that those misinterpretations, which also led to strong differences in the collected traces, only occurred in the control condition (during phase 1). Adding those subjects would have made the already significant results more significant, and would thus have strengthened our conclusions regarding the added value of a behavioural scientist at the crime scene.

questionnaire, background information was gathered about each participant regarding their age, gender, level of education, police district, years of experience with deceased person cases and experience with virtual crime scene experiments. Participants were told that the goal of the experiment was to obtain more insight into the decision-making process at a crime scene, so the real purpose of the study was not disclosed to the participants prior to the experiment. Once the informed-consent form was signed, laptop navigating controls were explained to the participants.

Prior to the virtual investigation, all participants (both forensic examiners and investigative psychologists) received information containing preliminary findings of the investigation. This information included a witness statement from a relative of the victim indicating a possible suicide and a search warrant from the public prosecutor (see Appendix D). Participants had 40 min to investigate the virtual 3D mock crime scene on a laptop. Additionally, participants were provided with overview photographs of the scene on paper. Participants were instructed to imagine that the mock crime scene was a real case, and that they had to conduct their investigation as trained. The participants received the following instructions; 'Walk' through the virtual crime scene and think out loud during this process, so we can gain insight in your thought patterns. When you are done, write down the possible scenarios you are considering, i.e. homicide, suicide, natural cause and accident, and rank them according to probability and write down items you want to secure and/or samples you want to collect. After you have written down all the items you want to secure/collect, write down which specific examination you want to perform on an item and justify why and select a maximum of six traces⁸ for fictitious further investigation and justify why.

⁸ Forensic examiners usually have set limitations on the number of evidence they may submit for further investigation. The six traces they selected gave insight into which pieces of evidence they thought were most important¹⁷.

Hereafter a short pause followed. The participants received additional information⁹ depending on the investigative condition to which the participant was randomly assigned. Participants in the experimental condition received a short behavioural report based on the crime scene, while participants in the control condition received general forensic information (see Appendix E). The participants received the following instructions: 'walk' through the virtual crime scene again. When you are done, you can – if desired - change the ranking of your scenarios, add items to secure and/or change the six items/traces you selected to submit for future investigation.

Lastly, with a short exit questionnaire, all participants were asked to write down their thoughts on the goal of the experiment. Participants also received a 6-item questionnaire that used a 7-point Likert-scale to monitor participants' view on the study and the presence of an investigative psychologist at the crime scene. In total, it took participants 1 h to complete the experiment. For a schematic overview of the experimental procedure, see Table F.1.

2.5. Assessing test scores

The data scoring method used for this study was based on that used in de Gruijter et al. (2017) [17]. The data generated by the participants before and after they received the additional information was coded in four sections: (1) most likely scenario, (2) deviant behavioural cues mentioned (3) items secured and (4) items selected for further investigation (dependent variables).

- (1) For the most likely scenario there were four possibilities: domestic homicide, suicide, natural cause and accident [41]. Homicide was coded with a 1 and suicide with a 0. As no participant chose the options natural cause and accident as most probable scenario, these options were not coded.
- (2) Deviant behavioural cues mentioned were scored (not mentioned = 0 and mentioned = 1).
- (3) In a similar manner, a list of all items/traces that could be secured was scored (not secured = 0 and secured = 1). Beforehand, a list of all potential traces and items was drawn up by the researchers, and this was supplemented with additional entries from participants.
- (4) Items selected for further investigation were listed in a top 6; all items were given the same weight.

2.6. Statistical analysis

For the first phase, the scores on the variables were compared between crime scene examiners and investigative psychologists to assess the decision-making process of the participants during the experiment. The dependent variable (1) selection most likely scenario was evaluated with a chi-square test. Descriptive statistics, independent samples *t*-test and one-sample *t*-tests were used to analyse the dependent variables (2) items mentioned, (3) total number of items secured and (4) items selected for further investigation.

For the second phase, we used a repeated-measures ANOVA, to assess whether the behavioural report given to the crime scene examiner in the experimental condition had any effect on the dependent variables (i.e., total number of items secured and items selected for further investigation). The scores of the participants before and after they received the additional information were compared between the two conditions. For all analysis a significance level of 0.05 was considered statistically significant. In addition, a post-hoc power analysis was executed to investigate the effect of sample size.

⁹ Note that participants were not aware that there was a second phase to the experiment.

3. Results¹⁰

3.1. Phase 1: crime scene examiners vs. investigative psychologists

This paragraph states the results of the comparison between crime scene examiners ($N = 36$) and investigative psychologists ($N = 14$) in the first phase of the investigation, i.e. before any additional (behavioural or basic forensic) information was provided. In doing so, this section answers to what extent (1) investigative psychologists detect deviant behavioural cues compared to forensic examiners when investigating a crime scene (2) forensic examiners are able to find the relevant traces that can be associated with this behaviour.

3.1.1. Most likely scenario

Participants provided scenarios and ranked them after their CSI. The scenario they ranked as most likely differed between the crime scene examiners and the investigative psychologists. A chi-square analysis showed a significant effect of profession (crime scene examiners and investigative psychologists) $\chi^2(1) = 4.20, p < 0.05$. Investigative psychologists selected domestic homicide significantly more often (13 out of the 14 psychologists) as the most likely scenario than crime scene examiners (23 out of the 36 crime scene examiners).

3.1.2. Deviant behavioural cues

During the experiment, participants talked out loud. At phase one, there was a significant difference in the number of deviant behavioural cues mentioned between the crime scene examiners (control ($n = 15$) and experimental ($n = 21$) condition) ($M = 7.5, SD = 3.9$) and investigative psychologists ($M = 14.3, SD = 3.2$) $t(45) = 5.503, p < 0.001$, indicating that investigative psychologist named significantly more deviant behavioural cues than the crime scene examiners.

Additionally, for each deviant behavioural cue it was examined how often they were mentioned. This resulted in the observation that (proportionally) almost all cues were mentioned more often by investigative psychologists, than by forensic examiners (figure G.2.). The items that were mentioned (proportionately) the most by investigative psychologists were the strange positioning of the victim, the type of glass next to the victim, the different types of books on the bookshelf, the games with a murder theme and healthy products in the fridge. From these results it can be concluded that investigative psychologists tried to get an impression of the victim's persona and lifestyle by trying to answer questions such as: what kind of person is the victim, what are her daily activities and which cues at the crime scene can be associated with this person, and which cues deviate from the expected behaviour? This information is useful to decide which cues may be relevant. It may lead crime scene investigators to consider more relevant hypotheses, thereby improving the recognition of evidence.

3.1.3. Suicide vs. domestic homicide

Crime scene examiners who stated domestic homicide ($n = 23$) as most probable scenario, mentioned significantly more deviant behavioural cues than crime scene examiners who thought suicide was the most plausible scenario ($M = 8.9$ vs. $M = 4.8, p = 0.002$). Similar results were found within the group of investigative psychologists. Psychologists who thought domestic homicide ($n = 13$) was the most probable scenario, mentioned significantly more deviant behavioural cues than the one participant who thought suicide was the most plausible scenario ($M = 14.9$ vs. $M = 8.0, p = 0.030$).

Considering this, there seems to be a 'cut-off point' in the number of deviant behavioural cues noticed after which participants switch from the suicide scenario to the homicide scenario. All participants who noticed more than 10 deviant behavioural cues thought domestic homicide was the most probable scenario. The only investigative

¹⁰ In Appendix H, all the outcomes of the analysis can be found.

psychologist who thought that suicide was the most likely scenario saw eight deviant behavioural cues, which supports the idea of this apparent 'cut-off point'. See Figure G.3. for a visualization of the data. More information on the suicide vs. domestic homicide scenario within the crime scene examiners group (control vs. experimental) will be described in 3.3.

3.2. Phase 2: crime scene examiners: control condition vs. experimental condition

This paragraph shows the results related to the research question to what extent the availability of a psychological report drawing attention to these behavioural aspects helps forensic examiners in finding more relevant traces. It shows the comparison between the control condition ($n = 15$; participants receiving basic forensic information) and the experimental condition ($n = 21$; participants receiving additional behavioural information).

3.2.1. Most likely scenario

The analysis of the variable 'most likely scenario' demonstrates whether forensic examiners change the ranking of their most likely scenario after being informed with the additional (behavioural or basic forensic) information. Prior to receiving this information, no significant effect between the groups (experimental - domestic homicide 11/21, suicide 10/21; and control - domestic homicide 12/15, suicide 3/15¹¹) was present on the selected most likely scenario $\chi^2(1) = 3.74, p > 0.05$. In this study, none of the participants changed the scenario they ranked as most likely after receiving the additional information, indicating that the availability of a behavioural report did not influence the final scenario.

3.2.2. Total number of items secured

The analysis on the total number of items secured by the crime scene examiners showed a significant difference in the number of items secured before and after the participants received the additional information ($F(1,34) = 6.250, p = 0.017$). Crime scene examiners in the experimental condition secured more traces. However, a directional one sample t -test (one-tailed) showed this was not significant ($M = 12.7$ vs $M = 13.4, p = 0.245$). In percentages, 28.6% of the participants in the experimental condition secured additional evidence after receiving additional information. Of this group, 19.6% selected 3 additional items and 9.5% selected 2 additional items. Participants in the control condition, did not secure additional evidence ($M = 13.1$ vs. $M = 13.1$) (see Table F.2).¹²

3.2.3. Traces of deviant behaviour

When solely looking at the secured deviant behavioural items, i.e., traces that are likely to be found only when a participant notices the deviant behavioural cues, the data show a significant interaction effect (for the experimental and control condition before and after the additional information 'condition*time') ($F(1,34) = 7.083, p = 0.012$). Participants in the experimental condition secured more deviant behavioural items ($M = 3.8$ vs. $M = 4.4$) after they received the additional information, while participants in the control condition did not ($M = 3.9$ vs. $M = 3.9$). When the deviant behavioural items were split in items with a 'high' evidential value and a 'low' evidential value, there

was a significant interaction effect ($F(1,34) = 4.823, p = 0.035$) for items with a 'high' evidential value¹³. This interaction effect ('condition*time') for the deviant behavioural items with a 'high' evidential value can be explained by the different effect of the factor 'time' between the experimental condition ($M = 2.9$ vs. $M = 3.3$) and the control condition ($M = 2.7$ vs. $M = 2.7$). This interaction implies that there is a tendency to secure more deviant behavioural items with a high evidential value after having received behavioural information than before having received any information, or after having received just basic forensic information.

3.2.4. Items selected for further investigation

The next step for the participants was to select six items for further investigation. The two groups did not differ on the deviant behavioural and forensic items selected for the top six before they received the additional information (see Table F.3). After having received the additional information, none of the participants in the control condition changed their top six selection. However, participants in the experimental condition selected significantly more deviant behavioural items ($M = 1.5$ vs. $M = 2.0, p = 0.004$) and significantly less forensic items ($M = 4.5$ vs. $M = 4.0, p = 0.004$) (see Table F.4).

3.2.4.1. Deviant behavioural items. When concentrating on the selection of deviant behavioural items with a 'high' evidential value the analysis shows a significant interaction between condition and time ($F(1,34) = 9.320, p = 0.004$). This interaction was caused by a significant difference between the number of behavioural items with a high evidential value selected before and after having received information in the experimental condition ($M = 1.3$ vs. $M = 1.8, p = 0.002$), which was not present in the control condition ($M = 1.4$ vs. $M = 1.4$). Hence, participants selected significantly more deviant behavioural items with a 'high' evidential value for analysis after they received behavioural information than before having received behavioural information.

3.2.4.2. Forensic items. For forensic items, there was also a significant interaction effect for the different conditions before and after the information had been given ($F(1,34) = 7.650, p = 0.009$). When this data was split in forensic items with a 'high' and 'low' evidential value, results show that neither participants in the experimental condition nor in the control condition made any changes to the selected forensic items with a 'high' evidential value, meaning that no analysis could be computed on this data. This indicates that the significant effect can be explained by changes the participants made in the experimental condition in the forensic items with a 'low' evidential value. The number of forensic items with a 'low' evidential value indeed decreased significantly after the participants received information in the experimental condition ($M = 2.8$ vs. $M = 2.3, p = 0.004$). The experimental group exchanged forensic items with a low evidential value for deviant behaviour items with a high evidential value after having received the behavioural report. Such change was not present in the control condition.

3.3. Phase 2: crime scene examiners (experimental condition): suicide vs. domestic homicide

An observation the researcher made during the experiment was that most of the participants in the experimental condition who chose suicide were very certain¹⁴ of their case and claimed not to see the benefit of the extra behavioural information because they already 'knew' what happened, while crime scene examiners selecting domestic homicide

¹¹ We are very aware of the differences between the groups with regard to the 'most likely scenario' they initially choose. Participants were randomly assigned to a condition prior to the start of the study, and phase 1 was identical for both groups. We do not have an explanation for this difference this occurred. Based on the statistics this is most probably an unfortunate coincidence.

¹² All the output of the ANOVA's can be found in tables in Appendix F.

¹³ For more information on the evidential value see section 2.1. and Appendix C.

¹⁴ The 'certainty' of participants was not measured quantitatively. This observation is based on comments the participants made.

seemed more likely to incorporate the new information into their scenario. Therefore, it was decided to analyse differences between participants in the experimental condition who chose a suicide scenario and those who chose a domestic homicide scenario. From the 21 forensic examiners who received the deviant behavioural information, 10 selected suicide as the most probable scenario and 11 domestic homicide.

3.3.1. Total number of items secured

The number of items secured by these two groups (suicide vs. domestic homicide) was analysed with a directional one sample *t*-tests. The results showed that the 11 participants who chose domestic homicide as the most likely scenario selected significantly more items after having received the additional information than before ($M = 13.7$ vs. $M = 15.0$, $p = 0.008$). This effect can be explained by the increase of deviant behavioural items ($M = 4.1$ vs. $M = 5.3$, $p = 0.005$), especially those with a 'high' evidential value ($M = 3.5$ vs. $M = 4.1$, $p = 0.026$), indicating that the information provided in the behavioural report caused participants who selected domestic homicide to secure more evidence (see Table F.5). This effect did not occur for the participants who selected suicide as the most likely scenario ($M = 11.5$ vs. $M = 11.6$, $p = 0.343$).

3.3.2. Items selected for further investigation

Changes in the six items selected for further investigation were also compared between the participants who chose domestic homicide as the most probable scenario, and those who chose suicide. The participants in the domestic homicide group selected significantly more deviant behavioural items ($M = 1.7$ vs. $M = 2.4$, $p = 0.011$) and significantly less forensic items ($M = 2.6$ vs. $M = 2.0$, $p = 0.011$) after having received the behavioural information, whereas the participants who chose suicide did not change their top six selection significantly (see Table F.6).

3.3.2.1. Forensic items. A paired sample *t*-test showed that after receiving the additional behavioural information, the domestic homicide group significantly decreased the number of forensic items selected ($M = 4.3$ vs. $M = 3.6$, $p = 0.011$). No one in this group made any changes to the selected forensic items with a 'high' evidential value. This indicates that this effect can be completely explained by the forensic items with a 'low' evidential value, $F(1,19) = 11.358$, $p = 0.003$. Hence, crime scene examiners considering a homicide scenario selected less forensic items with a 'low', and more items with a 'high' evidential value after receiving additional information.

3.3.2.2. Deviant behavioural items. A paired sampled *t*-test indicated that significantly more deviant behavioural items were selected after receiving the additional information by the group selecting domestic homicide ($M = 1.7$ vs. $M = 2.4$, $p = 0.011$). No significant difference was found for the group selecting suicide as the most probable scenario ($M = 1.3$ vs. $M = 1.5$, $p = 0.168$). Deviant behavioural items with a 'high' evidential value showed a significant difference before and after the additional information ($F(1,19) = 14.801$, $p = 0.001$). When the data is further explored with a paired sample *t*-test, it showed that crime scene examiners who thought domestic homicide was the most likely scenario submitted significantly more deviant behavioural items with a 'high' evidential value for further investigation after they received extra information ($M = 1.6$ vs. $M = 2.4$, $p = 0.004$). Crime scene examiners who considered a suicide scenario as most likely did not show a significant difference in the deviant behavioural items with 'high' evidential value they submitted before and after they received extra information ($M = 1.0$ vs. $M = 1.2$, $p = 0.168$).

4. Discussion

The primary research question was whether the report of an

investigative psychologist would influence the decisions of a crime scene examiner during the investigation of a deceased person in a home. The behavioural information from investigative psychologists positively influences the recognition and selection of relevant traces. A significant difference was found between crime scene examiners who only received general forensic information and crime scene examiners who received behavioural information coming from a psychologist. The latter group secured significantly more deviant behavioural items. More specifically, they selected more deviant behavioural items related to the offender. For the top six selection of items to investigate, examiners who received behavioural information replaced forensic items with a 'low' value for deviant behavioural items with a 'high' evidential value. This indicates that the additional behavioural information made crime scene examiners select more items with a 'high' evidential value and therefore will receive more forensic information on the offender.

Also, the number of deviant behavioural cues noticed seems to be highly important for participants to make their decision on their most likely scenario, given that noticing a high number of relevant traces that can be associated with behaviour led them to consider a homicide scenario (the ground truth). This may indicate that having a broader view and identifying more relevant aspects of the potential crime and the persons involved aids crime scene examiners in creating relevant scenarios. When searching for recovering, and securing traces can be substantiated with knowledge from disciplines such as behavioural sciences, it is possible that more scenarios are considered and more relevant traces can be secured and that crime scene investigations can be standardly improved. Data used to analyse to what extent investigative psychologists, compared to forensic examiners, can recognize deviant (behavioural) cues in a case with a deceased person in a home showed that investigative psychologists see significantly more deviant behavioural cues than forensic examiners. Further research will have to show to what extent this finding can be generalized.

4.1. Crime scene examiners vs. investigative psychologists

When looking into the number of deviant behavioural cues mentioned, it was found that overall, investigative psychologists mentioned significantly more cues than the forensic examiners. Remarkably, crime scene examiners who selected domestic homicide as the most likely scenario saw significantly more cues associated with deviant behaviour than the crime scene examiners selecting suicide as the most likely scenario. The results showed that when 10 or more deviant behavioural cues were seen, participants chose domestic homicide as their most likely scenario. The paper of de Gruijter et al. (2017) has shown that there are large differences among crime scene examiners when it comes to their selection of traces, and that important traces can be easily missed advocating the urge for improving scene investigation procedures [22]. Why certain participants noticed these cues and others did not, and what is needed to create a broader view deserves attention in future research.

In our study, participants received prior information indicating suicide. Possibly, participants who noticed less than 10 deviant cues were more likely to select suicide as most likely scenario as a result of our prior information. This would be in line with the results by van den Eeden et al. (2016) who demonstrated that prior information influences the interpretation of a crime scene [19]. Besides the crime scene investigation, it is known prior information influences almost every field in forensic science (Dror et al., 2006; Dror et al., 2011, Elaad et al., 1994, Kassin et al., 2003, Bogaard et al., 2014, Nakhaeizadeh et al., 2014, Osborne et al., 2014; as cited in van den Eeden et al., 2016). Therefore, information management is a crucial (and difficult) aspect of the CSI. When the information is correct, it can improve the CSI, when it is incorrect, it can hinder the CSI. This does not mean that we should refrain from giving information to crime scene investigators. It means that we have to find out how information management can be organised in CSIs.

We also found that investigative psychologists try to gain an overall impression of the victim, trying to answer questions as: What kind of person is the victim and what daily activities can be expected associated with this person? This information is useful to decide what deviates from that perception and may therefore be relevant. These findings are in line with the papers of Rossey et al. (2018), Baechler et al. (2020) and Roux et al. (2022) indicating that behavioural sciences can help create a broader image of the scene and therefore be of added value in searching for and securing traces as well as for the creation and examination of hypotheses at the crime scene [2,7,14].

The study shows that the combination of behavioural and forensic knowledge could contribute to improving the quality of the CSIs. Nowadays, in some cases, investigative psychologists work together with crime scene examiners at the crime scene. A different future perspective could be that crime scene examiners themselves are trained in evaluating crime scenes based on more behavioural aspects and by doing so creating a broader image of the scene and the people involved. In this way, you would avoid adding extra people and additional information to the CSI. Future research should show how this can best be integrated into the investigation of a crime scene.

4.2. Confirmation bias

When the data on crime scene examiners selecting suicide as the most likely scenario were compared to those selecting domestic homicide after receiving the behavioural information, the results showed that the group selecting suicide differed significantly from the group selecting domestic homicide after they received the behavioural information. This study shows that the participants selecting domestic homicide secured significantly more items linked to the offender after receiving this information, while this effect was not shown for the group selecting suicide as the most likely scenario. Participants selecting domestic homicide chose significantly more deviant behavioural items with a 'high' evidential value in their top six selection than participants selecting suicide.

The fact that the crime scene examiners who selected suicide as most likely scenario, were not influenced by the extra information given, is in line with the literature reviews of Klayman (1995) and Nickerson (1998) [42,43] and (among others) studies of Kassir & Dror (2013) and Kukucka et al. (2020) [44,45]. They found that information that contradicts an existing belief is likely to be ignored. This phenomenon is better known as confirmation bias. This is in line with observations made during the experiment, as most of the participants who chose suicide, were very certain of their case, and did not see the usefulness of the extra information. On the other hand, crime scene examiners selecting domestic homicide were more likely to incorporate new information into their scenario, which is also in line with the phenomenon confirmation bias, as the additional information confirmed their pre-existing beliefs [42,43]. None of the participants changed their scenario after the additional information. On this point literature seems to be contradicting. A study by de Gruijter et al. (2017) showed that crime scene examiners were able to change their scenario when provided with information after having already constructed a provisional scenario [17]. On the other hand, it is well known that once someone had formed an idea, it is likely they will stick with it [43,46]. This discrepancy might be present because the study by de Gruijter et al. (2017) gave information on trace analysis results, and possibly more value may be attached to this kind of information. It would be useful to study the value and influence of different kinds and sources of information on decision making. Also, when making use of a new source of information, it is essential for crime scene examiners to explicitly evaluate any new information and consider possible alternative scenarios to make sure the information is not just neglected.

4.3. Limitations

This study was set up empirically to gain insight into the decision-making process of crime scene examiners and investigative psychologists under controlled conditions. However, there are limitations to our method. Firstly, no standards and procedures currently exist for investigative psychologists at a scene of crime. Our study shows that additional psychological information can positively influence the recognition and selection of relevant traces, but psychological information could also potentially focus the attention of crime scene examiners towards less relevant traces. It is known that additional information is prone to cause bias in the decision making, and therefore additional information must be well managed to minimize the risk of cognitive bias [13,16,19,20].

As suggested by Dror et al. (2021), van den Eeden (2018), and de Gruijter et al. (2017) information must be handled consciously. The utility of the information for the task should be empirically researched and the moment and order in which information is added to an investigation is important [20,36,37]. This also applies to information provided by an investigative psychologist. The kind of knowledge and information they could bring to an investigation should be studied more thoroughly, as well as the most effective moment to add this information to the CSI. To prevent a crime scene examiner from biased decision-making, an initial judgment of the crime scene should be based on the crime scene itself. After this judgment, information may be added and evaluated for different scenarios. Also, to ensure transparency of the forensic decision-making process, any information received during the investigation and decisions made should be well documented.

Next, a virtual crime scene is not the same as a 'real-life' crime scene. This was also the most mentioned point of improvement participants wrote down on the exit questionnaire. The question how well crime scene examiners could interpret the artificial scene as a real crime scene, using a 7-point Likert scale, scored a 4.5 ($SD = 1.5$). Verbally this corresponds with 'neutral' to 'I somewhat agree'. For investigative psychologists the score was slightly higher: 5.2 ($SD = 1.8$) corresponding to 'I somewhat agree'. These scores are higher than the outcomes (score: 3.5) found during the study of de Gruijter et al. (2017) [17]. This improvement may be explained by the progress 3D technologies have made. By including forensic experts in the creation of the mock crime scene, it was ensured that traces were left in realistic places to make the investigation as realistic as possible. For future research it would be interesting to let a new group of participants 'walk' through the virtual crime scene with a virtual reality headset to make the virtual scene more realistic and interactive and compare this data with the data of this study [47].

During the exit questionnaire, participants were also asked to write down their thoughts on the goal of the experiment. Against expectations, only one of the crime scene examiners in the experimental condition noticed that he had received information from a behavioural report. All other participants thought the experiment was about the decision-making process on the crime scene. This was favourable for the study as it indicates that the participants were not influenced by knowledge about the real purpose of the study.

Another point that may have influenced the data is that during the experiment it was noticed that a part of the crime scene examiners based their selection of items for further investigation on the chance that the trace would produce a (e.g.) good fingerprint or DNA profile (motivated reasoning¹⁵). Based on that consideration, they sometimes prioritized less important traces over important traces. This same observation was made during the study of de Gruijter et al. (2017) [17].

Another limitation came forward from the power analysis, which showed that the estimated significance levels were based on very low to

¹⁵ Reasoning processes (a.o. information selection and evaluation and decision-making) are influenced by motivations or goals.

moderate powers (0.051–0.393). Power is affected by sample size and the size of the effect [48,49]. In our case the low power is most probably the result of the small sample size. Increasing the sample size would possibly result in a larger power.

It is noticeable that even though all the crime scene examiners said they were very open towards advice from colleagues (7-point Likert scale: $M = 6.4$, $SD = 0.6$), especially those selecting suicide as the most likely scenario, many did not use the additional information provided to them. Crime scene examiners were also asked with a 7-point Likert scale what they thought of the presence of an investigative psychologist at the crime scene. Overall they responded positively and on average gave a score of 4.6 ($SD = 1.5$), verbally corresponding to 'neutral' to 'I somewhat agree'. Most participants who scored neutral on this question stated that they did not have any experience with investigative psychologists at the crime scene yet.

5. Conclusion

Evidence-based studies on the selection and collection of traces as well as for the creation and examination of hypotheses at the crime scene is scarce. Yet, these studies are of the uttermost importance as decisions made at the crime scene play a key role throughout the further forensic reconstruction and legal processes. The lack of knowledge on forensic decision-making processes asks for more proactive and foundational work within forensic disciplines rather than forming research questions in a reactive way when problems occur in the field or a new procedure gains popularity. This study demonstrates that incorporation of behavioural sciences into the crime scene investigation can provide a diverse perspective leading to clues and traces that were otherwise likely to be ignored. Crime scene examiners who received information on deviant behavioural cues recognized and collected more and different traces at the virtual crime scene than those who did not receive this information. However, the study also shows that this information is likely to be ignored when it contradicts an existing belief. This suggests a need for a more structured crime scene approach to evaluate new information and consider alternative scenarios during an investigation. The results of this study provide valuable information that can be used to make crime scene examiners aware of bias in their decision-making and can be used to form a next step in bridging the forensic and behavioural sciences by learning from each other's expertise. Our final note is that, when searching for and securing traces can be substantiated with

Appendix A. In-depth description mock crime scene

Creation of the scenario

The basis of the scenario was to create an ambiguous crime scene with several deviant behavioural cues with the underlying idea that only upon noticing the deviant behavioural cues, the ground truth would be found. The term deviant behaviour encompasses behaviour that deviates from established social norms, rules, standards or expectations. To create such a scenario, meetings were held with investigative psychologists, forensic examiners, and scientist experienced in creating mock crime scenes.

The deviant behavioural cues were partially based on information provided by two investigative psychologists from the Netherlands [39]. Some elements (cues) used were adopted from real past cases, in which the investigative psychologists had given advice on deviant behavioural cues present at the crime scene. To prevent biasing results, direct colleagues of these particular investigative psychologists were excluded from participation. Part of the deviant behavioural cues was also derived from literature on mock crime scenes [17,19,22], and crime scene staging [40,50,51], to make the chance of participants recognizing specific cues, as minimal as possible. To make the scene as realistic as possible, the ideas for the deviant behavioural cues were discussed with two crime scene examiners from the Netherlands Forensic Institute and two crime scene examiners from the Dutch Police. With their input, the cues were embedded into a realistic scenario based on aspects of real cases. In addition, the crime scene examiners helped in creating realistic 'prior information' the participants received before starting their investigation (see procedure section). Lastly, together with two scientists experienced in the creation of mock crime scenes (from the University of Amsterdam and the VU University), some details were altered or added to create the final scenario.

Construction of the scenario

Most mock crime scene studies reviewed for this paper were executed in an academic setting. For example, a training house at the Dutch Police

knowledge from different disciplines, it is possible that more relevant traces can be secured with better coherence among different forensic examiners.

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Ethics approval statement

N.a.

CRedit

Rosanne de Roo: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Visualization, Project administration. Madeleine de Grijter: Conceptualization, Methodology, Resources, Writing - Review & Editing, Supervision. Christianne de Poot: Writing - Review & Editing, Supervision. Josita Limborgh: Resources, Writing - Review & Editing, Supervision. Paul van den Hoven: Resources, Writing - Review & Editing, Supervision.

Declaration of competing interest

No conflict of Interest.

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Academy was staged and used for research [16,17,22]. However, there are two major problems with the use of these academy houses. Firstly, the environment is often known to the participants, which might bias the results. Participants have indicated that they recognize elements that do or do not 'belong' in the academy house, and therefore are primed to recognize which items are relevant to the scenario. Secondly, people do not live in the academy houses. Therefore, these houses do not have many personalized characteristics that one would normally find in 'real' homes. To overcome these impediments, it was decided to create a mock crime scene in a 'real' house in Amsterdam, the Netherlands for the purposes of carrying out this study.

The mock crime scene consisted of a death case in an apartment. The hallway, bathroom, living room and kitchen were included in the scenario. To make the scene as realistic as possible, almost all actions associated with the ground truth were re-enacted. There were 24 deviant behavioural cues integrated into the scene, leading to/giving clues toward 10 traces/items connected to the crime (e.g. a messy bathroom, while the rest of the house was tightly cleaned, leading to the towels on the ground that could be a possible trace). These 10 traces are known as forensic-behavioural traces. In addition, there were 15 pre-determined forensic traces/items present at the scene on which multiple forensic examinations could be performed. For a detailed overview of the traces and cues presented at the scene, see [Appendices B and C](#).

With the help of the ETVR (Expert team Visualization & Reconstruction) department of the Dutch Police, the mock crime scene was scanned. With the aid of a Faro scanner (Faro Focus 3D X330) the scene was recorded and subsequently uploaded to the program Unity (version 2018.3). Unity is a program in which the data from the Faro scanner can be incorporated into a 3D environment. Unity allows you to virtually 'walk' through the crime scene. As a result, participants can investigate the scene behind a computer and do not have to be physically present. The program allows the creator to add 2D elements (e.g. pictures) into the virtual environment. With this application, a pictures of content (e.g. of a garbage bin and content of drawers) were added to the virtual crime scene. To avoid guiding information that might result from only adding pictures that are relevant to the scenario, 'filler pictures', of the content of all the drawers and of multiple details not relevant to the scenario were added [52]. Additionally, Unity was programmed in such a way that the additional pictures of, for example, the content of a garbage bin, would only become visible when the participant was within a close proximity to the bin. In this way, participants had to go through and investigate the whole scene and could not just 'walk' toward locations where pictures were added.

The ground truth – domestic homicide

A female student, Sophie Overtoom (SO), 25 years old, lived alone in a well-kept and tidy house. SO was interested in Forensic Science and (illegally) in possession of a gun (0.22 caliber). On the night of the crime, SO dressed herself nicely as she had a date with a new boyfriend. The ex-boyfriend of SO named X, found out that SO was dating another guy. On the night of the crime, X came by the house of SO to convince her that they had to become a couple again. X rang the front door. SO opened the door for him. X hung his coat on the coat rack and went into the living room to talk with SO. When X realized that SO did not want to go back into a relationship with him, X was overwhelmed with emotions. As a last resort, he grabbed SO's weapon and ammunition from the cabinet in the living room and pointed it at her. SO sat down in the chair in the living room and tried to calm down X. SO called her date to cancel it, in an attempt to calm down X. X took a cigarette out of his coat and lit it. While he was smoking, he paced up and down the house. While doing this, he saw a number of things that were not his, but from another man. X realized that SO her new boyfriend had been to the apartment. X got so angry with this thought that he loaded the weapon and shot SO through the head. Startled by his act X rushed into the bathroom. He changes his cloths in the bathroom and put on some old clothes of his that were still lying in the apartment.

X threw his clothes in the laundry basket. Next, X tried to conceal the murder as a suicide. He put the weapon next to the victim and put a bottle of wine and glass beside her to stage the case as a suicide. X realized that it was not wise to leave his clothes in the laundry basket and quickly grabbed his clothes out and while doing this, he threw a few towels on the floor. However, X forgot his underwear which remained in the laundry basket and also forgot his coat in his haste.

Alternative scenario – suicide

Since the relation of Sophie Overtoom (SO) and her ex-boyfriend (X) ended, SO suffered from depressive complaints. On the night of the crime, SO dressed herself up for a date with her new flirt. She grabbed a bottle of wine and a glass and put these next to her. After waiting on her date for a while she felt like he blew her off. Feeling depressed and left alone again, SO loaded her .22 gun, sat down in the chair in the living room and shot herself.

Appendix B. Behavioural cues

Table B.1

Behavioural cues (n = 24) present at the mock crime scene and the information the participants could retrieve from it leading to traces with a behavioural element (n = 10).

| Location | Behavioural cue | Information retrieved from cues |
|--------------------|---------------------------------|--|
| Hallway | Bull's eye target | Victim maybe had an interest in CSI/shooting |
| | Male coat | The victim lived alone → possible trace |
| | Pack of cigarettes | Smoking doesn't fit victim's lifestyle → possible trace |
| Bathroom | Towels on the ground | There is a laundry basket and towel rack right next to it → possible trace |
| | Two toothbrushes | Victim lived alone → possible trace |
| | 'Messy' sink | Rest of house was very clean and tight → possible trace |
| | Male boxer short | Victim lived alone and shorts were on top of the pile → possible trace |
| Living room | Victim in odd position | The position is very unlikely for someone who has committed suicide |
| | Wine bottle/glass on the ground | There were plenty of tables around the victim, so why on the ground → possible trace |
| | Type of glass | The type of glass was a water glass, while the victim had many wineglasses → possible trace |
| | Half open drawer | Cabinet with water glasses → possible trace |
| | Economic books on bookshelf | It stands out in the tight living room Victim seems to study Forensic Science or Life Science, economic books do not fit this picture |

(continued on next page)

Table B.1 (continued)

| Location | Behavioural cue | Information retrieved from cues |
|----------------|--|---|
| | Wine glasses in cabinet | Victim seems to often use these glasses |
| | Content of agenda was full | No signs that the victim wanted to commit suicide |
| | Flyer on table with 'solving the perfect murder' | Victim had an interest in CSI/Forensic Science |
| | Games with murder theme | Victim had an interest in CSI/Forensic Science |
| | Booking.com on laptop | No signs that the victim wanted to commit suicide |
| | Netflix show stopped at the beginning | No signs that the victim wanted to commit suicide/victim might be interrupted |
| | Two guns | Deviant that a 25 year old girl has two guns |
| Kitchen | Bioproduct in fridge/pantry | Victim has healthy lifestyle |
| | Full fridge/pantry | No signs that the victim wanted to commit suicide |
| | Meat sticks in pantry | Deviant, victim seems to be vegetarian |
| | 'Be vegetarian' flyer | Victim seems to be vegetarian |
| | Cigarette | Does not fit victim's lifestyle → possible trace |

Appendix C. Traces at mock crime scene

Table C.1

Traces present- and elements related to the scenario at the mock crime scene, divided between traces with behavioural element or forensic element, the corresponding category and evidential value per item

| Location | | Traces and elements related to the scenario | | | | Evidential value trace |
|--------------------------|---------------------------|---|--|---|------------------------|------------------------|
| | | Information on/pointing towards | Traces with behavioural element (n = 10) | Pre-determined forensic elements (n=15) | Trace/element category | |
| Hallway | Pack of cigarettes | Perpetrator | X | | Deviant behavioural | Low |
| | Male coat on coatrack | Perpetrator | X | | Deviant behavioural | High |
| Bath-room | Blood on basket | Victim | | X | Forensic | Low |
| | Blood on sink | Victim | | X | Forensic | Low |
| | Towels on ground | Victim | X | | Deviant behavioural | Low |
| | Two toothbrushes | Victim | X | | Deviant behavioural | low |
| | DNA form sink handle | Perpetrator | X | | Deviant behavioural | High |
| | Boxer shorts | Perpetrator | X | | Deviant behavioural | High |
| Living room | Phone of victim | Victim | | X | Forensic | Low |
| | Gun #2 in cabinet | Victim | | X | Forensic | Low |
| | Handle cabinet gun #2 | Mixture* | | X | Forensic | Low |
| | Ammunition box | Mixture* | | X | Forensic | Low |
| | Blood on the ground | Victim | | X | Forensic | Low |
| | Laptop #1 | Victim | | X | Forensic | Low |
| | Laptop #2 | Victim | | X | Forensic | Low |
| | Coffee cup #1 | Victim | | X | Forensic | Low |
| | Bloodstain pattern victim | Victim | | X | Forensic | High |
| | Gun #1 on the ground | Perpetrator | | X | Forensic | High |
| | Cartridge case | Perpetrator | | X | Forensic | High |
| | Wine bottle on ground | Perpetrator | X | | Deviant behavioural | High |
| | Glass on the ground | Perpetrator | X | | Deviant behavioural | High |
| | Kitchen | Coffee cup #2 | Perpetrator | | X | Forensic |
| Coffee cup #3 | | Victim | | X | Forensic | Low |
| Handle cabinet glasses | | Mixture* | X | | Deviant behavioural | Low |
| Cigarette in garbage bin | | Perpetrator | X | | Deviant behavioural | High |

*Mixture indicates that the information on the trace would lead to both the victim and the perpetrator.

Table C.2
Number of traces per category divided in 'high' value traces and 'low' value traces

| Trace/element | Number of traces | |
|----------------------|------------------|-------------|
| | 'High' value | 'Low' value |
| Forensic | 3 | 12 |
| Forensic behavioural | 6 | 4 |

Appendix D. Prior information participants

Preliminary findings

Date: 19-02-2019. Time 04:00 p.m.

Female victim, Sophie Overtoom (SO), of 25 years old. Lives alone according to the GBA (municipal personal records database). No antecedents (history with police). Found by sister who was worried after SO did not show up on their regularly lunch meeting. Victim has struggled lately with depressive complaints according to the sister.

Witness statement sister of victim – Marieke Overtoom

"When Sophie (Victim) did not show up on our regularly lunch appointment I went by her house. I rang the doorbell a couple of times. When she did not open the door, I picked up the set of spare keys I have at my place. When I walked in, I saw Sophie with her head down on the chair in the living room. It was dark inside. I opened one of the curtains to let some light in. After doing this, I saw the gun and the blood. I stepped back immediately, called the police and walked out of the apartment. I did not touch anything. My baby sister has lately been struggling with depressive complaints. She and her boyfriend broke up 3 months ago."

Public prosecutor

The public prosecutor has given permission for a house search.

Appendix E. Additional information provided in phase 2

Crime scene examiners in the experimental condition received a short behavioural report based on the crime scene, while crime scene examiners in the control condition received basic forensic information.

Behavioural report

When I entered the room, I noticed a big black jacket on the coat rack, it seemed to me this was rather a men's jacket than a women's jacket. On the cabinet in the hallway I saw a bulls eye target. The whole house is very orderly and clean. However, in the bathroom I saw towels on the floor next to the laundry basket. I found this remarkable because there were also towels in the laundry basket and towels hanging on the radiator. Didn't the prior information say that the victim lived alone? It seemed to me that there was a male boxer short in the laundry basket and I also noticed two toothbrushes. In the living room I didn't see any signs of a struggle. There is an agenda on the table in the living room. This contains a hospital appointment for Monday and for today (Wednesday) it showed a lunch appointment with probably the sister of victim. There are also plans for the rest of the week. Next to the victim was a bottle of wine with an ordinary water glass next to it, both standing on the floor. I notice that there are many beautiful wine glasses in the cupboard, I don't know if this means anything, but I notice it. Besides I found it odd that the bottle and glass were on the floor and not on one of the tables next to her. The bulls eye target in the hallway, the flyer on the living room table with "How do you track down the almost perfect murder", the forensic science books in the bookcase and the games with a murder theme, it seems to me as if the victim had an interested in forensic science/CSI. It is remarkable that on the one hand, the victim seemed to live a healthy lifestyle; There are many organic products and vegetarian cookbooks in the house. There was also a flyer that quoted: "Keep calm and be vegetarian". Yet, on the other hand there is a can of Monster energy drink in the fridge and there is a bag of meat sticks in the cupboard, which I don't think fit in the 'healthy lifestyle' picture. The thing that stood out most for me was the cigarette in the bin. I don't get the impression that the victim was a smoker, based on the house and the lifestyle of the victim. The victim lived alone according to the prior information, but it strikes me that there are a few things in the house that, I think, do not seem to suit her but rather someone else.

General forensic information

I did not see signs of a forced entry at the front door. Furthermore, I did not see anything strange in the hallway. I see a drop of blood on the laundry basket and faint spots on the sink that might also be blood. The house looks neat, I see no signs of a struggle. I notice the blood pattern on the head of the victim, it seemed to me that it had different directions. Maybe she sat first in an upright position and only later in this position.

The kitchen looks undisturbed. The balcony door is locked on the inside and to me it does not look like a robbery.

Appendix F. Tables

Table F.1

Overview of the experimental set-up

| Description | | Content | | |
|-----------------|--------------------------------|---|--|-----------------------------|
| | | Forensic examiners in experimental condition | Forensic examiners in control condition | Investigative psychologists |
| Pre-experiment | Intake questionnaire | Police district, age, gender, education level, years of experience, experience with virtual crime scene experiments | | |
| Experiment | Explanation | Navigating controls, answering sheets | | |
| | Phase 1 | Information containing preliminary findings of the investigation 40 min to investigate virtual crime scene, note most likely scenario, write down items to secure and maximum 6 items for further investigation, together with argumentation | | |
| | Pause – additional information | Receive a short <u>behavioural report</u> based on the crime scene | Received <u>general forensic information</u> | – |
| | Phase 2 | 10 min to investigate virtual crime scene again, write down (additional) items to secure, change final selection of 6 items for further investigation and possibility to change order most likely scenario | | |
| Post-experiment | Exit questionnaire | Monitoring thoughts on the experiment | | |
| | Debriefing | Presenting the final results of the investigation for the participating police districts. | | |

Table F.2

Mean scores and standard deviations (SD) of data crime scene examiners on the secured items on phase 1 and phase 2 of the experiment for the experimental and control condition, with p-value (one-tailed).

| Secured items | Experimental condition (n = 21) | | | Control condition (n = 15) | | |
|---------------------|---------------------------------|-----------------|-------------------|----------------------------|-----------------|------------------|
| | Phase 1 | Phase 2 | p-value (t-test*) | Phase 1 | Phase 2 | p-value (t-test) |
| Total | 12.7 (SD = 4.2) | 13.4 (SD = 4.4) | 0.245 | 13.1 (SD = 3.4) | 13.1 (SD = 3.4) | – |
| Min | 6 | 6 | – | 8 | 8 | – |
| Max | 23 | 24 | – | 21 | 21 | – |
| Forensic | 8.8 (SD = 2.6) | 8.9 (SD = 2.4) | 0.457 | 9.2 (SD = 2.1) | 9.2 (SD = 2.1) | – |
| 'High' value | 2.0 | 2.1 | 0.288 | 2.2 | 2.2 | – |
| 'Low' value | 6.8 | 6.8 | 0.493 | 7.0 | 7.0 | – |
| Deviant behavioural | 3.8 (SD = 2.3) | 4.4 (SD = 2.7) | 0.145 | 3.9 (SD = 2.1) | 3.9 (SD = 2.1) | – |
| 'High' value | 2.9 | 3.3 | 0.164 | 2.7 | 2.7 | – |
| 'Low' value | 1.0 | 1.2 | 0.174 | 1.2 | 1.2 | – |

*a directional one sampled t-test (one tailed) was used.

Table F.3

Mean (M) and standard deviation (SD) of data crime scene examiners on phase 1 of the experiment in the experimental and control condition with p-value

| Characteristic | Experimental (n = 21) M (SD) | Control (n = 15) M (SD) | p-value |
|--|------------------------------|-------------------------|---------|
| Number of deviant behavioural cues mentioned | 7.4 (4.0) | 7.6 (3.6) | 0.875 |
| Total of 'forensic' items secured | 8.8 (2.6) | 9.2 (2.1) | 0.630 |
| Forensic items with 'high' value | 2.0 (0.4) | 2.2 (0.6) | 0.242 |
| Forensic items with 'low' value | 6.8 (2.5) | 7.0 (1.7) | 0.752 |
| Total of 'deviant behavioural' items secured | 3.8 (2.3) | 3.9 (2.1) | 0.890 |
| Deviant behavioural items with 'high' value | 2.9 (1.6) | 2.7 (1.7) | 0.673 |
| Deviant behavioural items with 'low' value | 1.0 (0.9) | 1.2 (0.8) | 0.402 |
| Number of 'forensic' items selected for 'top 6' | 4.5 (1.1) | 4.5 (1.3) | 0.981 |
| Number of 'deviant behavioural' items selected for 'top 6' | 1.5 (1.1) | 1.5 (1.3) | 0.981 |

*a independent sampled t-test was used.

Table F.4

Mean scores for the items selected for further investigation of data crime scene examiners on phase 1 and phase 2 of the experiment for the experimental and control condition, with p-value.

| Selected for further investigation | Experimental condition (n = 21) | | | Control condition (n = 15) | | |
|------------------------------------|---------------------------------|---------|-------------------|----------------------------|---------|------------------|
| | Phase 1 | Phase 2 | p-value (t-test*) | Phase 1 | Phase 2 | p-value (t-test) |
| Forensic | 4.5 | 4.0 | 0.004 | 4.5 | 4.5 | – |
| 'High' value | 1.7 | 1.7 | – | 1.9 | 1.9 | – |
| 'Low' value | 2.8 | 2.3 | 0.004 | 2.6 | 2.6 | – |
| Deviant behavioural | 1.5 | 2.0 | 0.004 | 1.5 | 1.5 | – |
| 'High' value | 1.3 | 1.8 | 0.002 | 1.4 | 1.4 | – |
| 'Low' value | 0.2 | 0.1 | – | 0.1 | 0.1 | – |

*a paired sampled t-test (two tailed) was used.

Table F.5

Mean scores and standard deviations (SD) on the secured items on phase 1 and phase 2 of the experiment between crime scene examiners choosing the most probable scenario domestic homicide vs suicide, with p-value (one-tailed).

| Secured items | Most probable scenario | | | | | |
|---------------------|----------------------------|-----------------|-------------------|------------------|-----------------|------------------|
| | Domestic homicide (n = 11) | | | Suicide (n = 10) | | |
| | Phase 1 | Phase 2 | p-value (t-test*) | Phase 1 | Phase 2 | p-value (t-test) |
| Total | 13.7 (SD = 3.5) | 15.0 (SD = 3.5) | 0.008 | 11.5 (SD = 4.8) | 11.6 (SD = 4.8) | 0.343 |
| Min | 8 | 11 | – | 6 | 6 | – |
| Max | 22 | 24 | – | 23 | 23 | – |
| Forensic | 9.5 (SD = 2.7) | 9.6 (SD = 2.3) | 0.676 | 8.1 (SD = 2.3) | 8.1 (SD = 2.3) | – |
| 'High' value | 1.9 | 2.0 | 0.341 | 2.1 | 2.1 | – |
| 'Low' value | 7.5 | 7.6 | 0.341 | 6.0 | 6.0 | – |
| Deviant behavioural | 4.1 (SD = 1.8) | 5.3 (SD = 2.3) | 0.005 | 3.4 (SD = 2.8) | 3.5 (SD = 2.8) | 0.343 |
| 'High' value | 3.5 | 4.1 | 0.026 | 2.3 | 2.4 | 0.343 |
| 'Low' value | 0.8 | 1.4 | 0.052 | 1.1 | 1.1 | – |

*a directional one sampled t-test (one tailed) was used.

Table F.6

Mean scores for the items selected for further investigation on phase 1 and phase 2, between crime scene examiners choosing the most probable scenario domestic homicide vs suicide, with p-value.

| Selected for further investigation | Most probable scenario | | | | | |
|------------------------------------|----------------------------|---------|-------------------|------------------|---------|------------------|
| | Domestic homicide (n = 11) | | | Suicide (n = 10) | | |
| | Phase 1 | Phase 2 | p-value (t-test*) | Phase 1 | Phase 2 | p-value (t-test) |
| Forensic | 4.3 | 3.6 | 0.011 | 4.7 | 4.5 | – |
| 'High' value | 1.6 | 1.6 | – | 1.8 | 1.8 | – |
| 'Low' value | 2.6 | 2.0 | 0.011 | 2.9 | 2.7 | – |
| Deviant behavioural | 1.7 | 2.4 | 0.011 | 1.3 | 1.5 | – |
| 'High' value | 1.6 | 2.4 | 0.004 | 1.0 | 1.2 | – |
| 'Low' value | 0.1 | 0.0 | – | 0.3 | 0.3 | – |

*a paired sampled t-test (two tailed) was used.

Appendix G. Figure legend (print in color)

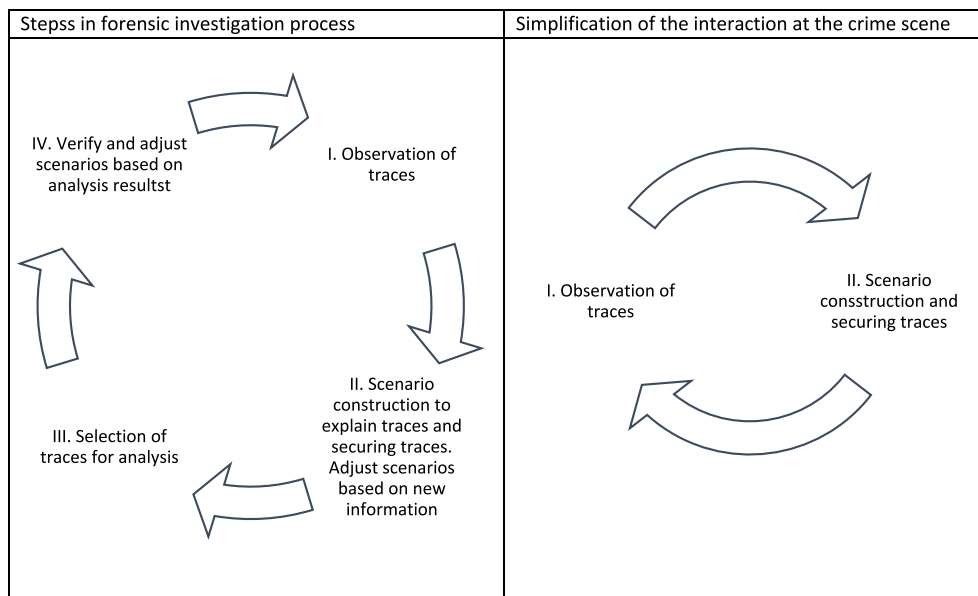


Fig. G.1. The current steps of a forensic investigation and a simplification of the interaction at the crime scene between the search for traces and scenario construction.

Proportion of deviant behavioural cues mentioned per profession

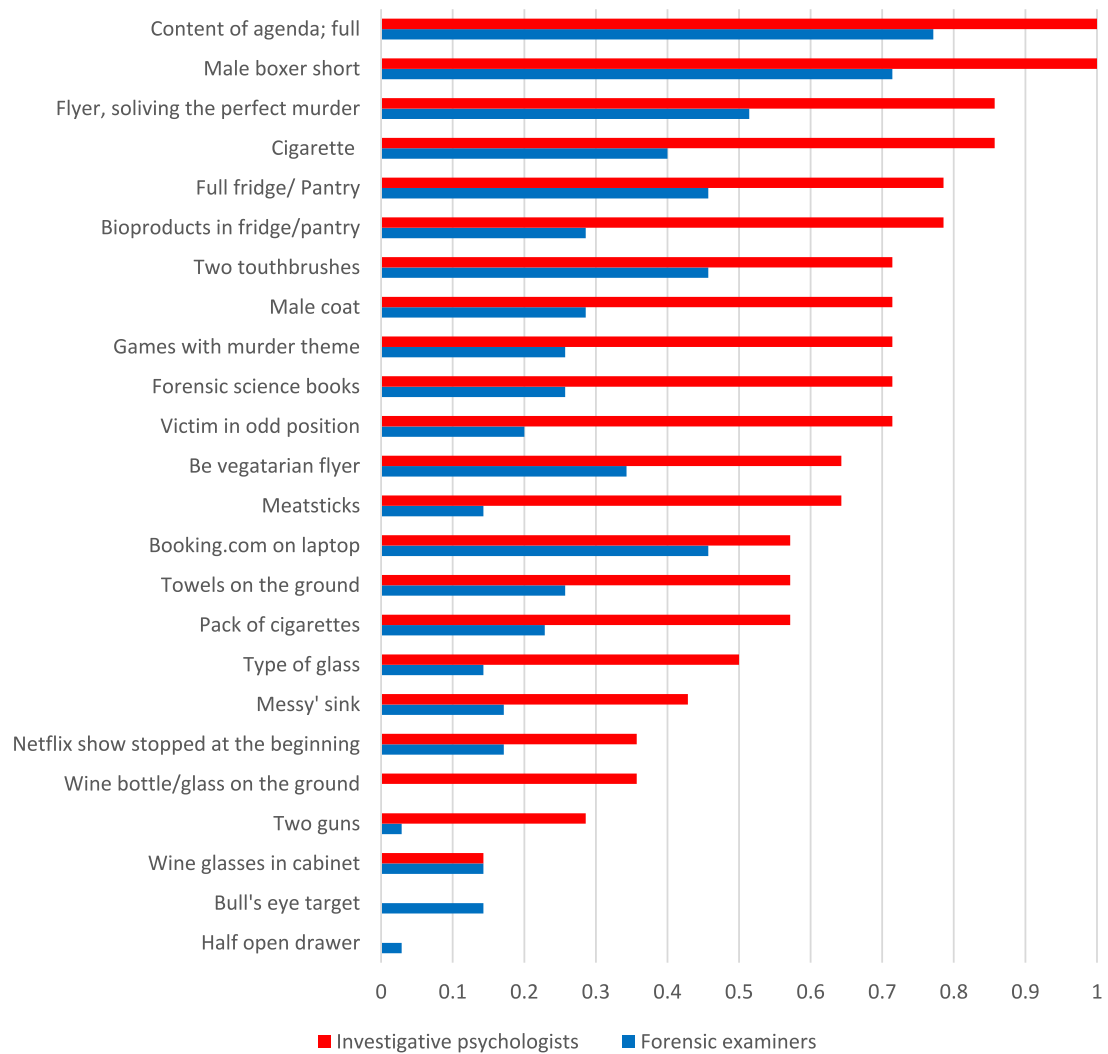


Fig. G.2. Proportion of deviant behavioural cues (N = 24) mentioned per profession (crime scene examiners and investigative psychologists).

Number of deviant behavioural cues mentioned by scenario per profession

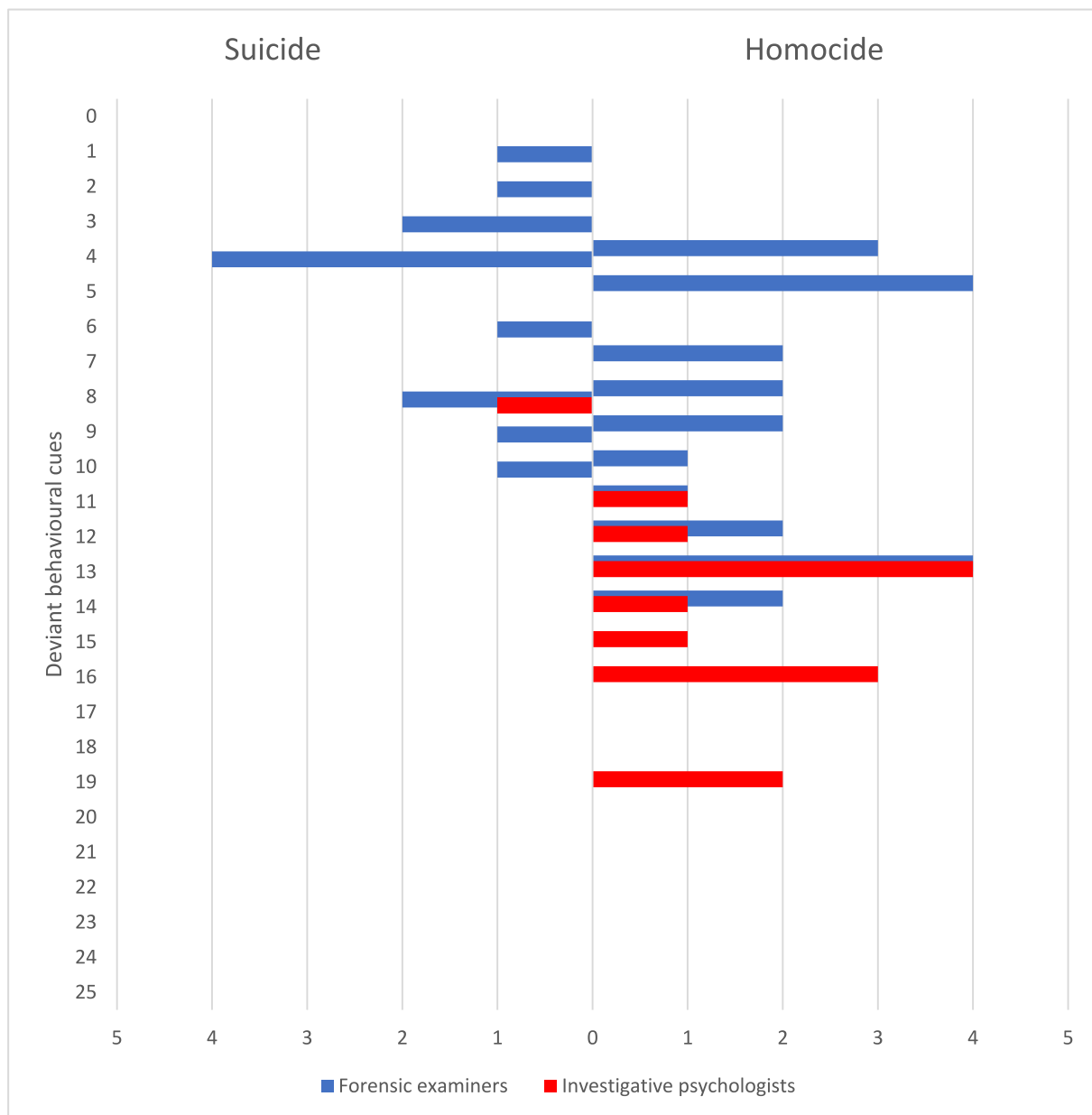


Fig. G.3. Horizontal 2-sided bar graph of number of deviant behavioural cues (total n = 25) mentioned per scenario by group (crime scene examiners (n = 36) and investigative psychologists (n = 14))

Appendix H. ANOVA output

The reason the outcomes of the repeated-measures ANOVA are in some cases the same on the factor ‘time’ (before and after they received additional information) and on the interaction ‘time*condition’, is because, in those cases, participants in the control condition did not change anything after having received the extra ‘forensic’ information.

Table H.1

Outcomes score total items secured, forensic items secured and deviant behavioural items secured over phase 1 and phase 2, between the experimental and control condition

| Secured items | ‘time*condition’ | ‘time’ | ‘condition’ | Power |
|---------------------|------------------------------|------------------------------|------------------------------|-------|
| Total | $F(1,34) = 6.250, p = 0.017$ | $F(1,34) = 6.250, p = 0.017$ | $F(1,34) = 0.007, p = 0.935$ | 0.051 |
| Forensic | $F(1,34) = 0.136, p = 0.714$ | $F(1,34) = 0.136, p = 0.714$ | $F(1,34) = 0.221, p = 0.641$ | 0.074 |
| Deviant behavioural | $F(1,34) = 7.083, p = 0.012$ | $F(1,34) = 7.083, p = 0.012$ | $F(1,34) = 0.086, p = 0.772$ | 0.059 |

Table H.2

Outcomes score forensic items selected for further investigation and deviant behavioural items selected for further investigation over phase 1 and phase 2, between the experimental and control condition

| Selected for further investigation | 'time*condition' | 'time' | 'condition' | Power |
|------------------------------------|------------------------------|------------------------------|------------------------------|-------|
| Forensic | $F(1,34) = 7.650, p = 0.009$ | $F(1,34) = 7.650, p = 0.009$ | $F(1,34) = 0.283, p = 0.598$ | 0.081 |
| 'High' value | - | - | - | |
| 'Low' value | $F(1,34) = 7.650, p = 0.009$ | $F(1,34) = 7.650, p = 0.009$ | $F(1,34) = 0.019, p = 0.890$ | |
| Deviant behavioural | $F(1,34) = 7.650, p = 0.009$ | $F(1,34) = 7.650, p = 0.009$ | $F(1,34) = 0.283, p = 0.598$ | 0.081 |
| 'High' value | $F(1,34) = 9.320, p = 0.004$ | $F(1,34) = 9.320, p = 0.004$ | $F(1,34) = 0.179, p = 0.675$ | |
| 'Low' value | $F(1,34) = 0.708, p = 0.406$ | $F(1,34) = 0.708, p = 0.406$ | $F(1,34) = 0.075, p = 0.786$ | |

Table H.3

Outcomes score for total items secured, forensic items secured and deviant behavioural items secured over phase 1 and phase 2, between crime scene examiners choosing the most probable scenario domestic homicide vs suicide

| Secured items | 'time*condition' | 'time' | 'condition' | Power |
|---------------------|------------------------------|------------------------------|------------------------------|-------|
| Total | $F(1,34) = 3.025, p = 0.091$ | $F(1,34) = 5.028, p = 0.032$ | $F(1,34) = 2.494, p = 0.124$ | 0.336 |
| Forensic | $F(1,34) = 0.108, p = 0.745$ | $F(1,34) = 0.108, p = 0.745$ | $F(1,34) = 1.431, p = 0.240$ | 0.214 |
| 'High' value | $F(1,34) = 0.558, p = 0.460$ | $F(1,34) = 0.558, p = 0.460$ | $F(1,34) = 0.283, p = 0.598$ | |
| 'Low' value | $F(1,34) = 0.558, p = 0.460$ | $F(1,34) = 0.558, p = 0.460$ | $F(1,34) = 0.283, p = 0.598$ | |
| Deviant behavioural | $F(1,34) = 3.272, p = 0.079$ | $F(1,34) = 5.659, p = 0.023$ | $F(1,34) = 1.707, p = 0.200$ | 0.246 |
| 'High' value | $F(1,34) = 1.491, p = 0.230$ | $F(1,34) = 4.192, p = 0.048$ | $F(1,34) = 3.287, p = 0.079$ | |
| 'Low' value | $F(1,34) = 2.278, p = 0.140$ | $F(1,34) = 2.278, p = 0.140$ | $F(1,34) = 0.096, p = 0.759$ | |

Table H.4

Outcomes score for forensic items selected for further investigation and deviant behavioural items selected for further investigation over phase 1 and phase 2, between crime scene examiners choosing the most probable scenario domestic homicide vs suicide

| Selected for further investigation | 'time*condition' | 'time' | 'condition' | Power |
|------------------------------------|------------------------------|------------------------------|------------------------------|-------|
| Forensic | $F(1,34) = 0.747, p = 0.393$ | $F(1,34) = 6.924, p = 0.013$ | $F(1,34) = 3.021, p = 0.091$ | 0.393 |
| 'High' value | - | - | - | |
| 'Low' value | $F(1,34) = 0.747, p = 0.393$ | $F(1,34) = 6.924, p = 0.013$ | $F(1,34) = 1.307, p = 0.261$ | |
| Deviant behavioural | $F(1,34) = 7.747, p = 0.393$ | $F(1,34) = 6.924, p = 0.013$ | $F(1,34) = 3.021, p = 0.091$ | 0.393 |
| 'High' value | $F(1,34) = 1.193, p = 0.282$ | $F(1,34) = 7.977, p = 0.008$ | $F(1,34) = 3.939, p = 0.055$ | |
| 'Low' value | $F(1,34) = 0.558, p = 0.460$ | $F(1,34) = 0.558, p = 0.460$ | $F(1,34) = 0.982, p = 0.329$ | |

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