Rapid DNA technologies at the crime scene
‘CSI’ fiction matching reality
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Chapter 10

Reflection and Future Perspective
10.1 Introduction

The work in this thesis shows that mobile Rapid DNA technologies are a promising effective tool for forensic intelligence purposes to identify a suspect. It also became clear that for an optimal implementation technological, behavioural and legal implications must be taken into account for Rapid DNA analysis to become a CSI reality. Before Rapid DNA can be implemented in criminal investigations, serving both intelligence and evidence purposes, the studies in this thesis investigated the importance of the DNA prioritisation and selection process, the impact of human factors and the juridical process. To make the most of the potential of Rapid DNA the last chapter from this thesis provides the Criminal Justice System (CJS) with a summary and discussion on the findings leading to a final evidence-based road map showing the practical and scientific value of the studies performed. The thesis concludes with a future perspective on the way forward in speeding up forensic DNA analysis.

10.2 Summary of Key Findings

Rapid DNA Technologies at the Crime Scene - ‘CSI’ Fiction Matching Reality

This thesis investigated the impact of implementing mobile Rapid DNA technologies at the crime scene to identify a perpetrator, and to optimally regulate the process of analysing and obtaining Rapid DNA profiling results to ensure acceptance within the criminal justice system.

DNA as an investigative tool

In the first study of this thesis (Chapter 2), it is shown that in 1% of the forensically investigated high volume crime cases a ‘cold hit’ was obtained through DNA analysis and database searching.

In serious crime cases, an unknown suspect was identified through the DNA evidence in 3% of the cases. The study also revealed that 17% of the analysed High Volume Crime (HVC) traces, and 38% of the analysed Serious Crime (SC) traces did not provide DNA typing results. In addition, the analysis shows relatively long turnaround times from crime scene to DNA result and forensic testimony. In a number of cases, a suspect was identified through other investigative methods before the DNA match was reported. In these situations, DNA loses its intelligence potential, but can possibly still serve as evidence in court.

It can be expected that in cases with enough DNA, Rapid DNA analysis can be used as an investigative tool to speed up the identification of unknown suspects. Rapidly identifying suspects could lead to a discontinuation of other investigations, such as...
Technological implications – DNA success rates
Rapid DNA analysis is less sensitive than laboratory analysis. This must be taken into account for future Rapid DNA analysis decisions, and implies that DNA success rates are of key importance. To define DNA success rates, the second study (Chapter 3) focuses on the DNA concentrations of a large variety of crime related samples, to predict DNA profiling results and select promising samples for DNA analysis. Saliva and contact traces from intensively used items, such as collars and headwear, show high DNA concentrations potentially leading to full profiles. The proximity, intensity, and duration of the contact are factors that seem to contribute to the profiling success. This study further indicates that from each category of traces a certain amount is expected to lead to informative profiles. These success rate data can assist the DNA prioritisation process. Although this gives an insight into the DNA concentrations of various categories of traces, it shows no actual DNA success rates. Actual data on DNA success rates are given in the follow-up and third study of this thesis (Chapter 4), where 28 different categories of trace exhibits were analysed. The study focuses on profile characteristics, including: the DNA concentration, the type of profile, and the matches that were obtained. Half of the samples contained too little DNA to obtain DNA typing data. A positive relation between the success probability and the DNA concentration was observed, and appears to be independent of the type of crime sample. Setting a DNA concentration ‘cut-off’ could, therefore, optimise the DNA analysis procedure at the laboratory to focus on analysing more promising crime samples. It is expected that this protocol will lead to a more effective procedure reducing the number of ‘empty’ traces.
In more detail, the study shows that samples from cigarette ends, bloodstains, and headwear had relatively high success rates; whereas, cartridge cases, tools, tape, and zip ties were on the other end of the spectrum. This leads to a trace specific detailed model on DNA success rates to assist SoCOs in prioritising and selecting DNA traces. In this model we have defined our four-step decision process: 1) collect evidentiary traces, 2) rank traces based on crime and/or offender relatedness, 3) use the DNA success rate figure to rank the highest crime and/or perpetrator related traces and 4) select the most promising traces for DNA analysis. We expect that this knowledge will make SoCOs more aware of what to sample at the crime scene, and which samples to analyse with Rapid DNA or forward for laboratory analysis.

Technological implications – Rapid DNA and our DNA success rate model
The fourth study (Chapter 5) aimed to use the DNA success rate knowledge to support the selection process of crime samples for analysis by Rapid DNA. The study showed
that less sensitive technologies will have a significant impact on the DNA success rates. Without careful consideration, this could lead to loss of potentially valuable crime scene DNA samples. Samples with a low quantity of DNA seem less appropriate for analysis with a Rapid DNA device. Crime samples that show a high success rate in the laboratory will therefore also have the highest potential for Rapid DNA.

Although Rapid DNA cannot compete with the full potential that the laboratory offers, it can lead to important intelligence within hours. To make optimal decisions for DNA trace analysis, knowledge on Rapid DNA success rates is of crucial importance. For this purpose, an easy to use model was designed that can deal with any sensitivity threshold. This model showed both the laboratory, and potential Rapid DNA success rates, depending on the sensitivity threshold. Exact sensitivity thresholds of the Rapid DNA technology are still unknown and need to be derived from future validation studies. For instance, when a Rapid DNA device has a sensitivity level of 25 pg/μL DNA, the model shows that a DNA profile would be derived from a balaclava sample in 85% of the cases, whereas the laboratory would produce a profile from a balaclava sample in 92% of the cases. This shows a false negative value of 7% when analysing a balaclava sample with the Rapid DNA device.

This information can be incorporated in our four-step decision process and used by the SoCOs to decide whether to analyse a trace rapidly at the crime scene or forward the sample to the laboratory.

**Behavioural implications**

The perception of the technological implications for Rapid DNA analysis is expected to be crucial for future crime scene practice, and the decision-making process. For this purpose, the fifth study (Chapter 6) outlines a ‘real-life’ experiment to test the behavioural implications. SoCOs all performed the same mock crime scene investigation of a violent home robbery, either with or without the opportunity for Rapid DNA analysis. This study implies that a criminal case can be solved more quickly with Rapid DNA. However, with Rapid DNA at hand, significantly more DNA traces were selected for analysis. These traces were often victim related, of which most were not even crime related. More importantly, the traces analysed with Rapid DNA analysis were often either contact or interdisciplinary traces. SoCOs appeared to lack adequate knowledge on DNA success rates, risking the loss of informative low template DNA traces through rapid analysis. On top of that, DNA success rates were rarely considered when making decisions for trace DNA analysis. The study reveals the need for a comprehensive framework to support the DNA decision process.

These behavioural implications clearly indicate that current crime scene procedures need adjusting, and could benefit from a more transparent decision process in which opportunities and risks are explicitly considered when Rapid DNA analysis will be implemented. The previously explained four-step decision process could be extended to
a ‘hierarchy of decisions’ for Rapid DNA analysis:

1) Detect and collect all evidentiary traces;
2) Rank the traces by crime relatedness;
3) Rank the presumed crime related traces by perpetrator relatedness;
4) Use the Rapid DNA success rate figure for further selection;
5) Select the most promising trace(s) for Rapid DNA analysis;
6) Reconsider all collected traces in the light of different crime scenarios with the investigative team after the crime scene investigation;
7) Decide for further DNA analysis.

The reconsideration step forces the SoCOs to evaluate their CSI, the analysis decisions, and subsequent steps. Especially when Rapid DNA analysis will lead to identifying a suspect, it is of importance to reconsider all other traces that could identify the offender(s) or give insight into how the crime was committed. This might not rule out potential error or biased decisions, but it could assist in a more transparent and thoughtful decision-making process.

**Legal implications**

It is expected that identifying information obtained in the intelligence phase of the investigation will also play a crucial role in the evidence phase when the case goes to court. However, the sixth study (Chapter 7) shows that the Dutch law states that only an appointed DNA expert working for an accredited laboratory is entitled to provide the DNA evidence.

So, although a SoCO could perform Rapid DNA analysis where the results are used for intelligence purposes, the results cannot be used in the evidence phase when the case goes to court. It should be taken into account that the law on forensic DNA analysis dates from 1994 when DNA analysis was labour intensive and time consuming. In the past two decades DNA analysis opportunities have grown exponentially. These developments can even lead to amendments of the DNA law, for instance as happened in 2012, when familial searching and eye colour analysis for forensic purposes became effective (1). This shows that amending the law can be a solution to regulate the use of Rapid DNA analysis at the crime scene. The study outlined in Chapter 6 shows that in this process the following safeguards should be considered: 1) the public prosecutor is the requesting authority, 2) the implementation of a protocol detailing the specifications that the device must comply with, 3) implementation of a protocol to regulate the DNA traces to be analysed, 4) SoCOs receive additional training in the Rapid DNA procedure, 5) additional analysis and contra-expertise must remain possible, and 6) the situation at the crime scene and the subsequent process must be recorded meticulously.
Decision Support System

The technological implications show that Rapid DNA analysis can result in false negative profiling results; whereas, the behavioural implications show that SoCOs have the desire to analyse crime samples (including low template DNA samples) rapidly. In addition, the legal implications require SoCOs to use protocols to support the knowledge-based decision process. For this purpose, the seventh study (Chapter 8) focused on designing and testing a DSS, to combine these implications, and to guide SoCOs in making Rapid DNA analysis decisions.

With a Rapid DNA opportunity at hand, the SoCO needs to decide whether to analyse a crime sample with a less sensitive Rapid DNA device to get results within 2 hours, or to secure and have the sample analysed at the laboratory with a much longer throughput time but with higher sensitivity. To make an optimal decision it is important to systematically define this ‘time/success rate trade off’ in some sort of numerical threshold that can be compared with the Rapid DNA success rates. Through a specifically designed DSS, SoCOs are forced to consider all the possible outcomes through assigning numerical weights that, based on Rational Decision Theory, will lead to a Rapid DNA analysis threshold for the specific case. This threshold can be combined with the Rapid DNA success rates to support their final decision on using the Rapid DNA technology. In this way, both opportunities and risks are made explicit before a decision is reached.

This model was tested in a vignette study, where SoCOs had to decide on the use of a Rapid DNA analysis device, either with or without guidance through a DSS. In this study, the participants received constrained case characteristics, and were forced towards considering only one perpetrator related trace in their decision to use Rapid DNA analysis. It should be realised that in real cases there are more characteristics that could be implemented in the DSS, such as possible additional perpetrator related traces, and the expected relevance of the traces.

The study showed that setting thresholds with the DSS is a difficult matter. More than half of the participants using a DSS made Rapid DNA decisions that did not correspond to their chosen threshold. However, the qualitative data suggested that these participants rationally decided against their chosen threshold, potentially because they learned the effect of the threshold when applying it in a concrete case. The future challenge is therefore to agree upon the best-fitting uniform thresholds for several cases, and create easy to use expert systems for this purpose. This study further shows that SoCOs made different, but more justifiable, decisions for Rapid DNA analysis when guided by a DSS. The decision to apply Rapid DNA analysis or not was significantly influenced by the factors ‘time-pressure’, and ‘trace characteristics’ like DNA success rates. This indicates that future crime scene practice could benefit from such a DSS, especially when this would be combined with the ‘hierarchy of decisions’. It is expected that such a decision model will minimise both human errors such as confirmation, commitment, or mood.
bias, and technological errors such as false negative profiling results through the rapid but less sensitive analysis, and will ultimately encourage the optimal use of a Rapid DNA analysis device at the crime scene.

**The future of Rapid DNA at the crime scene**

The eighth and last study from this thesis (Chapter 9), concludes that the CJS has a strong intrinsic motivation to gain rapid forensic analysis results to assist vastly identifying of suspects, solving crimes and making legal proceedings more efficient. Due to the technological possibilities and improvements of Rapid DNA, the role of forensic institutes is expected to change. This change of speeding up analysis at the crime scene is aimed at providing a robust field solution for routine practices. The future perspective is to create integrated forensic platforms, where forensic expert knowledge and police practice are integrated. Together with carefully considered legislation, extensive quality control measures and a thought-out decision model, the state-of-the-art Rapid DNA technology will have clear value for the CJS.

### 10.3 Making Rapid DNA Safe for Practice

This thesis extrapolated and combined the technological, behavioural, and legal implications to study how Rapid DNA technologies may be integrated in crime scene practice. This study delivered knowledge on the juridical process, DNA success rates, and human behaviour on the decision process for rapid trace DNA analysis. In this study we focused on the use of Rapid DNA for perpetrator identification purposes, and not for reconstruction or evidence purposes; neither did we analyse the impact of other traces, such as fingerprint traces, that could also lead to identification and therefore may influence the decision to use the Rapid DNA device.

Designing effective new strategies and guidelines for the integration of the Rapid DNA technology requires an understanding of the complete field of crime scene practice (2). This thesis serves as an important foundation for this purpose. However, the use of Rapid DNA will affect the entire criminal investigation process and all professionals involved. The speed of the analysis process requires real-time information flow between the parties involved in the criminal investigation; in particular, the investigative officers who have to act on the rapid identification information. It is essential to establish an optimal connection between forensic and investigative officers to further optimise the Rapid DNA analysis procedure. Rapid DNA results can lead to faster identification of a perpetrator but can also lead to an early onset of tunnel vision. These effects and side effects of Rapid DNA information were not taken into consideration in this thesis, but are a central theme in a parallel thesis (3).

Although the full picture on integrating Rapid DNA at the crime scene might not yet be complete, the Dutch police are dedicated to start the use of Rapid DNA technology in
their crime scene investigation. The results obtained so far enabled us to design a conceptual Rapid DNA decision-model and CSI procedure to facilitate this process. These concepts can be used as a prototype for guiding future Rapid DNA analysis decisions at the crime scene, and are outlined in the next two paragraphs. It is important to realise that the current knowledge for these processes will be kept up to date, and new information will be gathered to further optimise the decision-model. Additional knowledge will make the Rapid DNA decision-model, and CSI procedure more advanced.

The goal of this model and procedure is not only to minimise potential human bias and decision errors while keeping the focus on the crime scene investigation, but also to maintain the chain of custody at all times. Therefore, all steps need to be directed and easy to log. Implementation of Rapid DNA technologies at the crime scene entails testing this Rapid DNA procedure and decision-model within actual cases in an experimentally designed pilot. The first steps towards this pilot have been set out and confirm that Rapid DNA analysis may be a viable alternative in the future (4).

10.3.1 CSI Procedure

When integrating mobile Rapid DNA analysis technologies at the crime scene, the standard 4-phase model for CSI needs modification to allow for Rapid DNA analysis. Currently, in a criminal investigation the trace detection, prioritisation and selection, the analysis, and the final interpretation are all separate procedures. The Rapid DNA opportunity will lead to the integration of all these steps directly at the crime scene. Therefore, it is recommended to adjust and extend the 4-phase model for CSI to an adaptive CSI procedure as follows:

1. The first step in this CSI procedure does not change, and consists of an orientation and potential detection of the first visible (DNA) traces.
2. The second step is to create the plan of approach and to define the initial scenarios. In this stage, the use of Rapid DNA could be immediately considered. This either leads to continuing the standard procedure or following the Rapid DNA procedure (through using a decision-model, see next paragraph). After collecting the specific traces and using Rapid DNA analysis, the results could lead to new information which may result in revising the plan of approach. The continuous reassessment of the plan of approach is a fundamental new element in the proposed reassessment CSI procedure.
3. The third step is to proceed with the CSI, and detect, collect and document all the localised physical evidence on the crime scene. This step could again be a reason to decide to use Rapid DNA and reassess the plan of approach.
4. When the third step is completed, the SoCOs perform a final walk through and round up of the CSI (step 4).
5. After rounding up the practical CSI, the fifth step is used to reconsider all collected traces and gathered information to define final scenarios with the investigative team, forensic analysts, and experts.

6. With the knowledge obtained, traces will be prioritised and potentially selected for further rapid or laboratory analysis. This step could again be a reason to decide to use Rapid DNA and reassess the plan of approach.

**CSI Procedure**

1. Orientation, detection of first (DNA) traces
2. Plan of approach with initial scenarios
3. Detection and collection of (DNA) traces
4. Final walkthrough, rounding up CSI
5. Reconsider all collected traces: define scenarios to assist prioritisation and selection of traces for (additional) analysis using the ‘Hierarchy of decisions’
6. Decide for (additional) analysis

![Figure 1. Renewed CSI Procedure for Trace (DNA) Analysis](image)

When Rapid DNA analysis provides identification results, this potentially leads to immediate forensic intelligence that could require direct sharing with the investigative team. In that instance, it is crucial for SoCOs to realise the CSI practice is still on-going, and that it is therefore essential to follow the further CSI procedural steps.

To ensure that this new CSI procedure will become common practice, SoCOs need to be educated in operating CSIs with a Rapid DNA device. Deliberate practice will be a key factor in improving this process. This involves training through immediate feedback, time for problem-solving and evaluation, and having the opportunity for repeated practice to refine decision-making (5).

### 10.3.2 Decision Model

When in the previously explained CSI procedure it is decided to consider using the Rapid DNA device for intelligence purposes to identify a perpetrator, this decision can be guided by the Rapid DNA decision-model. This conceptual decision model was inspired by a scenario-driven DSS for serious crime investigation (6) and consists of the following stages:
1) The first stage consists of the ‘hierarchy of decisions’ where the crime and perpetrator relatedness of the detected traces are defined. In combination with the scientifically-based DNA success rates, the traces are ranked.

2) The highest ranked trace will follow the second stage of the DSS, where inferences on the type of case, time pressure, and additional traces are put into the system. In combination with the scientifically-based Rapid DNA success rates, the SoCOs are transparently guided through the decision process. This is achieved by explicitly considering the consequences of all possible outcomes.

3) In the third and final stage, the results of this decision process lead to deciding whether to use Rapid DNA on the trace or not.

The idea of this conceptual decision model is that the above-mentioned parameters can be assigned different weights, based on the case and trace characteristics. Through considering these several aspects in the model, this could lead to the decision to rapidly analyse a specific trace in one case; whereas, in another case, with other characteristics, it could be decided not to rapidly analyse a similar sort of trace.

To illustrate the effect of the Rapid DNA decision-model we will use two extreme examples. For instance, at the crime scene of a home robbery the following potential DNA traces were found: a crowbar, a fabric glove and a blood swipe. Based on the initially defined scenarios, the SoCO follows the first stage of the Rapid DNA decision-model: the ‘hierarchy of decisions’. This stage guides the SoCO to rate both the crime relatedness and the perpetrator relatedness of the crowbar trace and the glove trace as extremely high. The crime relatedness of the blood swipe is also rated as extremely high, but the perpetrator relatedness is rated as extremely low. The system contains the scientifically based knowledge of DNA success rates: the fabric glove trace has a DNA success rate of 78%, the crowbar trace has a DNA success rate of 11% and the blood trace has a DNA success rate of 81%. This prior knowledge is combined with the inferences on the crime and perpetrator relatedness of the traces, and leads to the following ranking of the traces to potentially identify a perpetrator: 1) Fabric glove, 2) Crowbar and 3) Blood swipe. The fabric glove trace is therefore selected to follow the DSS in the second stage of the decision-model. In this stage, the SoCO rates the type of case as a violent home robbery, with a low expected time pressure of the perpetrator to strike again, and one additional perpetrator related trace was found that has not yet been analysed. Based on these inferences, this stage further guides the SoCO through considering and rating the consequences of all possible outcomes, taking alternative decisions for analysis of traces into account. All this knowledge is combined with the scientifically known Rapid DNA success rate of the glove trace of 66%. The final stage shows the outcome and leads to suggesting not to pursue Rapid DNA analysis on a sample of the fabric glove trace.
In another case, a violent home robbery occurred where the perpetrator took a machine gun, and the police suspect an imminent terrorist attack based on the defined initial scenarios. The complete process of the Rapid DNA decision-model is followed in the same way as explained above. However, in this case the time pressure of the case is extremely high, and the consequence(s) of all possible outcomes is rated differently when taking the alternative decisions for analysis into account. Therefore in this case, with the same sort of traces, the final stage suggests to decide to pursue Rapid DNA analysis on a sample from the glove trace to potentially identify the perpetrator.

Figure 2. Rapid DNA Decision Model

10.4 Future Perspectives - The Way Forward

To implement state-of-the-art Rapid DNA technology a thought-out decision model, clear protocols, and training through deliberate practice are essential to get full acceptance by the professionals from the criminal justice chain. Forensic science and crime scene practice will become more and more intertwined. This thesis serves as the foundation for this future perspective of mobile Rapid DNA technologies at the crime scene. This should not be considered a threat for forensic institutes and their scientists,
but should be embraced as the new forensic future. Through integrating science and practice the throughput of criminal investigations could speed up - where ‘simple’ routine analysis is performed by the police, and forensic scientists focus on expert analysis - where data is shared and decisions are made together: entering the era of forensic science and crime scene practice connected.

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10.5 References


