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Reporting on forensic biology findings given activity level issues in the Netherlands

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1. Introduction

The sensitivity of current DNA typing systems and the robustness of the probabilistic interpretation methods applied to such data are unprecedented. Low template trace DNA samples and complex mixtures are routinely analysed and searched against growing national and international DNA databases [1], increasing the power of DNA as an investigative tool for law enforcement [7]. With this increased power however also comes an increased responsibility to consider the relevance of such latent DNA traces to the scenarios being considered in a case [16]. This responsibility lies with all actors in the criminal justice system, as all will need to consider how traces that were collected relate to activities under consideration.

Knowledge on the dynamics of biological traces lies primarily with forensic scientists as this knowledge is generally only accessible in scientific literature [43, 44]. This fact places the responsibility with the scientist to provide guidance on these issues to the other actors in the criminal justice system as they need this information to form their opinions on the relation between the traces found and the activities being considered. Nonetheless there is some hesitation within the forensic genetics community to formally evaluate and report on findings given activity level propositions. This hesitance in part stems from concerns about the lack of relevant data on the dynamics of biological traces and doubt about the relevance of such expert opinions to the trier of fact. At the Netherlands Forensic Institute formal evaluative opinions on the probability of case findings given propositions at the activity level are provided since 2013, if requested by a mandating authority. In this study we share the results from a retrospective analysis of 74 of such requests. We explore which party initiates requests, the types of cases that are submitted, the sources of data being used to assign probabilities to DNA transfer, persistence, prevalence and recovery (TPPR) events, the conclusions that were drawn by the scientists, and how the conclusions were used by the courts. This retrospective analysis of cases demonstrates that published sources of data are generally available and can be used to address DNA TPPR events in most cases, although significant gaps still remain. The study furthermore shows that reporting on forensic biology findings given activity level propositions has been generally accepted by the district and appeal courts, as well as the other parties in the criminal justice system in the Netherlands.

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1.1. The Dutch criminal justice system

In an adversarial system the court guards proceedings (with regards to expert evidence focussing on rules for the admissibility of evidence) but leaves the presentation of facts to the prosecution and defence counsel. These facts are generally presented to a jury of peers, e.g. lay persons. The Netherlands has an inquisitorial justice system. Such an inquisitorial system differs from an adversarial system in that, whenever a case is put to the court, the court is in control and takes responsibility for the pursuit of the facts. In the Netherlands no jury is involved. The judge(s) lead the proceedings and ultimately decide on guilt or innocence of the defendant, and rule on the sentencing [23].

The Netherlands has 11 district courts, 4 appeal courts, and 1 supreme court. Criminal cases may be presided by a single judge (at district courts for cases in which the maximum penalty associated with the charges laid–against adults only–is under 12 months of prison sentence). More complex and serious crimes and all appeals are referred to a panel of three judges.

Judges may also request additional forensic examinations. They may refer such a request to the prosecutor or to an investigative judge to act as the formal mandating authority. The appointment of forensic scientists by a mandating authority is governed by a specific law: ‘Experts in Criminal Cases Act’. This law –in summary– specifies that only a judge may appoint an expert to perform a forensic investigation, unless the expert is registered with the Netherlands Register for Court Experts (NRGD) [english.nrgd.nl]. A prosecutor, who in the Netherlands formally leads a criminal investigation by the police, may request a forensic examination through an examining judge. If an expert is registered, a prosecutor may also directly appoint that expert.

The NRGD is a register with statutory basis in Dutch law. The NRGD develops field specific standards with international experts and lawyers, to which experts can apply to be examined. A panel of two subject matter experts and a judge examine a portfolio of the expert against the standards and provide a recommendation for registration or not to the board. The board of the NRGD then decides on registration of the scientist. For the field of forensic biology the NRGD has developed standards for four subfields:

1. DNA Source Level
2. DNA Source Level Extended
3. DNA Kinship Analysis
4. DNA Activity Level

The most recent version of these standards can be found at https://english.nrgd.nl/fields-of-expertise/dna-analysis-and-interpretation/documents/regulations/2021/03/24/standards-human-dna-analysis-and-interpretation.

In addition, forensic DNA analysis in the Netherlands is also governed by separate legislation which preceded the Experts in Criminal Cases Act. This DNA legislation specifies that a prosecutor may appoint a DNA scientist to perform an investigation, regardless of whether or not this scientist is registered by the NRGD. Current practise is that experts are appointed, preferably from the register, by prosecutors for DNA source level (extended) investigations only. This means that any formal evaluative opinions at the activity level are only provided if the scientist is appointed to do so by the appropriate mandating authority [investigative judge, or prosecutor if the expert is registered with the NRGD for ‘DNA activity level’ interpretation].

1.2. Reporting given activity level propositions

1.2.1. Routine DNA analyses and reporting at the Netherlands Forensic Institute (NFI)

The NFI is an agency of the Dutch Ministry of Justice and Security. It is positioned independently from the police and prosecution service. The institute has three core tasks:

1. Forensic investigations,
2. Innovation, research and development,
3. Education.

At the NFI DNA investigations are performed in about 50,000 case requests yearly. The vast majority of these with a prosecutor as the mandating authority. This results in well over 100,000 DNA analyses performed. The results of the investigations are mostly reported addressing issues at the sub-source or source level. Each of these DNA reports contains the following caveat:

About the pertinent issue

The forensic research described in this report focuses on answering the question of who may be the source of recovered biological materials. This means that the conclusion of this report only relates to the origin of the biological traces. No statement is made about how or when the traces were deposited.

For more information on the criminalistic interpretation of the results, see the following documents via the QR codes or on the website.

The textbox further refers to a number of practitioner guidance papers and associated documentation [18–20,27,29]. With this textbox attention is drawn to the fact that issues are addressed given propositions at the sub-source or source level. Additionally, over time the NFI has invested strongly in education and training of the legal community and police officers on the interpretation of forensic evidence, raising awareness of the complexities of interpreting forensic biology findings given issues at the activity level. This resulted in regular requests being put to the institute to evaluate findings of forensic biology examinations given propositions at the activity level.

1.2.2. Formulation of requests when the pertinent issue is at the activity level

Formulation of requests for evaluation of findings given activity level propositions may either be through correspondence or through a meeting with an investigative judge, the prosecutor, and defence counsel. At this case meeting the pertinent issues are discussed and additional, task-relevant information for the scientist is requested. Based on this information the scientist proposes one or more sets of propositions at the activity level and lists a number of assumptions that need to be made on unknown or uncertain aspects of the case circumstances [39]. These propositions and assumptions are put to the investigative judge in writing for a formal mandate.

1.2.3. Reporting given activity level propositions

After this mandate the scientist will interpret the findings given the propositions, assumptions and other task-relevant information and formulates a conclusion on the probability of the findings given the propositions. The process is based on international guidance documents [i.e. Association of Forensic Science Providers [2]; [11,45]] and under ISO 17025 accreditation, while the opinions and interpretations that are formulated currently are not. The quality of these opinions is currently assured through a formal training requirement for scientists reporting given activity level propositions (beyond training of scientists who report at sub-source and source level only), and subsequent examination and registration by the NRGD. This training consists of (a.o.) structuring case information (including formulating propositions at the activity level), understanding DNA TPRP mechanisms and literature study, and the design and use of Bayesian Networks.

The reporting style has developed over time, and the current outline of the report is as follows:

1. Key issue

With a description of the questioned activities and general outline of the scenarios being considered.
2. Request
The request and mandating authority with the propositions being considered.

3. Methodology
With information on the process, highlighting the fact that the report contains an expert opinion that is conditional on the information received. The use of statistical methods (i.e. Bayesian networks) is explained.

4. Information received
With the sources of information and the information from those sources that is being considered in the evaluation of the findings.

5. Assumptions
With the assumptions on the uncertain or unknown case circumstances listed. Common assumptions are for example on the source of the biological material (assuming source attribution) or that the perpetrator did not wear gloves at the time of the incident.

6. Examination results
Summary of previous findings as well as results from any additional examinations.

7. Evaluation of the findings
Addressing:
1. How the ‘findings’ are defined (i.e. only presence or absence of DNA, or relative or absolute amounts being considered, and the combination of certain trace samples into one or more ‘meta-traces’).
2. Assignment of relevant probabilities of DNA transfer, persistence, prevalence, and recovery (DNA TPPR), and references to the sources of data used.

8. Conclusion
Generally phrased as: “The findings are, given the assumptions and undisputed task relevant information, X times more probable if proposition 1 is true than if proposition 2 is true. This means that the findings are ‘more probable’* if the defendant did Y with Z to the complainant than if somebody else than the defendant did Y with Z to the complainant.”
The asterisk refers to a footnote containing a scale of numerical ranges for the LR with verbal equivalents. The conclusion is always followed by two caveats:
1. That the likelihood ratio is conditional on the information received and that changes in that information or the assumptions may affect the weight of the evidence.
2. That the report contains an opinion on the findings given the propositions and not on the propositions themselves.
After this conclusion the impact of certain assumptions or probability assignments on the robustness of the weight of the evidence may be discussed if considered relevant by the scientist.

An example report can be found in [22].

1.3. Issues addressed in this paper
With a general introduction to the Dutch criminal justice system and the process for evaluative reporting given activity level propositions at the NFI we have set the stage for a retrospective analysis of cases. The analysis will address the following questions:
1. Who initiates the request?
2. What types of cases were addressed?
3. What data sources were used?
4. What conclusions were drawn?
5. How were the conclusions used by the courts?

While this study is partly quantitative, many aspects are discussed qualitatively. With this paper we intend to inspire casework scientists to pursue this avenue of evaluative reporting in their own casework by removing some of the perceived obstacles. By highlighting some gaps in our current understanding of trace dynamics as illustrated by casework needs, we further provide some directions for future research into DNA TPPR.

2. Methods
At the NFI no list is maintained specifically for cases in which issues are addressed at the activity level. Hence a heuristic search was performed of the Laboratory Information Management System, digital case files, and correspondence in an attempt to retrieve a list of cases. A longlist was collated of 141 potential requests for evaluation of findings given activity level propositions. The cases were ordered reverse chronologically and data was collected for 74 requests for evaluations. The remainder of cases was not examined as the number of 74 cases was considered sufficient to address the issues discussed in this paper. Fig. 1 shows the process and number of evaluative opinions that were analysed.

For the cases that are considered an attempt was made to retrieve verdicts through a public register (https://uitspraken.rechtspraak.nl) and by contacting the courts. For all 74 requests that were analysed the following information was collected:
- Whether or not the request progressed to evaluation
- Report issue date
- Requesting authority (district court, appeal court)
- Initiating party (district court, appeal court, prosecution, defence counsel, unknown)
- Case type (in four categories: violent crime, sexual assault, burglary/robbery, other)
- Case findings (in three categories: single trace, multiple traces from same item, multiple traces from multiple items)
- Propositions considered
- Weight of evidence reported (verbal equivalents as in Table 1, and ‘no evaluation performed’)

![Fig. 1. Schematic overview of the process and outcome of the retrospective analysis of cases.](image-url)
3. Results and discussion

Of the 74 requests that were retrieved and considered in more detail, 9 (12%) did not progress to evaluation and reporting. In 8 out of these 9 cases this was due to a lack of information on the case circumstances that was considered crucial for a proper assignment of probabilities to DNA TPPR events. In one case the request was not followed up by an evaluation due to the absence of crucial items for investigation.

The point at which the request did not progress differed between cases. Some stopped at the initial case intake where it became apparent that no alternative scenarios were presented or where details on the activities that were considered were not available and none of the parties wished to make assumptions on these aspects. Others progressed to a formal report (as this was already requested by the courts) but the report was brief, with a statement that no evaluation could be performed due to a lack of contextual information.

As it is expected that a number of cases in which case consultation took place on these matters were not retrieved in the search (for instance because handwritten notes on this were added to the case file), the 12% is likely to be an underestimate.

The remaining 65 requests progressed to a formal evaluation and report on the interpretation of the case findings given activity level propositions. In seven instances two separate evaluations were requested in the same case, in one instance three evaluations were performed. In the latter case two evaluations were performed as requested by the district court, and a new evaluation given the same set of propositions -but with additional contextual information- as requested by the appeal court. Multiple evaluations may be performed either because activities were considered for two defendants, or for two separate (sets of) activities which were allegedly performed by the same defendant. Multiple evaluations within the same case were considered as separate requests in the further analyses in this paper. For 8 of the cases no verdict was retrieved. A set of 57 requests therefore contains information on the use of the reports in verdicts.

Interestingly, 11 out of the 65 requests (11%) were part of an interdisciplinary investigation in which results from forensic examinations from two or more different fields were combined to address the issue at the activity level. Combinations of DNA analysis were made with results from (note that multiple fields may be involved in an interdisciplinary evaluation):

- Fingermarks (3x)
- Bloodstain Pattern Analysis (BPA) (2x)
- Forensic medical examination (2x)
- Marks (2x)
- Gunshot residue (GSR) (2x)
- Fibers and Textiles
- Ignitable liquid analysis
- Fire scene reconstruction

3.1. Who initiates the request?

Of the 65 requests that progressed to a formal evaluation and report, 69% of requests were issued by the district courts and 31% by the appeal courts. This may reflect the relative number of courts in the two categories, with the 4 appeal courts making up 27% of 15 requesting courts. Adjusting for the total number of criminal cases dealt with in the district courts (~167,000 in 2021) and in the appeal courts (~29,000 in 2021) we see that the appeal courts request about 2.5 times as many ‘activity level reports’ as the district courts. A further analysis of these data revealed no trends in the number of requests by district versus appeal courts in relation to year of issue of the reports. It did show that some courts requested substantially more evaluations at the activity level than others, which could not be accounted for by the size of their jurisdiction.

Anecdotally it appeared that some investigative judges, after having positive experiences with the type of reporting, were inclined to submit more of these requests. The differences between the courts highlights that further educational efforts may be opportune. Forensic advisors have been appointed at all Dutch district and appeal courts [9]. These advisors frequently play an important role in signaling the need for additional forensic examination in cases presented to the courts. No correlation was however found between the date of their first appointment at the respective courts (between 2012 and 2020) and the date of, or number of, requests being submitted to the NFI (data not shown).

Looking at the party that initiated the request we can see marked differences between requests submitted by the district courts and those by the appeal courts (Fig. 2).

Particularly striking is the higher percentage of requests initiated by defence counsel during appeal compared to district courts. Anecdotally, from discussions with defence lawyers, one explanation that was given was that ‘activity level evaluations’ by a scientist are seen as a ‘last resort’ strategy. Defence counsel may attempt different strategies in court to demonstrate innocence or reasonable doubt on the charges laid against their clients. Lettinga [24] has shown, based on a study of court verdicts, that defence counsel in The Netherlands generally presents an alternative scenario that fits in one of five categories (Table 2, after [Ton et al., 2018]). In only two of those categories a formal evaluation of the findings of a forensic examination may be relevant (categories 1 and 3). Category 2 is a source level issue, while categories 4 and 5 deal with alibi and motive respectively. An example of an issue at the activity level for category 1 might be a case where the defendant is charged with smothering the victim with a pillow. The defendant may deny this happening and suggest the victim died of natural causes. In category 3 any issue related to the relation between traces and activities may be considered. When alternatives 1, 2, 4 or 5 fail as a strategy in the district courts, type 3 is the only one remaining, possibly causing the increased number of requests by defence counsel for activity level reports in appeal.

3.2. What types of cases were addressed?

The types of cases were grouped in four categories; violent crime (21 cases), property crimes (21), sexual assault (17), and ‘other’ (6).

Table 1

<table>
<thead>
<tr>
<th>Verbal equivalent</th>
<th>Order of magnitude of evidential strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>approximately equally probable</td>
<td>1–2</td>
</tr>
<tr>
<td>slightly more probable</td>
<td>2–10</td>
</tr>
<tr>
<td>more probable</td>
<td>10–100</td>
</tr>
<tr>
<td>appreciably more probable</td>
<td>100–10,000</td>
</tr>
<tr>
<td>far more probable</td>
<td>10,000–100,000</td>
</tr>
<tr>
<td>extremely more probable</td>
<td>&gt; 1,000,000</td>
</tr>
</tbody>
</table>

The latter category consists of cases with charges such as firearms possession, arson, and illicit drugs possession or manufacturing.

We see that the types of cases presented to the scientist is roughly equally distributed over the three main categories with the other case types occasionally being requested.

The issues that are addressed in these cases vary widely. However, if we group the issue in whether the actor or the activity is being disputed [21], we can see that this varies per case type (Fig. 3). The ‘classical’ activity level issue is whether or not an activity has occurred. We see that these situations make up the majority of the sexual assault cases we encounter. These are generally cases in which the complainant and defendant are acquainted (family members, friends, housemates, etc.) and the dispute is whether or not the sexual assault took place. The exceptions are situations in which a complainant made a statement about a sexual assault and the defendant, not knowing the victim socially, claims that the assault may have occurred (there is from their point of view no reason to dispute the assault having taken place), but claim that somebody other than the defendant is the perpetrator. This is a situation with a disputed actor. The issue of a disputed actor is encountered most frequently in violent crimes and property crimes in which defence counsel will generally not dispute that the incident took place but disputed actor. The issue of a disputed actor is encountered most other than the defendant is the perpetrator. This is a situation with a disputed actor. The issue of a disputed actor is encountered most frequently in violent crimes and property crimes in which defence counsel will generally not dispute that the incident took place but claim that somebody other than the defendant performed the activity.

Of note is that only one of the 65 cases dealt with the time at which an event occurred. In this particular violent crime (resulting in the death of the victim), the issue was at what time oral penetration of the victim took place. It was questioned whether the oral penetration of the victim took place at a time prior to the incident as was claimed by the defendant, or during this incident as was the charge laid to the defendant by the prosecution.

### 3.3. What data sources were used?

Where the experts initially tended to provide an opinion based on their expertise only (the NFI started providing structured opinions on forensic biology findings given propositions at the activity level in 2013), increasing reference was made in the reports to peer reviewed and published sources of data available to assign probabilities to DNA TPPR events. This trend can be seen in Fig. 4.

This trend reflects both the increased number of relevant studies that are available over time, but also the increased efforts made (and as a consequence the increased amount of time invested in a case) to support the opinions that are provided with proper sources of information rather than relying solely on expert opinion.

In the 65 reports 71 different peer reviewed papers were referenced, 38 of those only once (54%). Of the 33 other papers we list the ones cited more than 5 times in Table 3.

When we look at the type of studies that are frequently cited, we can group them in four main categories:

1. Strictly controlled, mechanistic experiments
2. Iterations of real life events
3. Retrospective casefile data
4. General principles (subsequent use of objects)

The first two categories have been distinguished by [14] and [26]. The first category contains studies that focus on understanding the mechanisms of trace dynamics, generally by classical experimental

### Table 2

<table>
<thead>
<tr>
<th>Type</th>
<th>Alternative scenario</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No crime</td>
<td>Victim died of natural causes or through an accident, rather than through criminal activity</td>
</tr>
<tr>
<td>2</td>
<td>Traces from another individual</td>
<td>The DNA or fingerprint is from somebody else</td>
</tr>
<tr>
<td>3</td>
<td>Traces not crime related</td>
<td>A legitimate explanation for traces from the defendant is presented</td>
</tr>
<tr>
<td>4</td>
<td>No opportunity (alibi)</td>
<td>Self-defence rather than intent to cause harm</td>
</tr>
<tr>
<td>5</td>
<td>Motive</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2. Percentage of requests for evaluation of findings given activity level propositions by initiating party in district courts (left) and appeal courts (right). White – court, light grey – prosecution, dark grey – defence counsel, black – unknown. Numbers in chart represent absolute number of requests.

Fig. 3. The issue of a questioned activity (light grey) or a questioned actor (black) grouped per case type.

Fig. 4. Average number of peer reviewed sources cited per activity level report per year of issue of the reports. Six reports that resulted in the conclusion that no evaluation could be performed (see paragraph 3.4) are omitted (as often no sources are cited and occasionally 1 or 2), as is one outlier (with 19 sources referenced) in 2017.
design, varying a single parameter in strictly controlled studies. The two papers by Goray et al. (8 and 13) can be grouped in this category. These studies do not allow for assignment of probabilities to recovery of a DNA profile (as they focus on the percentage of transfer from a known amount of biological substance between surfaces only, and not on DNA profiling results). In the case reports these papers were referenced to illustrate a general principle (e.g. effect of substrate on probability of transfer), followed by the experts assignment of a probability based on these principles.

The second category are studies that attempt to replicate real life events. These studies generally have a number of different volunteers perform an activity and the study yields some information on the variation between individuals and allows for the assignment of a probability to the recovery of a DNA profile for an average member of the (relevant) population. These types of studies make up the majority of the papers cited in casework reports (1,3,5,6,7,10,11,12,14 and 16). They are a rich source of information and can often be used in a variety of cases (i.e. the most cited study by Fonnelop et al. on activities of focus) are frequently cited (as are those in category 1) to describe a general principle, but no probabilities can be assigned directly based on the way the data are presented in these studies.

Beyond peer reviewed publications, two other sources of data were seen to have been used to assign probabilities to DNA TPPR events. The first are case specific experiments. These were performed for two cases in this study. One was a study on DNA transfer to pillow cases in a smothering scenario, the other was on the prevalence of DNA in vehicles. The latter study has been published [46] since the report has been issued. Due to constraints on time and resources, case specific experiments are rarely performed.

The second additional source are data from NFI retrospective casefile data. In 9% of cases reference was made to retrospective analyses of similar cases or items sampled to inform DNA TPPR events. In all instances the data was only used to assign a probability to recovering background DNA in the traces under consideration.

Ultimately we must realise that all probabilities that are assigned to DNA TPPR events in casework are subjective. No single study will perfectly align with the case circumstances and the scientist will have to make an informed decision on which studies to use and which not. Frequencies of events occurring may be obtained from experiment, but the subsequent assignment of a probability to such an event is an individual decision.

Over half (57%) of the reports included one or more probability assignments that were based on expert opinion only, with relevant data not being available from peer reviewed studies or other sources. An analysis of these cases and the reported lack of information yielded the following list of factors that appear understudied:

- The effect of subsequent use of an item by another individual on the persistence of DNA of a prior user. Examples of this that were encountered were:
  - the wearing of an item of clothing by somebody else during the incident, or the use of an item by the perpetrator while the defendant claims to have used this item prior to the incident. These two studies (as well as the study by Oorschot et al. on activities of focus) are frequently cited (as are those in category 1) to describe a general principle, but no probabilities can be assigned directly based on the way the data are presented in these studies.

### Table 3

<table>
<thead>
<tr>
<th>Reference</th>
<th>Number of times cited</th>
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<tbody>
<tr>
<td>1. Fonnelop et al.[10], The implications of shedder status and background DNA on direct and secondary transfer in an attack scenario. Forensic Science International: Genetics, 29, 48–60.</td>
<td>16</td>
</tr>
<tr>
<td>2. van Oorschot et al.[42], Persistence of DNA deposited by the original user on objects after subsequent use by a second person. Forensic Science International: Genetics, 8(1), 219–225.</td>
<td>16</td>
</tr>
<tr>
<td>3. Szkuta et al.[36], Transfer and persistence of DNA on the hands and the influence of activities performed. Forensic Science International: Genetics, 24, 148–157.</td>
<td>16</td>
</tr>
<tr>
<td>4. Oldoni et al.[30], Shedding light on the relative DNA contribution of two persons handling the same object. Forensic Science International: Genetics, 24(1), 10–20.</td>
<td>14</td>
</tr>
<tr>
<td>5. Daly et al.[38], The transfer of touch DNA from hands to glass, fabric and wood. Forensic Science International: Genetics, 8(1), 41–46.</td>
<td>9</td>
</tr>
<tr>
<td>6. Szkuta et al.[37], Transfer and persistence of non-self DNA on hands over time: using empirical data to evaluate DNA evidence given activity level propositions. Forensic Science International: Genetics, 33, 84–97.</td>
<td>8</td>
</tr>
<tr>
<td>7. Szkuta et al.[35], Assessment of the transfer, persistence, prevalence and recovery of DNA traces from clothing: an inter-laboratory study on worn upper garments. Forensic Science International: Genetics, 42, 56–68.</td>
<td>8</td>
</tr>
<tr>
<td>8. Goray et al.[13], Investigation of secondary DNA transfer of skin cells under controlled test conditions. Legal Medicine, 12(3), 117–120.</td>
<td>7</td>
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<tr>
<td>9. McDonald et al.[23], Y-STR analysis of digital and/or penile penetration cases with no detected spermatozoa. Forensic Science International: Genetics, 15, 84–89.</td>
<td>7</td>
</tr>
<tr>
<td>11. van den Berge et al.[40], Prevalence of human cell material: DNA and RNA profiling of public and private objects and after activity scenarios. Forensic Science International: Genetics, 21, 81–89.</td>
<td>6</td>
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<tr>
<td>12. Buckingham et al.[4], The origin of unknown source DNA from touched objects. Forensic Science International: Genetics, 25, 26–33.</td>
<td>6</td>
</tr>
<tr>
<td>14. Graham et al.[15], Defining background DNA levels found on the skin of children aged 0–5 years. International journal of legal medicine, 128(2), 251–258.</td>
<td>6</td>
</tr>
<tr>
<td>15. van Oorschot et al.[41], Activities between activities of focus—relevant when assessing DNA transfer probabilities. Forensic Science International: Genetics Supplement Series, 5, e75-e77.</td>
<td>6</td>
</tr>
<tr>
<td>16. Stensnæs et al.[33], An inter-laboratory comparison study on transfer, persistence and recovery of DNA from cable ties. Forensic Science International: Genetics, 31, 95–104.</td>
<td>6</td>
</tr>
</tbody>
</table>
regular wearer (note that a relevant study on this topic [31] was published after the report was issued).
- the wearing of a wristwatch by somebody else than the regular wearer.
- The interpretation of bodyfluid testing results. Particularly the:
  - prevalence of bodyfluids on bodyparts, including fingernails and genitalia, and underwear (note that a relevant study on this topic [17] was published after the report was issued).
  - probability of false positives of regularly used tests.
- Handling of tape, for instance duct tape when tying a person or object.
- The dynamics of traces related to sexual activity:
  - persistence of traces on and in different body parts,
  - probability of contamination (site-to-site transfer) during the forensic medical examination.
- Prevalence of non-self DNA on male and female genitalia given different social interaction scenarios.
- The effect of the presence of blood of a victim on the probability of recovery of latent DNA from persons-of-interest.
- The probability of relocation and loss of traces during the forensic process (packaging, transport, storage).
- Probability of DNA transfer to hair during grabbing and pulling of the hair of another person.
- Indirect transfer of vaginal epithelial cells to the body of a person through bedding.
- Prevalence of DNA of wearer on regularly worn shoes and the probability of finding the same source of background DNA on both shoes of a pair.
- DNA transfer to shoes by kicking a victim; manner of kicking and locations of contact with shoes.
- Multiple transfer event scenarios. Specifically the probability of transfer of DNA of a person of interest from their worn clothing to the hands of a subsequent wearer who then uses duct tape to tie up a victim.
- DNA transfer to fingernails when scratching clothing rather than skin.
- Difference between probabilities of transfer and persistence of DNA on different locations on finger tops (under nails, edge of nails/top of finger, cuticle, etc.)
- Indirect transfer of DNA from car interior surfaces or clothing of vehicle occupants to an expanded airbag.
- Loss and relocation of (perpetrator) DNA on the clothing of a victim due to medical intervention.

While some of these issues have (partly) been addressed in published studies after the reports were issued, many of these still require further study. An additional complication is that older publications on DNA TPPR issues were performed using older STR typing systems (i.e. SCMP1us or Profiler) and without probabilistic interpretation of the resulting data. This reduces their applicability to current casework using STR typing systems with increased sensitivity and specificity. Using older published studies therefore increases the subjectivity in probability assignments by the scientist as they need to be ‘corrected’.

3.4. What conclusions were drawn?

Of the 65 evaluative opinions that were reported, six did not result in a conclusion. This was generally due to the lack of contextual information, preventing the assignment of case relevant probabilities to DNA TPPR events. Each evaluation that did result in a conclusion (n = 59) has been categorized in one of the verbal equivalent categories shown in Table 1. The results are shown in Fig. 5.

From this analysis we can see that 22% of evaluations in which the scientist was able to provide an opinion resulted in a likelihood ratio of approximately 1. These reports serve the same crucial function as those with a reported LR different than 1. They should flag to the decision makers in court that the findings from the DNA analysis have no power to distinguish between the propositions put forward by the two parties. In this way these reports may prevent the overevaluation of the DNA analysis results in the context of the case by reducing the risk of an ‘activity level fallacy’ [26].

Particularly when findings from multiple traces or multiple items are evaluated, the findings may provide conflicting results in the evaluation. Consider for instance a situation where absence of DNA of a person-of-interest (POI) on one item supports the defence position, while the presence of DNA of the POI on another item support that of the prosecution. While aspects of the evaluations may have supported the defence position, only 3% of case reports (2 opinions) provide overall support for the defence position. These situations where there is an absence of DNA from the POI on locations where it was expected under the prosecution scenario. This reflects the importance of consideration 3 made by a DNA commission of the International Society for Forensic Genetics [11], which states: “1) Absence of biological material from a person of interest (POI), where there is an expectation of an observation under prosecution’s proposition, will generally support the competing defence proposition. 2) If an alternate, unprofiled, offender is being suggested then the presence of a profile that is different from the POI will generally add further support to the competing defence proposition.”

Such cases, where there is an absence of DNA of a person-of-interest in traces relevant to the scenarios being considered, will often not progress to court. This may explain the under-representation of such cases in the examined reports.

Fig. 6 shows the weight of the evidence reported in relation to the nature of the findings. Multiple traces from the same item, or multiple traces from multiple items of evidence, tend to increase the diagnostic power of the findings, although this weak trend is likely influenced by a number of confounding factors like the nature of the activity being considered and the relevance of the traces and exhibits to those activities.

3.5. How were the conclusions used by the courts?

Verdicts were retrieved relating to 57 evaluative opinions provided in cases. In 16 verdicts (28%) no mention was made explicitly of the report containing the expert opinion. As the report would have been part of the documentation submitted to the court, this begs the question why this is. In four verdicts conviction or acquittal/exoneration was based on other evidence (CCTV imagery, witness statements, decrypted electronic communication) which led the
court to their decision. Six verdicts discuss the scenario presented by the defendant and rule that it is not supported by the facts or (highly) improbable, and therefore not considered further. In both these situations the evaluative opinion expressed by the scientist appears not to have been required for the court’s decision. Two verdicts mention the findings from the DNA analyses as supportive of other evidence, but their relation to the case circumstances is not discussed in further detail. Once the court ruled that one of the assumptions made in the report (that no gloves were worn by the persons involved) did not hold, and hence the evaluative opinion was not relevant to the deliberations of the court. It was further discussed that a new evaluation under different assumptions was not opportune due to the absence of information on the type of gloves and their history of use.

In the three remaining verdicts the court assessed the relevance of the biological traces with regards to the activities being at issue themselves, without reference to the evaluative opinion of the scientist on these matters. In one of these verdicts argumentation on DNA TPPR issues was nonetheless taken from the expert report, suggesting that the information contained in the report provided some guidance in the deliberations of the courts. In 41 verdicts (72%) the report was used in the legal argumentation accompanying the verdict. Fig. 7 shows the use of the reports per verbal equivalent category for the weight of the evidence. An expected trend is shown, in that evaluative opinions by the scientist expressing a higher weight of evidence supporting one proposition over another are more likely to be mentioned in the verdict. Further exploration of these data revealed no differences in this trend between the district courts and appeal courts (data not shown).

There is a tendency for the opinion provided by the scientist and the verdict issued by the court to align. This means that if the opinion supported the prosecution position, the court ruled a guilty verdict and vice versa. There were six exceptions to this.

The first two exceptions are from one case with two opinions addressing two separate sets of activities allegedly performed by the defendant. One opinion being neutral (the result was considered equally probable if the activity had taken place as if it had not). The other opinion supported the defence position (the results being considered slightly more probable if the activity did not take place). The court issued a guilty verdict based on other evidence presented in the case, arguing that the absence of traces did not necessarily rule out physical contact between the defendant and the victim.

Another case was one of alleged sexual assault. One aspect of the sexual activities that the defendant was charged with was questioned and the opinion at the activity level supported this activity having occurred (the result was considered appreciably more probable if the activity had taken place rather than not). The court argued that one of the assumptions made on the case circumstances, as well as one of the sources of data used to assign probabilities to the case findings, were insufficiently aligned with the circumstances of the case. Hence the opinion was found irrelevant to the deliberations of the court and it was found that there was insufficient evidence to conclude that this activity had taken place, resulting in an acquittal.

The third case dealt with an alleged sexual assault in which the findings provided support (they were reported as being more probable if the alleged contact occurred rather than if it did not) for the prosecution position. The defendant was acquitted as the court ruled that they could not rule out, based on the report, that the findings were a result from an indirect DNA transfer.

A fourth case, contained two opinions addressing the involvement in arson of two defendants. Examination of items of clothing left in a garden close to the crime scene resulted in opinions supporting the charges laid against the defendants (the result was considered more probable and far more probable if the defendants wore the items of clothing at the time of the incident rather than somebody else). Both the district court and the appeal court ruled that the link between the items of clothing and the incident was uncertain and that the DNA findings were therefore irrelevant to the deliberations of the court. Both defendants were acquitted.

These four examples highlight that the courts (1) took the prior probability of the scenarios into account (the first and third case), (2) considered the relevance of the exhibits for the crime reconstruction (fourth case) and (3) critically reviewed the evaluation by the scientist (second case). This demonstrates that evaluations given activity level propositions by a scientist are not taken for granted and that these reports are properly considered with other information and evidence in the case.

4. Conclusion

In this paper we have attempted to provide some insight in the practise of reporting on forensic biology findings given activity level propositions at the NFI, exploring the sources of data used to assign probabilities to DNA TPPR events. We further explored the use of said reports by the Dutch criminal courts. From the verdicts we can only glimpse at the way the reports were understood by the users, and how they were valued in relation to other evidence presented in the cases. Use of evaluative opinions provided by scientists to guide the parties in the criminal justice system on DNA TPPR issues beyond the court rulings remains unseen. Have decisions been made, for instance, on
the extension of custody of suspects? Or were suspects confronted with the findings during interrogation, or possibly altering the defence position at trial? Further studies aimed at understanding the provision of guidance by scientists on TPPR issues and its use by the criminal justice system may elucidate the impact of this work.

Reports containing an opinion on forensic biology findings given activity level propositions are currently generally accepted by Dutch criminal courts, with mention in one or more verdicts of all district courts and all but one appeal court. While the quality of the opinions (measured by the data sources being available to support the opinions) increased over time, significant gaps in our understanding of the dynamics of biological traces remain. Of particular note are data on sexual assault type cases where, partly due to ethical considerations, the collection of experimental data remains problematic. Retrospective casework studies are a valuable source of data in these types of cases. Nonetheless, the absence of data should not in general deter the scientist from providing opinions on their findings given propositions at the activity level. The availability of relevant data should be considered on a case-by-case basis. Refusing to provide an opinion on the relevance of the traces given the scenarios being considered in the case poses a significant risk. As [3] state: “Besides, if a scientist refuses to assign a probability of observing some finding under a given set of propositions, there is a risk that the fact-finder will nonetheless assign such probabilities according to their own unaided judgment which, as highly-publicized past cases suggest, will often play out to the detriment of the defendant.”

CRediT authorship contribution statement

**Bas Kokshoorn:** Conceptualization, Methodology, Formal analysis, Visualization, Investigation, Writing – original draft preparation.

**Maartje Luijsterburg:** Conceptualization, Investigation, Writing – review & editing.

Declarations of interest

none.

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