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CHAPTER 1

GENERAL INTRODUCTION

The 18th of May at 2.30 AM. Roger's neighbours hear a cry of pain and noise coming from his home. A 32-year-old single man, Roger, is not seen in the days that follow, and the neighbours warn the police two days later. Police officers find Roger lying on his living room floor, dead. Police detectives decide to call their crime scene investigation department for assistance. Two crime scene investigators (CSIs) go to the scene of the crime, where they collect information about the situation from police detectives. Some of the information that detectives provide them with is that the living room was a mess, though the bedroom seemed untouched. A witness had seen a man with dark short hair running away on the night the noise was heard. After gathering this information, the CSIs enter the crime scene and start with a general observation of the scene. They then begin considering explanations for what they observed at the crime scene. The living room and kitchen are a complete mess: bloodstains, a knocked-over chair, open drawers, a yellow scarf on the floor and lots of glasses and bottles scattered everywhere. The CSIs have to decide which traces are possibly connected to the crime and which might have been left during other events. That is not an easy task, especially because of the chaotic crime scene. During their search at the scene, CSIs discover more evidence and secure quite a few objects and traces: three knives, some of the bloodstains in the living room, 2 hairs, some fingerprints, beer bottles, glasses and coffee cups, a tissue with blood, cigarettes, two laptops and two mobile phones. The window in the kitchen is broken and the investigators find something that looks like drugs under a table. The body is sent to the pathologist for an autopsy. Once back at the police station, the CSIs have to select, in consultation with others, a subset of the secured traces for analysis. Some traces can be analysed by the police, while others are sent to a forensic institute. The CSIs select two hairs, some fingerprints, two bloodstains and some cigarettes for analysis. They also decide to have the laptops analysed. The CSIs suspect that these traces will provide information about the crime.

1.1 Introduction

Forensic investigations are part of an overall police investigation and are used to obtain information about the actions that have taken place at the scene of a crime and the individuals involved in those actions. As a result of various technological advances, forensic information is becoming more important in criminal investigations. Moreover, advanced mobile technology is causing a shift in the current traditional criminal investigation process (Kloosterman et al., 2015). The analysis of trace material is currently primarily performed at a laboratory, but several technological developments will bring

this laboratory work to the crime scene. As a result, the findings of forensic analyses will become available at an earlier stage in the investigation, and crime scene investigations will become more prominent within the investigation process. For example, the development of a spectral camera that can be used to detect blood on visually problematic places such as dark surfaces seems to be a promising development (Edelman & Aalders, 2017; Edelman, Van Leeuwen, & Aalders, 2015). Such a tool will allow crime scene investigators (CSIs) to detect blood traces and to determine immediately whether a red trace is a bloodstain or red lipstick without touching it. It especially facilitates CSIs in the search for bloodstains on dark surfaces; places where blood is difficult to detect with the naked eye. The camera can also provide an indication of how long ago the bloodstain was left there. CSIs can then establish the relevance of such a bloodstain, distinguishing between blood that was left during the crime and blood that must have been left there either before or after the crime. Furthermore, the current analysis procedures and provision of results, which can currently take weeks or even months, can be sped up due to mobile equipment (Kloosterman et al., 2015; Mapes, Kloosterman, & De Poot, 2015; Strom & Hickman, 2010). For example, the screening and analysis of drugs can be done with mobile equipment in a short time period (Kloosterman et al., 2015). Similarly, "lab on a chip" technologies enable a rapid analysis of biological traces at the crime scene (Butler, 2015; Jovanovich et al., 2015; Turingan et al., 2016). With the use of mobile DNA technology, DNA-profiles can be obtained on the spot. Such a profile can then immediately be compared with the DNA-database, and investigators can be notified of a match while still at the crime scene. A similar technology has been developed for fingerprints (Kurpershoek, 2009). So, instead of the present practice of waiting for analysis and comparison results for days or even weeks, these results can be returned in the midst of the investigation itself. Such developments offer new opportunities to distinguish between traces and to quickly identify suspects, and forensic information can be incorporated at the start of an ongoing police investigation.

However, besides the positive effects outlined above, we should be aware that these new developments can also create new risks and fresh dilemmas. The availability of new technologies and rapid analysis results can affect the way CSIs operate at a crime scene. Seen from a psychological perspective, it can influence their goals and expectations and hence also their observations, interpretations and their decisions. Several cognitive processes interfere with an objective examination of crime scene information and analysis results (Chun & Wolfe, 2008; Heuer, 1999; Nickerson, 1998; Nisbett & Ross, 1980). Biased interpretations of identification information can have serious effects for individuals related to the crime scene, with, possibly, far-reaching consequences if biased interpretations are made about their role in a crime, possibly even resulting in unfair

punishment, or, on the other hand, to the unjustified conclusion that they are not the perpetrator. Before a suspect can be identified based on trace material, CSIs need to (1) *observe* the traces left by the offender, (2) correctly *differentiate between crime-related and unrelated traces*, (3) *secure* these traces and (4) *select* them for analysis and, finally, (5) correctly *interpret* the identification information. The introduction of mobile technology at the crime scene may influence the way information at the crime scene is processed during these activities and may subsequently influence the outcome of a crime scene investigation and the overall police investigation. The aim of this study is therefore to investigate the influence of rapid identification technology, identifying blood or characteristics of individuals such as fingerprints and DNA, on the way information is observed and processed during the different phases of a crime scene investigation. The next section describes the crime scene investigation process, followed by the cognitive processes that influence the way information at the crime scene is processed by CSIs. This will demonstrate the complexity with which CSIs are and will continue to be confronted.

1.2 Definitions

Throughout this dissertation, the term *traces* is used to refer to all types of trace and items at the crime scene possibly related with the crime under investigation, and can be collected and removed from the crime scene for scientific analysis and/or potential use as evidence. For convenience, the term *DNA traces* is used to refer to human biological material that could contain DNA material. *Hypotheses or inferences* refer to explanations for a specific trace or observation and the term *scenario* refers to narratives that explain the entire crime scene. The term *identification information* or *ID information* is used for the results produced by DNA or fingerprint analysis. Fingermarks or fingerprints refer to prints found at the crime scene and are used interchangeably. Fingerprints can also refer to prints used as reference material for the analysis of traces.

1.3 Forensic investigations

Within criminal investigations, the task of the crime scene investigation department is to find, register and secure physical traces at the scene of the crime and to analyse them or have them analysed by a forensic institution. A crime scene contains information on the actions, or *modus operandi*, of the offender and the crime that has been committed.

Individuals can leave all kinds of traces that reveal information about their actions: shoeprints, ear prints, traces of breaking and entering, fingerprints, bitemarks, biological material, handwriting, etcetera (Broeders & Muller, 2008; Van Amelsvoort & Groenendal, 2013). The task of CSIs is to find and select those traces that provide information about the crime. Obtained trace information is then used for the reconstruction of the alleged crime, to test other lines of evidence such as suspect- or witness statements, and it ultimately may serve as sound and relevant evidence in the judicial process (Gardner, 2012; Inman & Rudin, 2001).

In the Netherlands, crime scene investigation is divided into four phases: an orientation phase (1), a phase in which a plan of approach is created (2), forensic examination in which traces are collected (3), and a final round after which preliminary results are formulated (4) (Van Amelsvoort & Groenendaal, 2013). Dutch rules in this respect are in line with guidelines in international handbooks that instruct CSIs to use phases or steps to structure the crime scene investigation, so as to minimise the chance of missing important traces (Gardner, 2012; Weston & Lushbaugh, 2009). CSIs have to construct scenarios about what may have happened based on what they perceived during the orientation phase at the crime scene and contextual information about the event, such as any information about the victim or any witness statements. These scenarios serve as guidance for the recognition and selection of relevant traces and are, if necessary, adjusted based on new information (De Poot, 2011; Delémont, Lock, & Ribaux, 2014; Inman & Rudin, 2001). This is an ongoing dynamic process until CSIs think they have observed and secured all relevant traces. After the investigation at the crime scene, part of the secured traces is selected for analysis at the police laboratory or at an external forensic institute. When a trace can be compared with reference material, forensic experts make judgments about the extent to which the trace matches the reference material (Broeders & Muller, 2008). Once analysed, information will become available about the potential source of the trace, and the scenarios CSIs constructed at the crime scene can then be tested with the analysis results. Figure 1.1 shows the current steps in a forensic investigation from observation of traces at the scene until the verification of scenarios based on analysis results, and a simplification of the interaction at the crime scene between the search for traces and scenario construction.

So, forensic information contributes to the overall goal of the forensic investigation, which is, according to Broeders (2008), *"answering questions that can contribute to the reconstruction of an often complex (series) of event(s), that tries to approach the actual state of affairs of (alleged) offence as accurately as required for the purposes of justice"* (p. 48). The complexity of the investigation is due to the fact that we have no knowledge about the exact conditions that influenced the event and that determined the physical

consequences of the event. For that reason, it is by no means straightforward for CSIs to classify traces as either related or unrelated to the crime. It is for the CSIs to determine which traces are related. It requires creativity and imagination to figure out how traces are or may be associated, to consider possible explanations, and to differentiate between crime-related and unrelated traces. There will never be just one unique series of events that explains the traces, which means that CSIs can treat traces that are unrelated as related, while relevant traces may be overlooked. These decisions depend on the interpretation of the perceived crime scene, the scenarios CSIs consider based on their observations, their experiential knowledge and the routines learned during their training (De Poot, 2011; Inman & Rudin, 2001).

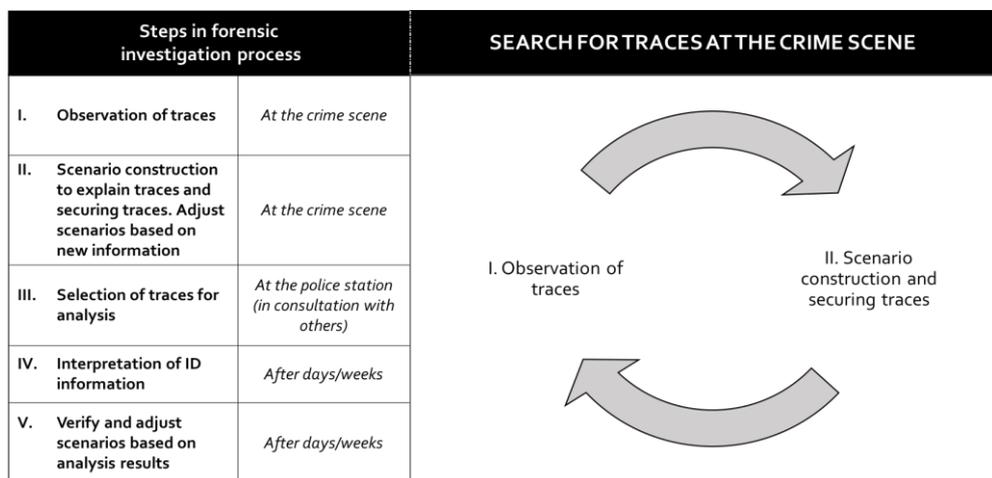


Figure 1.1: the current steps of a forensic investigation and a simplification of the interaction at the crime scene between the search for traces and scenario construction.

The necessity and influence of such contextual information can be illustrated with reference to the open drawers observed by CSIs at the crime scene of Roger’s murder. Without context, they are simply open drawers, so they should be assigned some meaning. Based on their experience and knowledge regarding criminal behaviour, CSIs consider the possibility that the offender searched for something and therefore opened the drawers. In that case, the offender could have left traces while searching the drawers; the drawers are then important objects. However, new incoming information can change the relevance of traces. Suppose CSIs receive information that the victim had been looking for his watch in the drawers before he was attacked. The drawers would then become less important and probably only the victim’s traces are present on the drawers. Hence, contextual information can influence the relevance of traces and the scenario of

the crime. CSIs should constantly consider the accuracy of information in order to find crime-related traces, which requires considerable cognitive skills. Subsequently, CSIs need to decide which traces need to be analysed to differentiate between multiple scenarios and find the most accurate explanation for the crime scene, and they should think about what information can be used as evidence. In short, investigating a crime scene is more than just simply learning the trick of collecting traces and analysing them; it requires cognitive skills to help overcome the various cognitive challenges with which CSIs are faced. The human aspect is significant during the investigation of the crime scene and the examination of its information. The next section will explain how various cognitive processes can interfere with the objective examination of crime scene information.

1.4 Cognitive processes

A fundamental aspect of human cognition is that we do not passively receive and encode information. People are not objective observers of the world; incoming bottom-up information comes to us from the outside world via sensory input and is processed by complex mental top-down processes that determine which information is attended to, how it is organised and what meaning is attributed to it (Heuer, 1999). The way we perceive and process information is strongly influenced by contextual information, past experience, education, cultural values, motivations, goals and intentions, organisational norms, as well as by the stimuli that are recorded. The lenses through which we perceive the world are known as schemas or mental models. They are distilled of that what we think we know about a subject. Top-down processing is essential since data without interpretation has no meaning such as the open drawers that needed interpretation to determine the relevance of them. Our schemas give guidance in our search for information and help to structure large amounts of data in order to understand a situation quickly (Kahneman, 2012) and to focus on relevant information and ignore irrelevant information (Klein, 1993). Moreover, our minds are not designed to optimise. We have developed a variety of simple decision strategies called heuristics in order to cope with our limited working memory capacity and the complexity of the world (Kahneman & Tversky, 1979). These 'heuristics' are useful in daily life because they enable us to make quick and effective decisions, but they can also mislead us and lead to cognitive bias, i.e. mental errors, in situations where there is insufficient information available (Gigerenzer, Todd, & ABC Research Group, 1999; Kahneman, 2012), as, for example, in police investigations.

There are several studies showing various cognitive phenomena that cause people to lose objectivity. Here we will focus on confirmation bias, belief perseverance and primacy effects, as these phenomena will return in later chapters of this thesis.

The primacy effect means that people tend to assign more weight to information acquired early on in the investigation than to information acquired later (Nickerson, 1998; Tetlock, 1983). Confirmation bias is the common tendency to search for and notice information that confirms an existing idea or meets a belief or a hope. Confirmatory data get high weights and when data quality is low and therefore ambiguous, people will interpret the data in ways that are consistent with their ideas. We tend to ignore or dismiss information that does not fit our ideas and give little weight to it (Klayman, 1995; Nickerson, 1998; Wason, 1968). Belief perseverance refers to the common tendency of people to keep believing in a theory, even when confronted with contrary evidence (Nickerson, 1998; Nisbett & Ross, 1980). These cognitive processes shape the way information is processed, which is an iterative process: the way data are perceived influences the way they are coded and interpreted and this subsequently influences the way new incoming information is perceived, coded and interpreted, and so on.

These cognitive processes, and thus people's decisions and the way information is being processed, can be guided by people's intentions and goals. Goals can be set consciously, when we pursue desired outcomes, but also unconsciously. Social situations and stimuli in the surroundings can activate or prime goals in people's minds outside of their awareness, thereby motivating and guiding them to act in a certain way (Custers & Aarts, 2010).

Information processing is also an important characteristic of criminal investigations. Criminal justice research has adopted the knowledge about cognitive phenomena, and the influence of cognitive processes on the work of police detectives has become a popular area of research. Various studies have revealed the influence of several biases on the investigative process, and cognitive effects can influence decision-making by police detectives in different phases of the investigation (Ask & Granhag, 2005; Eerland & Rassin, 2012; Kassin, Goldstein, & Savitsky, 2003; O'Brien, 2009; Semin & De Poot, 1997). The influence of social goal activation is also demonstrated in context of criminal investigations (Granhag, Rebelius, & Ask, 2011).

Knowledge about cognitive processes is also recognised by the forensic world and research has been conducted on the influence of cognitive processes on the phase after the crime scene investigation, so on the analysis and comparison of traces. The majority of these studies have demonstrated that forensic examiners' observations and judgments may be biased by contextual information, e.g. in fingerprint comparisons (Dror & Charlton, 2006; Dror, Charlton, & Péron, 2006), comparison of DNA-profiles (Dror &

Hampikian, 2011), forensic anthropology (Nakhaeizadeh, Dror, & Morgan, 2014) and odontology (Osborne, Woods, Kieser, & Zajac, 2014).¹

It seems reasonable to assume that the same cognitive processes will be of influence during the crime scene investigation. Nevertheless, no research has been conducted to investigate how these cognitive processes influence CSI decision-making. CSIs are active information processers as they have to observe and interpret incoming data in a complex environment with limited information, time pressure and other external influences. All kinds of factors can trigger specific schemas when CSIs enter a crime scene: experience, contextual information, their motivations, expectations and obvious traces. Understanding the observational and decision-making processes is becoming even more important with the introduction of new technology that can soon be used at the crime scene. This technology will lead to a shift in the current investigative process and may influence what information is observed and the way it is interpreted.

1.5 Mobile technology at the crime scene

Innovative mobile technology makes it possible to transfer the analysis and interpretation process to the crime scene by introducing the technology at or near the scene of the crime. Through the use of mobile technology, results from trace analysis can then be used during the crime scene investigation to decide on the further course of actions in the investigation. This shift allows CSIs to conduct their investigation more according to a hypothetic-deductive model (Roux, Crispino, & Ribaux, 2012). Analysis information will help CSIs make information-based decisions at the crime scene, since, in some cases, this information allows CSIs to distinguish relevant traces from irrelevant traces more easily during the investigation itself. For example, when a spectral camera shows a bloodstain has been left weeks before the crime and subsequently mobile DNA technology shows the stain is from the resident of the house, CSIs can (re)form their scenario. Scenarios can thus be tested at the scene. Based on the verified and, if necessary, adjusted scenarios, CSIs can search for new traces. This possibility creates a cycle of observation, scenario construction and scenario testing that can be repeated until the scenarios cannot be further adjusted based on the traces and analysis possibilities at the crime scene. Of course, additional information will still be necessary to assess the value of a DNA match at the crime scene.

¹ There are also studies that failed to demonstrate the influence of contextual information on the comparison of traces. See for example (Kerstholt et al., 2010; Kerstholt, Paashuis, & Sjerps, 2007).

The generation of identification information from bloodstains or based on DNA or fingerprint analysis at the start of police investigations will cause a shift in the current investigation process. Currently, the results of the analyses can only be interpreted and used within the overall police investigation after they are provided back to the police department. With DNA, for example, a study of Mapes, et al. (2015) showed average turn-around times of 66 days for serious crimes and 44 days for traces in high-volume crimes. Therefore, identification information is now mainly used for verification or falsification of crime scenarios only later on in the ongoing police investigation (Mapes, et al., 2015; Strom & Hickman, 2010). Figure 1.2 shows the shift of the analysis phase from the lab to the crime scene and the integration of the selection and interpretation phase at the crime scene.

Forensic investigation process	Current situation	Future situation	FUTURE CRIME SCENE INVESTIGATION PROCESS
I. Observation of traces	At the crime scene	At the crime scene	
II. Scenario construction to explain traces and securing traces.	At the crime scene	At the crime scene	
III. Selection of traces for analysis	At the police station (in consultation with others)	At the crime scene	
IV. Interpretation of ID information	After days/weeks	At the crime scene	
V. Verify and adjust scenarios based on analysis results	After days/weeks	At the crime scene	

Figure 1.2: current and future forensic investigation processes after the introduction of rapid identification technology at or near the crime scene. The figure shows the cycle of observation, scenario construction and scenario testing.

When rapid identification technology is introduced, this information can become more leading in the overall criminal investigation. This will allow detectives to find a link between a suspect and the crime based on physical traces and hence makes an investigation more crime-directed instead of offender-directed (Crombag, Van Koppen, & Wagenaar, 2006). Scenarios about the crime can be constructed based on crime scene information. An investigation that is built bottom-up, based on information about the crime, like identification information, provides a more secure form of investigating than a top-down investigation where a crime is linked with a potential suspect (Crombag et al., 2006). An example of the latter way of investigating is when an individual becomes a suspect via indirect evidence, like having a motive for the crime that has been committed. A well-known miscarriage of justice in the Netherlands, the Schiedam Park

murder, is an example of such an investigation, where the suspect was chosen based on his possible motive. Although the suspect was not immediately identified in this investigation, he was identified because of a motive and his presence in the park on the day of the crime. From there, the police investigation was focused on finding incriminating evidence, while contradictory evidence was ignored, ultimately leading to a wrongful conviction of the suspect (Van Koppen, 2003). New technologies with which identification information can be obtained at the start of an investigation will provide investigators with more opportunities to search bottom-up for potential suspects.

We conclude that the development of rapid identification techniques, in terms of speed, sounds like a welcome improvement of the current process. However, as explained in the previous section, we should be aware that cognitive processes may interfere with an objective search for and interpretation of information. Incorrect interpretations of traces and the associated identification information can have far-reaching consequences for judgments about individuals and their potential involvement in the crime under investigation.

1.6 Research topics

In this introduction, several cognitive processes that influence the behaviour of CSIs during different stages of an investigation will be discussed, culminating in the research questions for the studies in this dissertation. As CSI behaviour is a neglected area within the field of research, I found a lack of studies to build on. A study has been conducted to determine top attributes of well-performing CSIs, which contributes to a better understanding of who should perform crime scene investigations. It remains unclear, however, how cognitive challenges should be handled (Kelty, Julian, & Robertson, 2011). One of the few studies investigating search strategies by expert CSIs was conducted by Baber and Butler (2012). They explored how novices and expert CSIs investigated two mock crime scenes and found that experts mainly focused on objects that could be used as evidence and thus could contribute to the conviction of the offender. Novices, on the other hand, attempted to reconstruct the event by focusing on objects that could be related with the crime. Although the results give an important first impression of search strategies used by expert CSIs, Baber and Butler do not examine whether all crime-related traces were discovered and how traces were recognised as evidence. It is therefore unclear whether the search behaviour of experts is to be preferred over the behaviour of novices (Baber & Butler, 2012).

Furthermore, handbooks about crime scene investigations describe technical protocols extensively, such as how an investigation should be structured and how traces should be secured to avoid contamination, but any guidelines on how to handle the cognitive challenges just described in the previous paragraphs is lacking (Gardner, 2012; Weston & Lushbaugh, 2009). On the one hand, this is not surprising as the study of decision-making at the crime scene is a complex process, which is difficult to study. The essence of effective research is the comparison of different methods or strategies under identical conditions. This is a problem when it comes to crime scene investigations. Every crime scene is unique and there are lots of external factors influencing CSI behaviour, which makes it extremely difficult to study strategies and overarching cognitive processes (see also De Poot, 2011). Nevertheless, the lack of research is remarkable and it is definitely a shortcoming. Crime scene investigations form a critical element of criminal investigations, as they usually are the start of police investigations and CSIs are the first people involved in making decisions about trace-evidence. Forensic science starts at the crime scene and the decisions made at the scene influence the further police investigation.

In the next sections, I will describe the different phases of an investigation with their associated cognitive challenges and sketch the possible influence of new technology on the way information is being processed. As discussed above, the different phases of observing, selecting and interpreting information constitute an iterative process. Distinguishing phases is, therefore, rather artificial, but necessary in order to explain the cognitive processes underlying the different activities at a crime scene. In that way, I hope to make the complex crime scene investigation process easier to understand and easier to study. General literature on human decision-making is used to make predictions about CSI behaviour at a crime scene. I will initially discuss cognitive processes and the possible influence of technology during the observation of the crime scene and the recognition of traces. This will be followed by an examination of the next phases: the construction of hypotheses and the selection of traces for analysis. Finally, I will discuss the cognitive factors influencing the interpretation of ID information that may result from trace analysis.

I will use the progression of the example outlined at the start of this chapter throughout the paragraphs to illustrate the complexity with which CSIs are confronted during the different phases of a crime scene investigation.

1.7 Phases of crime scene investigation

1.7.1 Phase I - Observation of the scene

A crime scene is full of information: relevant information that is related to the crime and that can be used to reconstruct what has happened, but the scene is also contaminated with irrelevant or even misleading information. Think of the crime scene where the police found Roger. It is full of stimuli (traces), relevant but also irrelevant, that CSIs should perceive. Goals, knowledge and expectations of the CSIs will partly determine what is observed at the crime scene. To create order at the scene of the crime and to be able to reconstruct the crime, CSIs have to focus on important information and try to dismiss unrelated information. Such a selection process starts with a visual screening of the scene during the first observational round at the crime scene. Based on their goals, expectations and experiential knowledge, CSIs will, wittingly and unwittingly, focus on certain stimuli and ignore other stimuli by using an attentional mechanism known as 'visual attention'. Visual attention has two critical effects: it selects behaviourally relevant information and it ignores irrelevant or even interfering information (Chun & Wolfe, 2008), an important process during crime scene investigations. Information can remain unnoticed because it is not seen or it can be seen but not registered as important information because it is beyond our goals or expectations. The availability of rapid identification technology could have an influence on the visual attention of CSIs, as it may change goals, knowledge and expectations.

1.7.1.1 Visual attention

In everyday life, visual attention is generated by both bottom-up factors that reflect sensory stimuli in the environment, and by top-down factors, which are cognitive factors such as knowledge, expectations and current goals. These cognitive factors provide a context in the search for information. Attention is held to be goal-driven when it is controlled by the observer's strategies and intentions. Hence, guided by their goals and by their expectations, the observer's attention is focused on certain aspects of the situation, while other aspects are ignored (Chun & Wolfe, 2008; Yantis, 1998). For instance, if we are searching in a crowd for a friend wearing a green hat, we will notice people wearing green clothes more often, and people wearing clothes made of other colours less often. Attention is held to be stimulus-driven when it is controlled by prominent characteristics of the environment that are not essentially relevant to the observer's intentions and goals. Instead of operating as independent mechanisms, it is an iterative process where both mechanisms complement one another; certain strategies

and expectations influence the observed stimuli and these stimuli trigger certain strategies and expectations and so on (Yantis, 1998).

When goals or expectations of the observer dominate his search, important information that deviates from these expectations may be overlooked. Mack & Rock (1998) showed in several studies that people often miss unexpected objects, even when the object had a unique colour and were visible for quite some time. To describe the results of their studies on the visual perception of unexpected objects, Mack & Rock (1998) introduced the term inattentional blindness. Earlier work had already explored similar failures of awareness under conditions of selective attention. Neisser & Becklen (1975) explored the role of attention in the detection of unexpected events by using a selective tool task. Observers had to focus attention on one of the events shown on a video, for example, a basketball game. Observers often failed to notice an unexpected event occurring during the event they focused on. Simons & Chabris (1999) showed in replications and extensions of this approach that inattentional blindness occurs even when the unexpected object is fully visible in a dynamic display.

Inattentional blindness has not only been demonstrated within lab situations, but it also occurs in expert tasks. In an experiment in which professional radiologists performed a familiar lung nodule detection task, 83% of the radiologists did not see a gorilla that was inserted in the last case. While the gorilla was 48 times larger than the average nodule, they failed to detect it (Drew, Vo, & Wolfe, 2013).

1.7.1.2 Visual attention at the crime scene

Related research within the forensic field has concentrated on the influence of contextual information on the comparison of traces. Trace comparison requires a visual inspection of the trace and reference material. As already mentioned in a previous section, several studies have demonstrated an effect of contextual information on the observations and interpretations made by forensic experts. If forensic experts suspected, based on the contextual information, that two traces originated from the same source, they discovered more similarities between traces and attached more value to these similarities. If they thought these traces had different sources, they observed more differences and attached more value to these differences (Dror & Charlton, 2006; Dror et al., 2006; Dror & Hampikian, 2011). This tendency seems to be present mainly when data are ambiguous and open for multiple interpretations.

Crime scene investigation also requires visual inspection. Surprisingly, there is no research on how to search for relevant information at a crime scene. Handbooks propose systematic approaches, such as walking in circles or lines, that can be used during the search for traces (Gardner, 2012; Van Amelsvoort & Groenendal, 2013). This may

contribute to the registration of more information, but it does not teach us how to recognise crime-related information. Given the observational task of CSIs at the crime scene, it can be expected that CSIs also use their observational mechanism and thus are prone to errors. During their observations, CSIs will then be influenced by the prominent cues that are presented at the crime scene, but at the same time they will be guided by their goals and expectations. The aim of a crime scene investigation is to find traces with which a reconstruction of the crime can be made and to collect evidence that can be used in the judicial process (De Poot, Bokhorst, Van Koppen, & Muller, 2004). To do so, CSIs will start looking for information that can provide them with information about the crime. Many different stimuli may potentially provide this kind of information, e.g. bloodstains, shoe prints, fingerprints, broken glass, but many of these signs may also contaminate their search: in addition to potential offender(s) and victim(s), other people connected with the scene, but not involved in the crime, will have left traces as well. By focusing their attention on crime-related information, CSIs try to recognise relevant information and ignore irrelevant, contaminating information.

Given the visual task at a crime scene, contextual information could influence the search for traces in a similar way as it does with trace comparisons. Before CSIs enter the crime scene, they usually receive information from police officers who have visited the scene and called for the CSIs. For example, officers will give a general description of the situation at the crime scene, discuss the victim and mention any witness statements. Such information, together with experiential knowledge of CSIs, provides a framework that will direct the search for traces at the crime scene. Klein (1993) describes how expert experience gives a heightened situational awareness of which cues are relevant and what information can be ignored. For example, by visiting the same grocery store multiple times, you will become more focused in the search for your groceries, as you will learn where to find the products you want. The same goes for experienced CSIs who have visited multiple crime scenes. CSIs develop schemas based on their experience at crime scenes (Nee & Ward, 2015). They store common characteristics of particular crime scenes and learn where to search for traces.

This strategy is useful when crime scenes share similar characteristics, however, crime scenes will almost never be identical. Some traces, if uncommon, will be far beyond the expectations of CSIs. Consequently, the presence of such extraordinary traces may go unnoticed and important information may be overlooked due to inattentive blindness (Mack & Rock, 1998). CSIs should also keep an open mind and let themselves be guided by the specific characteristics of the scene. The influence of prior information on the search for traces can be illustrated by the Roger murder. As it would emerge weeks after the crime, the CSIs investigating the scene missed a bloodstain in the victim's bedroom.

This stain was beyond the expectations of the CSIs because the police detectives told them that the bedroom looked untouched. This information narrowed their search for traces at the crime scene.

Therefore, both the goal of the observer and his expectations influence the focus of his attention. When the goal of the observer changes, his focus will change accordingly. Like the example of the green hat, once CSIs have the possibility to use mobile rapid technology at the crime scene, their goal may change from finding all kinds of crime-related traces to finding traces suitable for that technology. Other kinds of traces may remain unnoticed. After all, rapid identification technology can provide rapid identification information and could, in the best case, rapidly lead to the identification of a suspect. The use of a spectral camera with which bloodstains can be more easily detected, especially on dark surfaces, and analysed for age, may change CSIs' goals in finding bloodstains and their focus on dark surfaces. A focus on suitable traces for new technologies could lead to higher registrations of such traces, but may also lead to missing other important information and to less attention for the distinction between crime-related and non-related traces.

1.7.2 Phase II - Explanations for the observed traces and securing traces

While observing the scene, CSIs will think of explanations for the observed traces in order to decide on the relevance of these traces. Seeking for explanations is a difficult task which requires reasoning from effect to cause, and it is generally impossible to reconstruct one unique event based on the traces. Given the multiple explanations for traces, multiple scenarios will always exist that fit the crime scene. CSIs need to make use of contextual and their experiential knowledge to determine the potential association between a trace and the crime and should propose hypotheses.

Using contextual and experiential knowledge is a form of top-down processing (Dror & Stoel, 2014). Given the inextricable connection between observing and interpreting information, schemas also influence the interpretation of information. For example, based on expectations and experience with homicides and the traces that are left during these activities, CSIs will have an idea about the potential association between a bloodstain and a crime. Categorization of information can also be influenced by knowledge about the frequency of events, i.e. base rate information (Wagenaar, Crombag, & Israels, 2010). Some crimes are more common than others and have higher prior odds. Knowledge about prior odds can guide the interpretation of a crime scene. However, the same knowledge can also lead to incorrect interpretations. Information is placed into categories and those categories are based on previous experience or stereotypes (Gigerenzer et al., 1999). When CSIs come to an incorrect classification of the

scene and its traces, information may be interpreted incorrectly. At the scene of Roger's murder, the attending CSIs found a scarf. They considered it unrelated because they incorrectly attributed it to a woman and concluded that the witness had seen a man running away.

Eventually, CSIs should create a story encompassing the acts that took place at the scene supported by the evidence. The inferences need to be combined into a coherent and plausible story, explaining all the perceived traces at the crime scene. Pennington & Hastie (1993) describe how jurors created narratives to explain all the available evidence and to find the most plausible explanation. Research into police investigations also show that detectives create narratives to structure all the information (Innes, 2003; Wagenaar, Van Koppen, & Crombag, 1993). CSIs should also construct stories to see the associations between the traces and to give meaning to all the information available (Jamieson, 2004). However, multiple more or less plausible stories will always exist that correspond with the traces and CSIs should try to falsify scenarios based on new incoming information and by selecting traces for analysis. If CSIs visual attention is influenced by the new technology this may have its effect on the explanations for traces, given the recurring cycle of phases.

1.7.3 Phase III - Selection of evidence

Based on the interpretations of traces and in order to distinguish between different scenarios, CSIs have to select traces for analysis. They should select those traces that can provide information about the donors of these traces and hence verify or falsify scenarios. However, cognitive processes may interfere with an objective verification process. Once CSIs become convinced of a scenario, confirmation bias and belief perseverance can come into play and CSIs may ignore disconfirming information and alternative scenarios (Nickerson, 1998; Nisbett & Ross, 1980). Confirmation bias and belief perseverance have a mutual strengthening effect on each other. In criminal investigations, combination of biases is also called tunnel vision (Findley & Scott, 2006; Liedenbaum, De Poot, Van Straalen, & Kouwenberg, 2015). Such biases can also influence information processing at the crime scene: traces may be perceived and interpreted consistent with one most plausible scenario and contradicting traces may be overlooked. During the Roger murder investigation, police detectives told the CSIs prior to their investigation that a witness had seen a man with dark short hair running away. Based on this information, the CSIs considered a scenario with this man as the offender. The dark short hairs they found were consistent with this scenario and were selected for analysis. They did not consider the scarf relevant for analysis since they assumed that the offender was not a woman.

Currently, CSIs collect traces at the crime scene and take them back to the police station. Decisions regarding which traces should be sent in for analysis are taken in consultation with others. Due to limited resources and financial restrictions, traces cannot be analysed limitlessly, so the most relevant traces should be selected. When rapid identification technology allowing person identification is introduced at or near the crime scene, decision-making regarding the selection of traces for analysis is shifted to the crime scene. Such technology may allow CSIs to verify or falsify their scenarios at the crime scene by gaining information about individuals who have left the traces. The fact that technology can be used to identify people may result in an overload of DNA traces or fingerprints for analysis without considering the association between a trace and the crime. CSIs may also become too heavily focused on identifying an individual to link a person with the crime scene. They might also decide to stop analysing traces when they have received a match with an individual in the database.

1.7.4 Phase IV & V - Interpreting person identification information and verification of scenarios

Once traces are analysed with rapid identification techniques, the results can be used to discriminate between hypotheses. Within the current process, identification information cannot be used during the crime scene investigation itself, but only much later in the police investigation. On the one hand, this separation of the processes of selecting, analysing and interpreting interferes with an efficient use of potentially relevant information. On the other hand, separation of these processes also prevents CSIs from the risks of expectation effects that might influence the interpretation of ID information at the crime scene (Dror, Morgan, Rando, & Nakhaeizadeh, 2017).

Contextual information cannot only influence the search for traces, it may also hinder an objective interpretation of their analysis results. Recent research conducted by Van den Eeden and colleagues demonstrated such effects at the crime scene. The researchers asked CSIs to examine the same virtual crime scene. The participants either received prior information indicating suicide, information indicating a violent death, or they received no prior information. This information influenced both the initial and the final judgments of the participants (Van den Eeden, De Poot, & Van Koppen, 2016).

When the analysis of traces and the interpretation of the results are shifted to the crime scene, the interpretation of ID information will take place during the investigation. Contextual information could influence CSIs' interpretations of the ID information in a similar way. The CSIs' most plausible scenario can then influence the way this information is interpreted. This may have consequences for the interpretation of the crime scene, especially for ID information identifying individuals. Once traces are

analysed, hypotheses can be tested with ID information and scenarios can be adjusted, if necessary. However, cognitive processes like confirmation bias and belief perseverance could influence the interpretation of ID information when provided after scenarios are constructed. If one scenario becomes already leading at the start of the investigation, ID information may be interpreted in such a way that it fits this scenario, even when it could very well be seen as suggesting another suspect. After all, convinced of a theory, people wittingly or unwittingly recall only information that supports expectations and hypotheses and have difficulty changing their theory (Klayman, 1995; Nickerson, 1998).

Another risk that may arise when ID information becomes pivotal in the investigation without considering the association between the trace and the crime beforehand is that CSIs may become too heavily focused on the identification itself. In general, people assign more weight to information acquired early on in the investigation than to information acquired later (Nickerson, 1998; Tetlock, 1983). Primacy effects could lead to a dominance of identification information in the formulation of scenarios when provided early in the investigation and could consequently influence the ongoing investigation. Also, ID information may be assigned too much value compared to other pieces of evidence. Research of Granhag, Ask & Rebelius (2008) showed that police trainees who were asked to read a homicide case and then received a piece of evidence that either confirmed or disconfirmed their prior suspicion against the suspect, considered DNA evidence more reliable than witness evidence. The trainees considered the same piece of evidence, e.g. a witness statement, less reliable when it challenged the contradictions against a suspect than when it confirmed suspicions. This effect was shown to a lesser degree for DNA evidence. When rapid identification technologies are introduced and a DNA-match is found in such an early phase of the investigation, it may be assigned great value because of the perceived reliability of forensic evidence. This can be helpful when the identified traces are in fact crime-related and the scenario can thus be supplemented with information about the offender. However, the reverse may occur, too, when the identified traces are not crime-related and CSIs construct a scenario with the wrong person cast as the offender. Such scenarios may become leading in the unfolding investigation, and investigative actions may become too heavily focused on finding incriminating evidence against the person identified through a database-match while neglecting exonerating evidence (Granhag et al., 2008; Kassin et al., 2003; O'Brien, 2009).

This pitfall can be illustrated with Roger's murder. The forensic team found hairs close to Roger and decided to have them analysed. Fortunately, it seemed, the DNA profile obtained from the hairs matched an individual in the database. The detective team was convinced of this individual's guilt; indeed, his traces were found at the crime scene. However, the database match was, unjustly, perceived as the most important

information. The fact that no other evidence confirmed his guilt was neglected. Also, other traces that were collected from the crime scene were not analysed after the match was found. Consequently, important information about the involvement of other individuals was missed. Eventually, it would emerge that this person had had a fight with the victim earlier, but he was not the person who killed Roger. Ultimately, the police found the actual offender who confessed to the murder and told the police he had left his scarf at the scene and had been in the victim's bedroom.

When ID information becomes pivotal in the investigation, CSIs may consequently assign too much value to traces with database-matches, compared to other traces without a database-match. A match provides direct investigative opportunities as it leads to an individual and therefore may evoke a feeling of satisfaction. Fingerprint examiners interviewed by Charlton, Fraser-Mackenzie, & Dror (2010) experienced feelings of joy when they discovered a match. CSIs may experience similar feelings when a match is discovered at the scene. Moreover, a search for possible evidence at the scene, as demonstrated by Baber & Butler (2012), may contribute to an emphasis on database-matches. However, to determine the relevance of traces, the context in which a trace is found is very important. It is not whose DNA is it, but how did it get there (Broeders, 2003). Ideally therefore, whether traces are perceived as relevant should thus not be influenced by the results of a database search too much, too early on. Obviously, when the results show that a trace is left by an innocent witness or by the victim, the results will influence the perceived context of the trace and the relevance of a trace. However, if a CSI expects a trace to be left by the perpetrator, it should not matter whether a match is found with a known person from the database or no match is found. The context of the trace has not changed based on the match. For example, if two possible murder weapons are found at the crime scene and a profile is obtained from one of the weapons that matches a profile in the database, it should not be concluded that this murder weapon is more important than the one not producing a profile with a match in the database.

CSIs goals and intentions can also influence the value that is assigned to traces and matches. Generally, people's behaviour and decisions can be, consciously or unconsciously, guided by their goals and intentions. An example of the influence of the operational context and people's associated intentions is demonstrated by Murrie and colleagues (2013). They asked forensic psychologists and psychiatrists to review the same offender case files by scoring each offender on two risk-assessment instruments. Some of the participants believed they were consulting for the defence while others believed they were consulting for the prosecution. The participants assigned different risk scores to the same offenders, showing that the interpretation of information can be shaped by the perceived goal of a task. Similar influences of goal activation within a criminal

investigation were demonstrated by Granhag et al. (2011). Unconscious activation of different goals influenced the way criminal evidence was processed by criminal investigators. Exposure to norms associated with efficiency led to a reduction of the depth of investigators' processing of the evidence. When CSIs are primed with efficiency norms, they may focus on traces rendering an identification, as these traces can quickly lead to the arrest of suspects, and pay less attention to a thorough reconstruction of the crime.

Subsequently, the way these traces are interpreted will influence the way the crime scene investigation is continued. If a match with an individual in the database is found, CSIs may think they have found the offender and stop the investigation.

1.8 Research questions

The investigation of crime scenes involves interactions between several phases of information processing activities with influence of the human factor. With the introduction of new technology, all phases can take place at the crime scene itself, meaning that CSI behaviour during the different phases of the investigation may be influenced. Hence, the outcome of an investigation in which rapid identification technology is available may deviate from the outcome of such an investigation without the use of these technologies. In this thesis, I therefore attempt to answer the following main research question: *How does the introduction of rapid identification technology at the crime scene influence the behaviour of crime scene investigators during the several phases of a crime scene investigation?* In order to answer this question, I developed three sub-questions about the influence of rapid technology during the different phases (see also figure 1.3):

1. What is the influence of rapid blood and person identification technology on the visual attention of the crime scene investigators?
2. What is the influence of rapid person identification technology on the interpretation of the crime scene, before ID information is provided, and on the selection of traces?
3. What is the influence of rapid person identification information on the interpretation of an ambiguous crime scene?

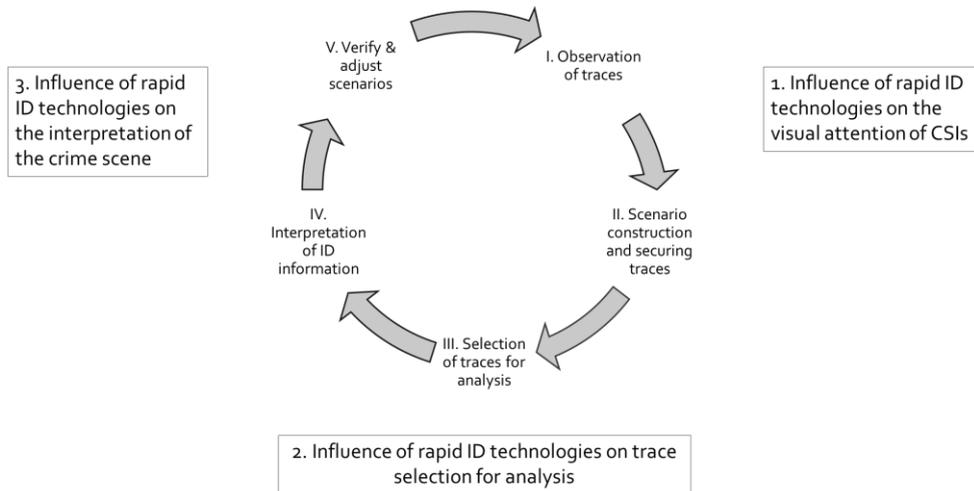


Figure 1.3: The cycle of observation, scenario construction, trace selection and scenario testing with the three sub-questions about the influence of rapid identification technology on the observation, selection and interpretation phase.

1.9 Methods

As we presently have limited knowledge about how CSIs conduct their investigations, observations of CSI behaviour could provide us many new insights about the way crime scene investigations are conducted. Due to the lack of previous studies to build on, I designed two innovative research designs for two different experiments. Unique to these studies is that the ground truth is known, which allows me to test the results of different strategies used during the investigation. Within the first experiment, all phases of the investigation were analysed and an attempt was made to answer all three sub-questions. During the second experiment, the interpretation phase was studied more thoroughly and more data were collected to answer question three, which is investigated under various conditions. However, due to the recurring interaction between different phases, the second experiment also generated information related to the first two sub-questions. I will start with a description of experiment 1.

Experiment 1² – research questions 1-3 In order to study CSI behaviour through all phases of the investigation, we developed an experimental study with a mock crime scene where experienced CSIs could conduct real investigations. This method allowed me to study the similarities and differences in investigative strategies together with the considerations and decisions of CSIs. In addition to the control condition in which CSIs investigated the scene in the traditional way, we developed several experimental conditions. CSIs in experimental conditions had the possibility to use one of a suite of mobile technologies for trace analysis that could generate forensic information during the investigation. Although these technologies are not yet operational as such in daily practice, during the experiment we provided participants with the information they would get by using these technologies. The mock crime scene was created in the CSI-lab of the Netherlands Forensic Institute. Besides the possibility to create a mock crime scene, this lab offers an observational room from which CSIs can be observed when conducting their investigation at the mock crime scene, without them being disturbed. CSIs' behaviour is captured by cameras and microphones at the crime scene. The mock crime scene could be set up identically for each participant and the experimental design permitted me to investigate the influence of the technologies without the confounding influence of external factors that would be present during real-life investigations. To increase the external validity of this study and make the scene as realistic as possible, real crime cases were used as an inspiration for the construction of the mock crime scene, and actual crime scene investigators were asked to conduct the investigation. The mock crime scene showed the consequences of an armed robbery committed by two offenders.

Because of the complex and innovative character of this study, a pilot study was initially conducted with 40 experienced CSIs to test the research design. The pilot study revealed some complications in the design, hence the design was adjusted, improved and tested again with a small pilot before the actual data collection. In the main study, 50 CSIs originating from 10 police regions in the Netherlands participated and investigated the crime scene. The data were obtained during two rounds of studies over two years: 30 CSIs in round one and another 20 CSIs in round two. CSIs were sent to the crime scene accompanied by a trainee who asked them about their thoughts and considerations. This method provided us with profound insight into CSIs observations and their

² This experiment was designed and developed as part of a larger research programme at the Amsterdam University of Applied Sciences (HvA) about behaviour at the crime scene and the use of new technologies. Both the development of the design and the data collection were a joint production by a larger research team.

interpretations of the crime scene and its traces. It was decided not to use the 'thinking out loud' method (Van Someren, Barnard, & Sandberg, 1994) since this would have made the investigation feel less natural and hence could affect the validity of the data. This innovative method with experimental design produced initial insights into the influence of rapid identification technology on the visual attention and decision-making processes of CSIs.

Experiment 2 – research question 3 In order to study the influence of rapid identification information about individuals on the interpretation of the crime scene, a more ambiguous crime scene than the one created in the first experiment was required. In the first experiment, we deliberately chose a crime scene that was not too complex and not too ambiguous because it was the first study on this topic. However, to test any interpretation effects of rapid ID information, a more ambiguous crime scene was more appropriate. In order to study the influence of rapid identification information on the interpretation of the scene, the second study used a more ambiguous crime scene and a more controlled provision of identification information at fixed moments. This study also used a different method: instead of a mock crime scene in the NFI laboratory, a virtual crime scene was built. In order to create the virtual scene, a mock crime scene was set up in a crime house of the Dutch police academy. The scene was photographed by an expert with a panoramic camera which produced a 3D computer coverage of the scene. Participants were asked to investigate the scene from behind the computer. In this way, participants did not have to be physically present at the scene, making it less time consuming.

Similar to the initial study, a real police investigation was used as inspiration for the set-up of the crime scene and the scene was created with CSI experts to make the investigation as realistic as possible and therefore of more value to the end-user. The chosen police investigation had been complex for the investigative team due to the ambiguous crime scene and contradictory information about the crime from witnesses, and was therefore very suitable for this study. The mock crime scene was set up in such a way that it was compatible with two very different interpretations of what had happened, allowing me to investigate the influence of different kinds of information on the interpretation of the crime scene. In order to investigate the influence of rapid identification information on the interpretation of the crime scene, two elements were manipulated: (a) the moment that ID information was provided to the participants; (b) which of the traces resulted in a database-match or non-match. In total, 48 English CSIs from 4 different police regions and 65 Dutch CSIs from 10 police regions participated in this study. Before starting with the actual data collection, this set-up was also tested in a

pilot study with 64 English university students. Due to the more controlled provision of identification information and the many CSIs from two different countries, I was able to study the influence of rapid identification information on the interpretation of the crime scene and to compare the results obtained by English CSIs with the results of the Dutch CSIs. The data collected with the aforementioned studies and their analyses are presented in the five publications that make up this thesis. Some phases of the investigation are presented together in a publication because of their inextricable connection. Also, the experimental studies are presented in parts over multiple publications, given the large amount of data obtained.

1.10 Outline of this thesis

Chapter 2 describes the first phase of the investigation; the observation of the crime scene during the orientation phase and attempts to answer the first sub-question presented in the previous section: what is the influence of rapid identification technology on the visual attention of the crime scene investigators? To answer this question, the data obtained in round one of the first experiment were used. The results of the control group were compared with the results of the two experimental groups: the 'rapid ID of persons' group and the 'rapid ID spectral camera' group. All recordings of the commentary by the 30 CSIs during the orientation phase of the crime scene investigation were analysed with two different analyses. A qualitative analysis was conducted to gain insight into the interpretations of traces. A quantitative analysis investigates the traces mentioned during the orientation phase to analyse the focus of CSIs.

Chapter 3 builds on chapter two and investigates how rapid person identification technology influences the selection of traces for analysis (sub-question 2) and the interpretation of the crime scene (sub-question 3). In order to answer these questions, the phases after the first orientation at the crime scene were analysed. The data obtained during round one and round two of the first experiment are presented. The group that had the option of using a spectral camera was excluded from further analysis. The aim of the data collected with the camera was to study the influence on visual attention because it was hypothesised that this technology would influence CSIs observations. The second round of experiments was held to obtain more information about the influence of rapid identification technology on the selection of traces and interpretation of the crime scene. The decisions of CSIs were analysed by means of decision trees and this chapter looks more profoundly into the impact of identification information on the CSIs' final scenarios. This chapter provides insight into the selection process of traces for analysis. It shows

that CSIs are focused on analysing offender traces and pay less attention to traces left by the victim. This study also shows that identification information can lead to more accurate reconstructions of the crime. However, the crime scene we used in experiment one was not too ambiguous and identification information mostly confirmed an existing belief.

Chapter 4 presents part of the data obtained through the virtual experiment and investigates sub-question three more thoroughly and under different conditions, i.e. when confronted with a more ambiguous crime scene. The influence of rapid identification information is more systematically analysed in this chapter by studying whether a) scenario formation is influenced by the moment the ID information is provided and 2) whether database matches influence the evaluation of traces and the reconstruction of the crime.

Chapter 5 builds on Chapter 4 by providing additional insight into the interpretation process of identification information. The chapter investigates in more detail how ID information further influences the construction of scenarios. More specifically, this chapter analyses more precisely how three types of information, namely (1) investigative, (2) crime scene information and (3) ID information, of which the latter two together represent forensic information, is used by CSIs to build scenarios, draw inferences, and select forensic evidence.

Chapter 6 investigates sub-question three, i.e. the influence of identification information on the interpretation of the crime scene, again under different conditions. Recognising the special circumstances under which CSIs in a given country operate, the study presented in this chapter investigated the robustness and generalisability of the findings presented in chapter four by studying whether identical decision-making phenomena are found in a replication study within a different police environment. It was investigated whether Dutch CSIs, who operate within a context where more emphasis seems to be placed on caution and less on efficiency, make similar decisions as their British counterparts. In order to study this question, I compared how English and Dutch CSIs interpret identification information by investigating (1) whether English and Dutch CSIs differ in the perceived aim of a crime scene investigation and (2) the robustness of the observed influence of ID information on the interpretation of the crime scene within the two different police environments. I tested these questions by replicating the virtual experiment with Dutch CSIs and compared the results between the English and Dutch CSIs.