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DOI
10.1016/j.scijus.2023.11.009

Publication date
2024

Document Version
Final published version

Published in
Science & Justice

Science & Justice 64 (2024) 63–72

Contents lists available at ScienceDirect

Science & Justice

journal homepage: www.elsevier.com/locate/scijus

Short Communication

CSI-CSI: Comparing several investigative approaches toward crime scene improvement

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ARTICLE INFO

Keywords:
Crime scene investigator (CSI)
Crime scene investigation
Expert decision-making
International comparison
Context information

ABSTRACT

Crime scene investigations are highly complex environments that require the CSI to engage in complex decision-making. CSIs must rely on personal experience, context information, and scientific knowledge about the fundamental principles of forensic science to both find and correctly interpret ambiguous traces and accurately reconstruct a scene. Differences in CSI decision making can arise in multiple stages of a crime scene investigation. Given its crucial role in forensic investigation, CSI decision-making must be further studied to understand how differences may arise during the stages of a crime scene investigation. The following exploratory research project is a first step at comparing how crime scene investigations of violent robberies are conducted between 25 crime scene investigators from nine countries across the world.

Through a mock crime scene and semi-structured interview, we observed that CSIs have adopted a variety of investigation approaches. The results show that CSIs have different working strategies and make different decisions when it comes to the construction of relevant hypotheses, their search strategy, and the collection of traces. These different decisions may, amongst other factors, be due to the use of prior information, a CSI's knowledge and experience, and the perceived goal of their investigation. We suggest the development of more practical guidelines to aid CSIs through a hypothetico-deductive reasoning process, where (a) CSIs are supported in the correct use of contextual information, (b) outside knowledge and expertise are integrated into this process, and (c) CSIs are guided in the evaluation of the utility of their traces.

1. Introduction

Crime scene investigations are complex environments as they require a crime scene investigator's (CSI's) highly technical skillset and cognitive mindset to find and interpret highly ambiguous clues. If the appearance of one scene could potentially have multiple different explanations, then it is the CSI's responsibility to determine, through hypothetical-deductive reasoning, which explanation is the most likely and why [1]. For example, the presence of large blood stains could be due to a violent physical attack or a self-inflicted injury such as cutting oneself with a knife.

Over the past decade, interest in crime scene investigation research has increased due to a greater awareness of the subjective nature of crime scene investigations and the importance of this first phase of the forensic process [1–8]. The importance of crime scene investigations as part of the forensic process is clearly stated in The Sydney Declaration [9]. Also, in 2020, Earwaker and colleagues proposed a six phased approach to improve "transparency and reproducibility of decision making in forensic science" (p. 2) [3]. Briefly, the proposal starts with establishing the importance of decision-making within the forensic and legal realms, continues with a discussion of how decision-making can and should be studied, and concludes with ways to effectively communicate these results with the forensic community and larger criminal justice system.

In short, overlooked or wrongly interpreted traces could have great ramifications downstream throughout the criminal justice process.

Abbreviations: CSI, crime scene investigator; EAFS, European Association for Forensic Science; ENFSI, European Network of Forensic Science Institutes; ENFSI SoCWG, ENFSI Scene of Crime Working Group; LSU, Linear Sequential Unmasking; LSU-E, LSU-Expanded; ISO, International Organization for Standardization.

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https://doi.org/10.1016/j.scijus.2023.11.009
Received 1 June 2023; Received in revised form 20 November 2023; Accepted 27 November 2023
Available online 5 December 2023

Current handbooks and guidelines are mainly focused on the mechanical processes at the crime scene, such as the documentation and methods of collecting and preservation of traces [10]. However, as stated by multiple researchers, crime scene investigations have a highly subjective character and contain much more than 'bagging and tagging' [1,3,4,11–15]. Some studies investigating CSI decision making showed how CSIs can differ in their considerations and decisions at the crime scene [16–20]. Hence, CSIs can have different outcomes for their investigations despite investigating the same scene. Factors such as personal knowledge and interests, the ability to recognize traces, communication skills, and organizational and managerial factors are assumed to play a role in CSI decision making [2,14,21–23].

Delémont and colleagues described how differences in crime scene examination can arise due to differences in a CSI's a strategic level, knowledge of the criminal background, situational analysis, or reasoning of the physical environment [2]. For example, intelligence awareness (Delémont and colleagues' dimension of the criminal background) may lead to different search strategies. CSIs in the study of Wilson-Kovacs described their expertise as being cost-effective by asking themselves how many traces are needed to (a) identify an individual, (b) identify multiple individuals, and (c) to stand up as evidence in court [5]. In contrast, CSIs in the study by Resnikoff and colleagues considered the relevance of traces in a broader way, with regard to the whole crime environment, such as their potential contribution in identifying crime series or learning about different modus operandi [20]. These CSIs also use intelligence in their decisions related to whether to attend the crime scene, their search strategy, and the collection and triaging of traces (See also [2,24]).

Clearly, differences in CSI decision making can arise in all stages of a crime scene investigation. To learn more about the different personal attitudes that may influence CSI decision making, we first describe the different stages in more detail and touch upon the human factor aspects during these stages.

1.1. Stages of crime scene investigation

Delémont and colleagues have described three fundamental decision phases: crime scene attendance, crime scene investigation, and triage, the decision about which traces qualify for further analysis [2]. Although we assume that the available forensic analysis resources assigned to the specific case influence the selection of traces at a crime scene, we will leave the triaging decision and the decision to attend the scene out of this paper's scope. In this study, we will focus on the CSIs' actions and decision making at the crime scene itself.

During the crime scene investigation, examiners are faced with a series of choices: the location to examine, the investigation strategy, the invested material and resources, the kind of traces to search for, and the selection of traces. In most CSI handbooks, the investigation is structured along the lines of four broad phases: information gathering and orientation, plan of approach, investigation, and the completion of the investigation in which preliminary results are evaluated [10,25].

Examples of manuals guiding crime scene investigations include the Best Practices Manual for Scene of Crime Examination published by the European Network of Forensic Science Institutes (ENFSI) [26], the Practical Crime Scene Analysis and Reconstruction manual [10], and the International Organization for Standardization (ISO) 21043 (Part 2) [27], and the ILAC-Guidance document [28]. These manuals refer to similar processes during the crime scene investigation as they aim to establish good practices and prevent errors from occurring; however, in our opinion, how to perform each step lacks precision, thus leaving room for potential differences in crime scene examination by CSIs around the world.

Baechler and colleagues [1] discussed more specifically how the crime scene investigation reasoning process can be explained by a hypothetico-deductive reasoning model. During the aforementioned general steps proposed by the manuals to structure the crime scene investigation, a CSI's reasoning process should incorporate "the development of hypotheses based on observations with the testing of these hypotheses through experiments or further observations, in a cyclic manner" (p. 309) [1]. In the following sections we explain how this reasoning process can be integrated into the general structure of a crime scene investigation.

1.1.1. Information gathering & orientation

During the initial information gathering stage, CSIs receive prior information before they enter the crime scene and may also seek additional information from police or other personnel to better understand what events might have occurred. The amount of contextual information provided to the CSI can vary greatly – sometimes nothing is known about the cause or nature of the crime, while other times significant information is provided to CSIs, or information is intentionally withheld from the CSI to avoid introducing bias [29]. Several studies have shown that, on the one hand, contextual information, either provided by an emergency call center, the first attending officer, or a witness, may be crucial for interpreting an ambiguous crime scene and guiding the search for additional traces [7,30]. In contrast, it can also threaten objectivity as it may restrict and bias the perception and interpretation of the present information, ultimately leading to confirmation bias [16]. Whether contextual information is helpful or hurtful to crime scene investigations is still highly debated [2,7,18,20,31–33], and to our knowledge, there are no explicit guidelines on the use of context-information.

The orientation stage is the latter part of the first stage and consists of the CSI conducting an initial walkthrough of the scene to make an initial assessment. During this stage, CSIs should look for abnormalities or irregularities and target and prioritize areas which are most likely to yield significant material of evidential value [26], however it is unclear how they should identify these abnormalities.

1.1.2. Plan of approach: Hypotheses and search strategy

Following a hypothetico-deductive way of reasoning, CSIs should next consider possible hypotheses based on the gathered information, general knowledge about crime and the first observations, and think about traces they would expect if those hypotheses held true [1]. These hypotheses are contingent on a CSI's ability to identify possible actions of the offender in the environment where the crime took place. In order to consider possible traces that may have been left during these actions, CSIs need to take into account the likelihood of the presence of traces at the identified physical places and the possibility of retrieving information from these traces [2]. Knowledge on transfer, persistence, prevalence, and recovery of traces is therefore essential [34–36]. The development of hypotheses and expectations for traces lead to the search strategy or plan of approach. Based on this plan, CSIs can start their more detailed search at the scene, optionally by using specialized equipment (e.g., forensic light sources) [26]. This reasoning process should be viewed as iterative as new observations or information can lead to modifying hypotheses and considering new hypotheses [1].

1.1.3. Investigation stage: Search and collection

This stage refers to the more physical aspect of searching rather than the theoretical development of search strategy. In this stage, CSIs start their more detailed search at the scene, according to the constructed search strategy. As previously mentioned, CSIs are encouraged to adjust their hypotheses based on new findings [1]. Furthermore, CSIs should decide what traces to collect from the scene. This selection process can be influenced by intelligence gathered during the investigation but also by personal attitudes [6,16,18,20,37,38].

1.1.4. Completing the investigation: Evaluation and preliminary findings

After the crime scene investigation has been completed, the CSI should inform the investigative authority about the results [26]. It is unclear, however, how the obtained findings should be evaluated in light of the considered hypotheses and what kind of conclusion can be

provided based on the investigation. Based on the findings of the investigation, a recommendation should follow regarding the further analyses required to test the hypotheses.

The final decision – whether to analyze a trace or not (the triaging stage) – involves additional personnel beside the CSI [26]. As this stage is not part of the decisions made at the crime scene itself, we will not discuss this further here.[1]

In summary, while it is clear into what steps a crime scene investigation can be divided, the way these steps should be put into practice remains vague, and decisions of the CSIs may depend on their previous experiences, interpersonal skills, and personal attitudes. This may be problematic, as slight variations in practices can create long-term effects as it might result in searching for different traces, considering different interpretations, and ultimately, settling on different conclusions. With limited guidelines on how to execute each stage of an investigation, one CSI's actions may differ from those of another. As a result, it is critical that more research is conducted on investigative approach styles to identify which factors contribute to any discrepancies. A way to explore different approach styles is to compare approaches of CSIs from different countries.

1.2. Current study

The following exploratory research project is a first step in comparing how crime scene investigations are conducted by 25 crime scene investigators from nine countries across the world. The research question guiding this study was, "At violent robbery investigations, what different approaches do CSIs around the world use to conduct an effective crime scene investigation?" Results from this study will be discussed in the context of four stages of an investigation, as described in Section 1.1. The results presented here should not be perceived as being representative for the selected countries. Instead, the results should highlight the similarities but also emphasize the differences that exist in investigation approach styles between crime scene investigators.

2. Methods

2.1. Case type selection

This study focused on how CSIs conduct investigations for violent robberies. This offense type was chosen because (1) they are common serious crimes where crime scene investigations are mostly conducted and (2) this study made use of photos of a violent home robbery mock scene that were used in studies by de Gruijter and colleagues [6,38].

Table 1
Summary of the number of CSIs interviewed, by country.

Country	Number of CSIs interviewed
Australia	5
Canada	1
Germany	2
Netherlands	3
South Africa	1
Sweden	3
Switzerland	5
United Kingdom	1
United States	4
Total	25

[1] For more information about triaging, see Bitzer et al., 2015; 2016.

2.2. Study design

25 experienced CSIs from nine countries were recruited for this study (Table 1). Recruitment for CSIs started in early February 2022, continued simultaneously to the data collection period, and ended in early April 2022. As this research project was exploratory, it aimed to interview 3 expert CSIs from each participating country. For this study, we selected CSIs with experience in handling robberies.

Names of prospective participants were collected by two methods. First, a list of CSIs interested in participating was compiled during the ENFSI Scene of Crime Working Group (ENFSI SoCWG) that took place in February 2022. To reduce bias for the ENFSI BPM, we also sought out CSIs by word of mouth. Forensic science researchers (within and outside Europe) were contacted and requested to help find CSIs willing to participate in this study. Once we had the contact information of CSIs, our research team directly contacted them to schedule an interview. Reminders to participate were sent weekly for up to a month or until the CSI declined to participate or scheduled an interview date. Informed consent was obtained to use the data anonymously.

To set the scene and be able to record any differences in search styles and traces the CSIs would collect, we presented CSIs a virtual mock crime scene of the interior of an apartment using photographs at the beginning of the interview and asked them to discuss their investigation strategy. The virtual mock crime scene used photos taken from an in-person mock crime scene used in previous studies [6,38]. At the beginning of the interview, CSIs received basic information regarding the initial findings. After confirming that each CSI understood the initial briefing, the mock crime scene continued with a "walkthrough" (based on photographs) throughout the apartment.

After the walkthrough, semi-structured interviews were conducted. Questions were structured along the lines of the general phases of an investigation (See Appendix for interview question list). CSIs were asked to provide descriptions and justifications for their decisions and actions during crime scene investigations. Interviews were transcribed verbatim using the transcription service, otter.ai. Transcribed interviews were anonymized and exported as a Microsoft Word Document for qualitative analysis. CSIs were assigned a random identification number that was used to refer to them in the study.

2.3. Study procedure

CSIs were presented with a mock crime scene (Fig. 1) and asked to walk the researcher through their crime scene investigation and through their process of selecting and collecting traces.[2] In total, 35 possible traces were created for the mock crime scene. Of the 35 traces, fourteen were crime related, meaning that the trace was directly related to either the victim's or offender's behaviors that occurred during the robbery. Each CSI viewed the same sixteen photos from the crime scene presented at a rate of ten seconds per slide to represent a brisk initial walkthrough and then given unlimited time to re-examine the photos. Verbal descriptions of the objects were described only if the CSI struggled to identify the object. No explanations for the origin of the objects were provided. After seeing all photos once, CSIs were encouraged to describe their initial thoughts and what they would be doing to begin their investigation. CSIs could reexamine any photos they requested and were encouraged to think out loud. After looking at each photo again and discussing any interesting traces and potential scenarios, CSIs identified their five "Top Traces" of interest that they would like to immediately send to the lab. In addition to recording their "Top Traces," any objects the CSI mentioned in passing were also recorded in a larger list called "Overall Traces.".

[2] Traces refer to both objects and traces that may be present on objects or surfaces.

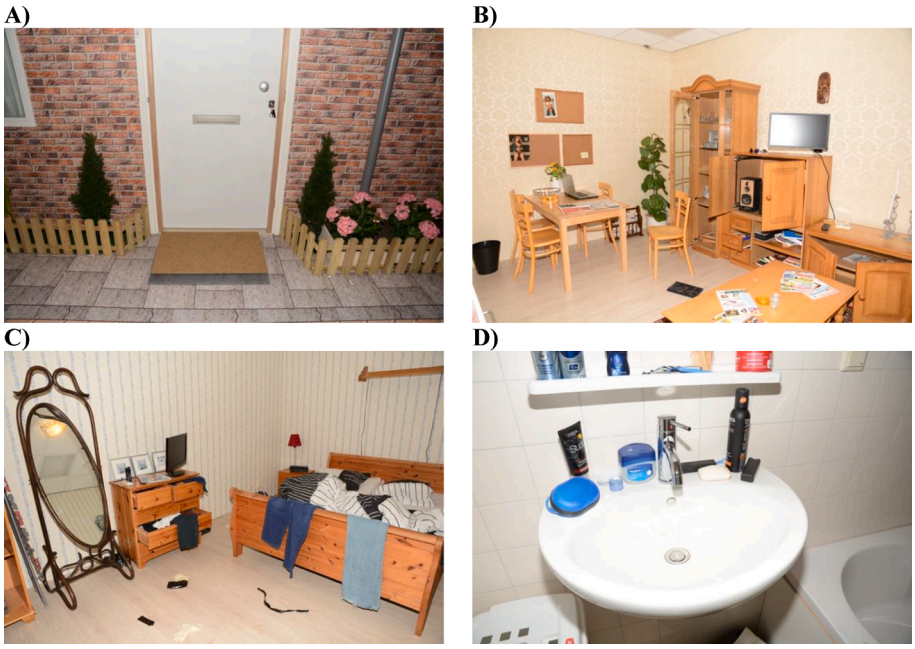

Fig. 1. Four example photos of the mini mock crime scene. Photos taken from a previous study conducted by de Gruijter [8].

2.4. Data analysis

Qualitative data was processed using MaxQDA and thematically coded following Smith's sequential idiographic approach [39]. This approach requires each interview to be read in full so that recurring characteristics of the texts can be highlighted and noted. Thematic codes were determined through an inductive approach, meaning the codes were derived by the data. Strengths of this coding approach is that it can increase validity, decrease bias, accurately represent participants, and promote transparency [40]. Once an initial round of coding was completed, the codes were reviewed a second time to determine if there are any relationships between the codes (axial coding), if there are any recurring broader themes (thematic analysis coding), or perhaps if a group of similar codes could be covered under one overarching code (pattern coding) [41]. Transcripts were coded by two additional researchers. After agreeing that the coding matched, synthesis and interpretation of the analysis began. Due to the exploratory nature of this project and the small sample of CSIs interviewed per country, results were analyzed on a CSI-to-CSI basis. Only if a CSI explicitly mentioned a generalization about their home country's practices would we discuss country-wide practices.

3. Results

Due to the small number of participants, we can only highlight the responses from individuals. We cannot generalize our findings to be representative of the country.

3.1. Descriptive statistics of participants, education, and training

Table 2 shows the background information from the participating CSIs (n = 25). From the ENFSI SoCWG meeting, 20 CSIs volunteered to participate in the study. Of these 20 contacts, only two participants followed through to schedule and conduct an interview. Forensic science researchers provided us with the contact information of 25 prospective participants, however only eighteen scheduled and completed interviews. We also used our own CSI network to recruit five additional participants. In summary, 14/25 (56 %) of the participating CSIs worked in Europe, while the rest were non-European CSIs.

Table 2
Descriptive Statistics of CSI Sample (n = 25).

Recruitment method
via ENFSI SoCWG (n = 2)
via forensic science researcher referral (n = 18)
via authors (n = 5)
European affiliation
European (n = 14)
Non-European (n = 11)
Sex
Male (n = 15)
Female (n = 10)
Profession
Current CSI (n = 18)
Promoted to a more managerial position (n = 5)
Transitioned to university professor (n = 2)
Degree
Applied school/CSI training (n = 10)
Bachelor's (n = 8)
Master's (n = 6)
PhD (n = 1)
Police status
Sworn police officer (n = 23)
Forensic scientist (n = 2)

3.2. The mock crime scene – Variation in approach styles

The purpose of presenting the mock crime scene was to illustrate any differences that exist between CSIs in terms of developing and executing crime scene investigations. At the beginning of the mock crime scene, CSIs were asked to mention all traces and observations they found interesting, regardless of if they intended to collect or further analyze it. Despite being presented with the same virtual mock crime scene and asked the same interview questions, CSIs varied on which traces they mentioned as interesting or collected. While the initial trace list contained 35 possible traces (of which fourteen were crime-related), CSIs during the experiment identified six additional traces that they found interesting that were not originally on the list. These additions were added to the traces list, bringing the list to a total of 41 traces. Nine traces (all of which were non-crime related) from the updated list were not mentioned by any of the CSIs. Across all interviews, all fourteen crime-related traces were mentioned as interesting at least once, but the

number of crime-related traces mentioned by each individual CSI differed. The fewest number of traces a CSI mentioned during the interview was four, while the most traces mentioned was sixteen. The five most mentioned traces were 1) the zip tie, 2) a pair of gloves, 3) duct tape, 4) a set of keys left in the front door, and 5) two beer bottles left in the kitchen (Table 3A). Mention of the zip tie and duct tape was universal as all CSIs were confident the offender would have touched those items, making them appear as reliable sources of DNA from the victim and/or from the offender. While all the CSIs mentioned the pair of gloves, it was not for the same reason. Some CSIs mentioned the gloves because they viewed it as a useful source of DNA, while others mentioned it because they were curious about its unexplained presence. In all but two interviews, CSIs asked, "who left the gloves?" While acknowledgement of the gloves was universal, the actual collection of the object depended on the individual. If the CSI thought the gloves were left by paramedics, the gloves were not interesting; however, if the CSI thought the gloves could have been left by the offender, the object was considered very interesting. CSIs were unanimous in mentioning the presence of the door keys, but not everyone decided to collect the object. Similarly, many but not all CSIs mentioned the beer bottles, and a subset viewed them as a potential useful trace for reconstructing events. Together, results from the mock crime scene confirm that investigations can differ by CSI and provide preliminary insight as to how they may vary.

When CSIs were asked to elect five "Top Traces" for immediate analysis, 20 of the 32 mentioned traces were selected, with thirteen being crime related. CSIs differed in the amount of crime related traces they selected for their Top Traces. For instance, some CSIs' Top Traces were all crime related, while others' lists contained both crime-related and non crime-related traces. CSIs were still interested in the zip tie, pair of gloves, and duct tape, however instead of choosing the door keys and beer bottles, most CSIs opted to collect two possible blood sources – one stain on the door leading to the bathroom and one on the ground in the bedroom where the victim was found (Table 3B). This decision was the result of many believing DNA was the most important kind of trace to collect. This shared preference for blood traces suggests that, when limited by the number of traces they can collect, CSIs may revert to a similar approach style – one that prioritizes traces that are more obviously crime-related over those that are ambiguous.

The mock crime scene clearly demonstrated that differences in approach style are present between CSIs, however it did not explain why these discrepancies exist. To understand how these differences manifested throughout the investigation, a semi-structured interview was conducted after the mock crime scene exercise. To structure the results, we chose to present our findings in accordance with the four stages mentioned in the Introduction: 1) the information gathering and orientation stage, 2) the development of hypotheses and search strategy stage, 3) the investigation stage comprised of trace search and collection, and 4) the completing the investigation stage consisting of the evaluation and preliminary findings. In reality, the CSIs' answers about their approaches at each stage were less distinct as they touched upon different aspects of their reasoning and decision-making process during the interviews.

Table 3
Overall & Top Traces.

A) Overall Traces		B) Top Traces	
Trace	Frequency	Trace	Frequency
zip tie	24	zip tie	23
gloves	23	gloves	17
duct tape	19	duct tape	14
door keys	18	blood bathroom door	10
beer bottles	17	blood bedroom	8

Tables displaying the frequencies of A) the top five most commonly mentioned traces overall and B) the top five most commonly mentioned "Top Traces" by CSIs.

3.3. STAGE 1: Information gathering and orientation

3.3.1. CSI utilized a variety of information-gathering strategies before entering the scene

CSIs were first asked about what kind of information they preferred to have and what information they tried to avoid prior to investigating a scene. Overall, most CSIs welcomed prior information because it helped inform their expectations about the crime scene investigation. Information about the victim was almost unanimously agreed upon as important information (n = 24). All but one CSI mentioned that they would like to have information about the victim (e.g., the extent of his injuries) prior to investigating.

CSIs also frequently requested information about the urgency or complexity of the crime scene investigation to efficiently manage the investigation (n = 20). For CSIs responsible for attending crime scenes over large areas of land, knowing the urgency of the investigation was critical for planning departure and arrival times and predicting how traces at the crime scene might change over time. Similarly, knowing the complexity of the scene helped them determine if they needed additional help from experts like bloodstain pattern analysts or from advanced technology (for example, 3D imaging technology) not traditionally kept in their standard inventory.

While most CSIs welcomed additional information to help inform their expectations prior to arrival, this was not necessarily true for three CSIs from one specific country. These CSIs repeatedly emphasized they wanted "just enough" but not "too much" information upon arrival to the crime scene. According to them, too much information could bias their thoughts and interfere with an objective investigation.

> *"Just because we don't… We don't we don't want to be affected. We want to make… do an objective investigation." -#18*
> *"The first step is to… let the crime scene speak to you. And after that, you can take a step backwards, and then you can get information afterwards to make a new search for new traces." -#17*

When these CSIs were asked to explain the difference between "just enough" and "too much" information, they struggled to provide specific example and admitted that they themselves could not distinguish them.

> *"We don't want to know too much, but some basic information, anyhow." -#18*
> *"Specifically did not want… I don't know really… You have to always be careful with the information you get from victims. And try not to confirm their story… Specific information that we don't want, I don't know what really, I don't have an answer for that." -#18*
> *"I can get some information. They can say and there is some information that this room is a hiding place for a gun then, of course…. but as little information as possible, but so much so I can do my job good." -#16*

3.3.2. Initial walkthrough and orientation varied by CSI

Upon arrival at the crime scene, CSIs are expected to make an initial walkthrough to determine the best walking route and identify any areas of interest or of priority. Many CSIs agreed that they would prioritize vulnerable traces outside the apartment before searching inside the apartment. Locations with traces that could easily degrade due to inclement weather would be addressed first, either by placing a protective tarp over the traces or by immediately collecting them. Once prioritized locations were handled, CSIs walked through the scene to search for a potential entry or exit point. If the CSI had knowledge that a victim, dead or alive, were still on the crime scene, all CSIs agreed that the victim would need to be removed before the investigation to begin. For some CSIs, this decision is at the request of the head police officer. For others, CSIs prioritized the victim to help colleagues in emergency services begin their work. By removing the victim from the scene and having EMS personnel leave, CSIs believed they could reduce the

probability of further contamination.

After dealing with prioritized locations and establishing endpoints for their search, CSIs further oriented themselves by trying to determine what is "normal" for the scene. By discerning "normal" from "abnormal" scene appearances, CSIs hoped they could more easily distinguish between crime and noncrime-related activities. CSIs who collected information during the information gathering stage were more comfortable asking others (e.g., witnesses, police officers, etc.) about the "normal" status of the scene. Some CSIs were willing to seek out additional information for their orientation. For instance, they proposed talking to the victim to ask what might have been moved or altered. The CSIs that resisted collecting contextual information consequently exclusively relied on their own reading and interpretation of the scene and their prior experience to distinguish between "normal" and "abnormal" appearances.

> *"**#17:** When I come into a place, just the first thing I want to see is… what's the normal… Can I see what's the normal state in the room? What is behind the normal area? Does it look like this normal time or not? If the answer's no, then it catches my interest and I want to look further to see if the perpetrator has been touching or made some activities in that area.*
> ***Interviewer:** How do you know what looks normal if you don't have like information from those people?*
> ***#17:** It takes some time. You have to see, you have to go and look at the place in every room to see how it's built up. The normal state for me is not the normal state for you, for example. And you have to read the place to see what is the type of man living here. You can't decide that in just a moment. Take some time to do that."*

Regardless of the exact path they took, all CSIs stated that they would visit every room at a crime scene. How they identified which rooms to search first, however, varied based on the individual leading the investigation.

3.4. STAGE 2: Development of hypotheses and a search strategy

3.4.1. Prior experience, knowledge of offender behavior, and related traces influence the search for relevant traces

When CSIs started talking about their initial observations and thoughts, they seemed to construct hypotheses about what activities could have occurred and use these hypotheses to develop a search strategy. From our interviews, we observed two hypothesis forming styles. One strategy was to use more general observations (such as identifying possible entry points) to start imagining different offender behaviors (i.e., "think like the offender" (#20)) and develop hypotheses about which activities might have occurred. As these CSIs examined each room, they would "think out loud" and discuss potential actions that might have occurred and what kind of traces they would expect to find.

> "*They're offenders, they're not necessarily like us, they're not just going to go and knock on the door and see if the doors open, or they're not just going to go and check a window. Like, they might climb through the dog door, or they might pull the slats off this or they might try to go down the chimney, or they might do you know, X, Y, Z," -#20*
> *"Yeah, but when someone climbs through a window, just visualize when you stand in front of the window, just visualize how someone would get in. Where does he put his hands to climb in? Now, and that's where you look for fingerprints." –#12*

Another strategy was to use the specific observation of an abnormality (first observed during the walkthrough stage) to start hypothesis formation. When CSIs observed an abnormality, they attempted to provide an explanation (in the form of a hypothesis), and the explanation was often guided by CSI knowledge about possible offender actions. For example, five CSIs mentioned that they would search the front door of the apartment because it looked unexpectedly undisturbed. Instead of seeing pry marks or footmarks which they might expect for a robbery, these CSIs hypothesized that the keys left in the door indicated that the offender entered without force. Sometimes hypothesis formation was straightforward. For example, CSIs could confidently hypothesize that a large bloodstain on a wall in an otherwise clean room likely indicated that a crime-related act (e.g., assault) took place in the room. Other times, CSIs were less confident in their hypothesis formation. For example, CSIs might have theorized that opened drawers and cabinets and clothes scattered around the floor indicated that an offender searched a room, or they could have speculated that the homeowner lived in a disorganized house.

According to the hypothetico-deductive reasoning model as discussed in the introduction, CSIs can next develop a search strategy based on their hypotheses. In the results, however, we observed a less structured approach. Instead of constructing the search strategy following from the considered hypotheses and expected traces, some CSIs just preferred to begin their search in areas which they perceived the most activity occurred or "where the most energy was released" (#5). In contrast, two CSIs shared entirely different perspectives relative to their peers. One CSI (#25) stated that, in contrast to starting where the main activity occurred, she liked to start in the rooms that seem untouched or possibly unrelated to the offense. By adopting this "reverse" approach style and searching for more difficult-to-find potentially ambiguous traces before searching for the "obvious" crime-related traces, she believed that she could investigate more efficiently before becoming fatigued after multiple hours of investigation. Three CSIs mentioned searching for traces located on materials, compositions, and surface textures conducive to holding traces well.

3.5. STAGE 3: Investigation: Search and collection

3.5.1. CSIs collected traces based on forensic knowledge and personal goals

In addition to CSIs discussing different search strategies, CSIs mentioned executing different collection strategies during the interviews. As our research focused more on the CSI's theoretical search approach, we did not ask CSIs to explain their practical search on the scene (i.e., the tools involved). One of the collection strategies discussed was based on expected success rates of traces. For example, from years of experience, CSIs learned that collecting useful (i.e., analyzable) fingerprints on wooden cabinets would be more difficult than attempting to collect the same traces on smooth surfaces like laminated kitchen counters. Ten CSIs explained that they collected traces that they could use to either connect an offender to the scene, identify a possible suspect, or help eliminate noncrime-related individuals such as police officers or first responders. Lastly, a few CSIs mentioned that they would collect a trace if they knew it could help achieve other long-term goals such as enhance forensic intelligence or link cases, however during the mock scene this behavior was not observed. One CSI (#11) explained that her collection of traces was based on the trace's expected quality. In other words, the collection of a few high-quality DNA traces could mitigate the need to collect additional traces, while having many low-quality DNA traces was considered insufficient and would benefit from the collection of other traces. Collectively, these findings demonstrate the variety of ways CSIs collect traces.

Despite CSIs claiming to have different standards for which traces they were willing to search for and collect, we observed that many CSIs still explained they should collect as many traces as possible. CSIs who preferred to over collect traces were extremely aware that the crime scene investigation is only the first step in a long-term investigation, so they wanted to have extra traces as backups for re-running analyses. CSI #24 summarized his unit's general approach to collection as "overkill is our specialty" because "if you don't collect it, you don't have it." Agreeing with this logic, six CSIs acknowledged that the crime scene is only temporary and that "once you leave the scene, you're not likely going back" (#20). Similarly, four CSIs acknowledged that they often work with limited information, so they preferred to collect extra traces in case new information appeared later and turned a seemingly

irrelevant trace into a relevant one. Lastly, CSI #25 explained that collecting extra traces is sometimes a precautionary measure for when she later testifies in court. She preferred to collect more rather than less to feel prepared to defend herself against any questioning by the prosecutor.

3.6. STAGE 4: Completing the investigation: Evaluation and preliminary findings

3.6.1. CSIs evaluated their investigation's progress based on a variety of different aspects

With multiple traces collected, CSIs can next evaluate the status of their investigation to determine whether their work at the scene is completed (i.e., if they collected sufficient traces, or if they successfully executed their search strategy). During the interview, CSIs were asked, "how do you know when you've collected 'enough' traces?" This question intended to explore which, if any, criteria exist to help a CSI determine when an investigation is complete. While the overwhelming response to this question was "you never know," we observed CSIs adopting multiple strategies for evaluating their overall progress. A commonly expressed opinion was that the quality of the traces mattered more than the quantity of traces when assessing an investigation's completeness. For example, CSIs #21 and #6 judged an investigation's completeness by their traces' ability to add value to the investigation. For these CSIs, an investigation could be finished if their traces could answer "most of the question[s] that may arise from [the] investigation" (#6) or "actually add value to the investigation" (#21). Further, one group (n = 4) mentioned evaluating their progress based on whether their collected traces could aid in hypothesis testing. CSIs #10, #11, and #15 claimed that they evaluated the investigation based on their collected traces' evidentiary value. Lastly, CSI #19, aware of his company's policy that traces from non-portable DNA items were of higher probative value than those from portable DNA items, explained that his investigation's progress was closely determined by his collection of traces with high probative value.

In contrast, another group of CSIs (n = 4) evaluated their investigation's completeness based their ability to satisfy their superior's needs. CSIs explained that they would adopt whatever role the lead investigator desired at the time. By knowing their precise role at the crime scene as early in the investigation as possible (e.g., were they being requested to find a perpetrator, test whether a suspect could have committed the crime, or answer a specific question?), CSIs could more clearly identify when they had completed their assignment.

> *"Once I've done all my collection, and my notes and everything, I'll always go back over and just have another walkthrough at the end, and just put… you know, try and put my scenario head on and where they potentially walked in, and, and what they potentially touched just to make sure I've covered off on everything. So it's sort of comes down to the individual examiner and in discussion with the investigator, you will go through exactly what you've done, what you've collected, if they've got any further information, if they've got a suspect in custody, and they're getting further information, we can go back and revisit some areas that we may not have looked at before." – #1*

These examples show the variety of roles CSIs can adopt when conducting an investigation.

4. Discussion

Crime scene investigations require complex decision making. With limited guidelines on how to conduct an investigation, one CSI's decisions may differ from those of another. By interviewing CSIs from nine countries, this study revealed differences and similarities that exist in crime scene investigations from an international perspective. While differences in investigation approaches exist, they are not always linked to one specific country. CSIs expressed using a handful of similar strategies, however, they preferred different strategies when it came to gathering and incorporating information and searching for, collecting, and evaluating traces. Overall, this study revealed that there is no consistent approach for violent robbery investigations, and several factors seem to play a role in the achieved outcome of the investigation.

4.1. Hypothetico-deductive thinking – Structure is required to be guided through this reasoning process

This study revealed differences in how hypotheses are created and how search strategies are defined. Although all CSIs started with a first walkthrough at the scene to distinguish between "normal" and "abnormal" situations, they differed in how they constructed hypotheses and determined their plan of approach. One strategy used more general observations to start imagining different ways of offender behavior, while another strategy was mainly driven by explaining "abnormal" observations at the scene. Also, the link between constructed hypotheses, expected traces, and search strategy was not always explicit as some CSIs explicated more general considerations, such as starting where most or least energy was released. In our opinion, both hypothesis-forming strategies should be combined to obtain a complete overview of relevant hypotheses that can be investigated by a more detailed search at the scene. However, how to effectively combine these reasoning processes to create relevant investigable hypotheses needs further attention.

Furthermore, CSIs acknowledged that they might need to readjust their scenario based on the traces they find or new information they receive. While this open-mindedness sounds ideal, current literature focusing on crime scene investigator behavior makes us question whether CSIs incorporate this flexibility in practice. In general, CSIs mentioned the importance of keeping an open mind to potential scenarios that could have occurred, however previous studies have observed more narrow-minded thinking [6,8,17–19,42,43].

In addition to what literature suggests about a CSI's narrow-minded thinking, we observed many CSIs focused on offender traces during our mock scene. However, CSIs found multiple ambiguous traces interesting during their investigation (e.g., the gloves, the beer bottles, and the door keys). These ambiguous traces were less commonly selected as a "Top Trace" when CSIs were restricted to selecting only five traces. Rather, more obviously crime-related traces (e.g., the red stains) were chosen. Instead of focusing on ambiguous traces, CSIs focused on a particular type of trace that, from prior experience, they expected to have a higher chance to identify a perpetrator. By restricting the analysis resources available to CSIs, relevant information for reconstruction and intelligence purposes may be missed. This was also shown by research of de Gruijter and colleagues. CSIs that were driven by efficiency had a greater offender-oriented focus compared to those more driven by quality [17]. Additionally, as CSIs did not say that they would use the traces to disprove any information previously gathered, determine whether their scene reconstruction was accurate, or consider readjusting their current scenarios, we question the degree to which open-minded thinking takes place during an investigation.

Given the complexity of CSI decision making and the lack of guidance through a hypothetico-deductive approach as described by Baechler and colleagues [1], a more methodological framework to assist in their decision making seems essential. For example, by requiring a CSI to initially write down multiple potential scenarios or hypotheses describing what might have happened and then list traces that could confirm or disconfirm each scenario or hypothesis, CSIs can be guided through a hypothetico-deductive approach. However, future studies are necessary to investigate the best way to guide CSIs in this cyclic, systematic, and scientific approach.

4.2. Knowledge and expertise – CSIs must draw on different types of knowledge and could benefit from outside expertise

By following CSIs' decision-making processes, we recognized different types of knowledge on which CSIs must draw, and these dimensions corresponded with the knowledge dimensions first suggested by Ribaux and colleagues [24] and later elaborated on by Delémont and colleagues [2]. First, knowledge on criminal background, or in this case, intelligence awareness of traces, seems to influence a CSI's general practice. During the interviews, some CSIs stated that they focused on traces directly related to the current case, while others stated that they collected more traces to enhance forensic intelligence and link cases. Delémont and colleagues described how information about current criminal trends or series of crime can assist CSIs in their search strategy at the scene, and conversely, how CSIs can use traces to shed light on new aspects of the criminal activity or a criminal phenomenon [2].

Although the participating CSIs did not explicitly state that they would use intelligence about current criminal trends or series of crimes to determine their search strategy, some CSIs stated that they considered traces for their potential to add value and enhance forensic intelligence. According to Bitzer and colleagues, both methods of trace selection (i.e., selecting traces for the current case or selecting traces for intelligence purposes) are advantageous [44]. Bitzer and colleagues defined the utility of a clue as the "added value of information" (p. 509) [44]. One may argue that a CSI's awareness of intelligence also depends on more strategic factors (corresponding to Delémont and colleagues' strategic dimension), such as the resources available and the degree of efficiency desired [2].

Secondly, corresponding to the dimension of situational analysis, the interviews show that CSIs draw on their own knowledge and experience when distinguishing "normal" from "abnormal" situations during the initial walkthrough or by thinking like an offender when constructing hypotheses. As also discussed by Delémont and colleagues, CSIs use this knowledge to determine what might have been touched by the offender during the crime [2]. In addition to using one's own experiences and any available external sources of information and/or intelligence, CSIs could benefit from working with or learning from criminologists and investigative psychologists who have more scientific knowledge on offender and/or victim behavior than CSIs alone possess [33]. A recent study showed the potential benefits of incorporating the perspective of an investigative psychologist at the crime scene [19]. These experts could collaborate with CSIs to support CSIs in this knowledge dimension of situation analysis by considering relevant scenarios and pointing out relevant areas of interest for searching for traces.

Lastly, we recognized CSIs using knowledge on the technical aspect of the traces (also referred to as the physical environment dimension). For example, CSIs considered expected success rates of traces in their decision to collect a trace or not. Although not explicitly mentioned by the participants, CSIs must make an estimate of the transfer, prevalence, persistence and recovery of traces when considering potential traces at the crime scene. As this specialist knowledge is not always known by CSIs, we believe that this kind of knowledge should become more easily available for CSIs during their investigation. Moreover, given that CSIs have been shown to inaccurately estimate success rates of traces [25], having a third party of experts in trace dynamics and being able to access data on success rates of traces could significantly improve the chance of finding and collecting the most relevant and highest quality traces.

Pinpointing the types of knowledge and information that is beneficial for an effective crime scene investigation emphasizes the variety of knowledge a CSI should have. As the possession of such expansive knowledge is difficult for a single CSI to manage, the availability of outside expertise and knowledge systems would be helpful for CSIs. Furthermore, intelligence based on trace information could contribute to the ongoing development of these knowledge systems [2,20,24,45].

4.3. Use of information – Just enough to do my job?

To ensure consideration of relevant offender actions and traces, CSIs can make use of external knowledge from victims, witnesses or communication technologies, such as CCTV footage or smartphones. While CSIs debated whether such context information had a positive or negative effect on their decision making, it was apparent that information influenced their expectations and interpretations. Prior information gathered during Stage 1 was used to create expectations about the scene and its potential traces, to distinguish between the normal and abnormal situations at the scene, and to determine the relevance of ambiguous traces (such as the presence of the gloves). CSIs of one country emphasized the use of as little information as possible, "just enough" to complete the job.

These results reflect the debate around the necessity and/or risk of using context information, with some researchers proposing to start an investigation without any information and gradually incorporating relevant context information to avoid bias [46–48], and other researchers advocating to use context information and intelligence to frame the search and detection of traces [2,20,24,45].

The results and mentioned literature show how information or, more broadly, intelligence, can assist CSIs in their decision-making process. Without information, it is difficult to identify abnormalities, determine the relevance of traces, construct all relevant hypotheses, and identify potential serial crimes. However, we should also not neglect the possible biasing effect of information on CSI decision making [7,16–18,30,42]. Currently, the provision and use of information is unstructured [29,49]. It is therefore important to create guidelines that describe how to use information responsibly and effectively throughout the reasoning process and to develop a method where critical thinking is encouraged to mitigate potential harmful effects of cognitive bias. Linear Sequential Unmasking Expanded (LSU-E) is an example of a suggested method where potentially biasing context information is withheld from CSIs at the start of their investigation. It is known as the process of gradually revealing context information to the examiner from least to most potentially biasing only after the first walkthrough at the scene and writing down a first impression [47,48]. Of course, LSU-E may help minimize bias in the decision maker, but it does not consider the potential benefits of receiving information before the orientation stage, and it does not assist CSIs in *how* to use it in the crime scene investigation process.

Taken together, CSIs can have different ways of reasoning and consequently make different decisions. Thus, it is crucial to make the investigation more traceable. Multiple stakeholders throughout the criminal justice system use forensic evidence in their daily tasks – from police detectives developing a case to judges determining evidence admissibility and its probative value in court. Furthermore, transparency is necessary to increase our understanding of CSI decision making and embracing a dialogue between CSIs and other actors about effective and ineffective decision making [3].

4.4. Limitations

This study aimed to uncover how crime scene investigations are approached by CSIs from nine countries around the world. One limitation of this study is the limited number of countries and CSI participants that were interviewed. Relatedly, CSI recruitment by way of referral from forensic science researchers is a potential limitation as the researchers acted as "gatekeepers" and purposely referred to us CSIs that conducted investigations in a certain way. An additional limitation was the use of a fictitious vignette because a virtual mock crime scene is not equivalent to examining a real crime scene in-person. As a result, CSI responses may not have accurately experienced the same thought processes that would occur during a real, in-person investigation. While this study has showcased the many ways in which investigative approaches may vary, it is by no means exhaustive. This study is not intended to

appear as complete or representative for a particular country or region. Moreover, studies have shown that differences in CSI decision making already exist within a country [6,16,29,42] which was also seen in this study. Rather, it serves as a preliminary study to confirm that differences do indeed exist between crime scene investigations, and these differences warrant further attention. Despite these limitations, we were able to identify different preferences for investigative strategies. The identified strategies at each stage may help in the further development of an effective and practical approach for crime scene investigations.

5. Conclusion

Crime scenes are complex environments where CSIs face complex decisions and reasoning processes, and as these results show, there is no consistent approach for violent robbery investigations. This study provided insights into factors that vary between CSIs and can impact the outcome of the investigation. Crucial aspects of effective crime scene investigations are (1) the consideration of relevant hypotheses and (2) the search for and (3) collection of traces that can differentiate between these hypotheses and provide information for the further investigation. The way prior information is or is not used, the available knowledge and experience of the CSI, and the perceived goal of the investigation may, among other factors, influence these aspects. We argue that more practical tools should be developed to aid CSIs in their decision-making processes, especially in complex and ambiguous cases. Moreover, development of decision-support tools could maximize a certain level of systematism and standardization, thus making the investigation more robust. Being the first phase of the forensic process, crime scene investigations must be mindfully executed so that their results (i.e., the hypotheses and scenarios created, the hypotheses tested, and the traces collected) can be effectively used in forensic laboratories, as evidence in court settings, or contribute to intelligence. If we can develop tools that aid CSIs in a hypothetico-deductive reasoning process, integrate outside knowledge and expertise into this process, and broaden our view regarding the potential contributions of crime scene investigations, it is only then that the crime scene investigation can serve the criminal justice system to its full potential.

Ethical statement

As this research did not involve medical research involving human subjects, we do not believe an ethical statement is required. All participants read and agreed to an informed consent form prior to participating (available upon request). This consent form also permitted the authors to use direct quotes from the CSIs' interviews for publication.

CRediT authorship contribution statement

Anna S. Knes: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Madeleine de Gruijter:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision. **Matthijs C. Zuidberg:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision. **Christianne J. de Poot:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank all the participants for their time and useful insights into their CSI decision making. We also thank the anonymous reviewers for their thoughtful and helpful comments.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scijus.2023.11.009.

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