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The Value of DNA Material Recovered from Crime Scenes

ABSTRACT: DNA material is now collected routinely from crime scenes for a wide range of offenses and its timely processing is acknowledged as a key element to its success in solving crime. An analysis of the processing of approximately 1500 samples of DNA material recovered from the property crime offenses of residential burglary, commercial burglary, and theft of motor vehicle in Northamptonshire, U.K. during 2006 identified saliva and cigarette ends as the main sources of DNA recovered (approximately 63% of samples) with blood, cellular DNA, and chewing gum accounting for the remainder. The conversion of these DNA samples into DNA profiles and then into matches with offender profiles held on the U.K. National DNA database is considered in terms of the ease with which Crime Scene Examiners can recover DNA rich samples of different sources, the location of the DNA at the crime scene, and its mobility. A logistical regression of the DNA material recovered has revealed a number of predictors, other than timeliness, that greatly influence its conversion into a DNA profile. The most significant predictor was found to be Crime Scene Examiner accreditation with offense type and DNA sample condition also being relevant. A similar logistical regression of DNA samples profiled that produced a match with an offender on the U.K. National DNA database showed no significance with any of the predictors considered.

KEYWORDS: forensic science, DNA, crime scene examination

DNA evidence has become a standard forensic technique for investigating and solving a wide spectrum of crime types from property crime (burglary and autocrime) to serious and major crime such as rape and murder. DNA material recovered from a crime scene is processed to produce a DNA profile, which in the U.K. is loaded onto the National DNA Database (NDNADB). If the loaded profile matches that of a named individual already on the NDNADB (known as a DNA "match"), then that information is passed back to the police force who submitted the crime scene DNA material. This usually leads to the arrest of the individual (who would be considered a suspect for the crime) and a police interview follows in which the suspect is expected to account for how their DNA came to be at the crime scene. If the police do not accept the explanation offered or if the suspect confesses to the crime, then the suspect will be charged with the offense, which will be considered solved with the suspect implicated as the perpetrator.

The U.K. DNA Good Practice Manual (1) states that (page 5) "*DNA helps police link offenders to crime scenes by matching DNA profiles that have been stored in the National DNA database (NDNADB) to DNA samples taken from crime scenes or suspects. It can also be used to eliminate suspects from enquiries.*"

Tilley and Ford (2) were the first to raise the issue of processing DNA material from a crime scene and recommended that the time taken should be reduced by both the police and the forensic service providers (who process the DNA and manage the NDNADB) in order to maximize opportunities to solve the crime with DNA evidence.

Webb et al. (3) examined the effect of timely DNA processing on the outcome of police investigations and its impact on crime. They analysed the results of a joint initiative between a U.K. police force and forensic service provider to speed up the investigation of residential burglary offenses where DNA material had been recovered from the crime scene (known as fast-tracking). Where a DNA match had been obtained, Webb et al. showed that the initiative produced a reduction from an average 89 to 45 days between a residential burglary being reported to the police and a suspect being charged (i.e., the offense considered solved). They reported that the fast tracking of the DNA did, indeed, lead to more suspects being charged as a result of DNA matches although there was no evidence to suggest that the initiative had a crime reduction effect. Webb et al. did note that morale and job satisfaction of all those involved in the DNA process improved as a result of the initiative, which may itself have partially contributed to its success.

A more recent study (4) examined a different aspect of the DNA process, namely, the variation in evidential value that different types of DNA material have on the ability of a DNA match to solve the crime. It was shown that for offenses where a DNA match is obtained, there are a number of statistically significant predictors that influence the successful outcome of the DNA match. The study examined both residential and commercial burglaries and also theft of motor vehicle offenses over a 1-year period. The most significant predictor was found to be the accreditation of the police officer interviewing the suspect. The accreditation of the Crime Scene Examiner (CSE) who recovered the DNA material from the crime scene was found not to be significant. Figure 1 shows diagrammatically the five stages of the DNA process and the parts of the process considered by these two studies (3,4).

A review in 2002 (5) highlighted great variation in U.K. police forces with regard to the collection and profiling of DNA material. The review stated (page 5) that "*there remain significant variations in submission policies across the service. These range from (paraphrased) 'gather as much as possible and submit everything' to a more directed approach managed through tasking and co-ordination.*"

Subsequently, Williams (6) noted in a study of seven U.K. police forces that there were inter-force differences in DNA match rates associated with the different approaches to DNA processing

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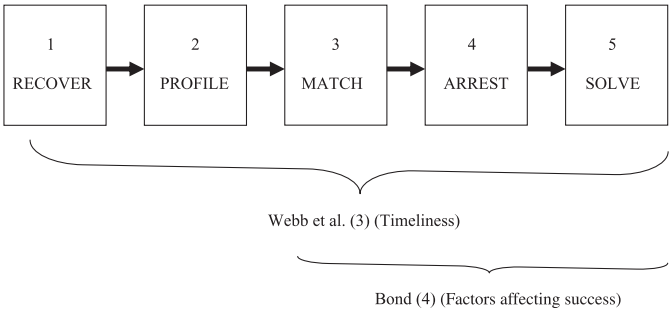

FIG. 1—*Diagrammatic representation of the five stages of the DNA process and the elements examined in two recent studies.*

adopted by individual police forces. In this paper, we consider what factors (other than timeliness) might affect the opportunities to convert DNA material recovered from a crime scene into a DNA profile and from a DNA profile into a DNA match, that is, stages 1 to 2 and then 2 to 3 of the process illustrated in Fig. 1.

DNA Source Data

For this analysis, we have taken data from the police force in Northamptonshire, U.K. for the period January–December 2006 and have considered the offenses of residential burglary, commercial burglary (from a shop, office, etc.), and theft of a motor vehicle. As explained in previous work (4), these offense types were chosen for a number of reasons as they:

- Offer potential to examine a large number of crime scenes for DNA material.
- Are key offenses for most police forces and also the U.K. Home Office (7).
- Are typically "recidivist" offenses, which means that offenders are likely to have their DNA profile on the NDNADB.

In the above period, all offenses in the above offense types that were notified to a CSE received a visit and scene examination for forensic evidence including DNA. In reality, this amounted to 99% of recorded residential burglaries, 94% of recorded commercial burglaries, and 81% of recovered stolen vehicles. The shortfall in all cases was because of crimes not being reported to a CSE rather than a conscious decision not to attend. This attendance policy was intended to prevent offenses not being visited by a CSE and thus ensure that the data was not affected by offenses being "screened out" without the opportunity for a CSE to recover DNA material. Also, all DNA material recovered from these crimes was sent to a forensic service provider rather than the "best sample for each crime" approach of Webb et al. (3).

For the three crime types under consideration, 1442 separate pieces of DNA material were recovered of which 890 produced DNA profiles that were loaded onto the NDNADB and these yielded 546 DNA matches.

The mean time taken from the crime being reported to a DNA match being made was 14.6 days. This is less than the mean time calculated in previous work (4) and is a consequence of previous work measuring the time interval between a crime being reported and a suspect arrested, the arrest of a suspect being the stage after the DNA match in the DNA process (stage 3 to 4 in Fig. 1). The time distribution of DNA matches is shown in Fig. 2. In common with previous studies (3,4), Fig. 2 excludes "outliers" where a suspect's DNA profile was not available for comparison at the time the DNA profile was loaded onto the NDNADB.

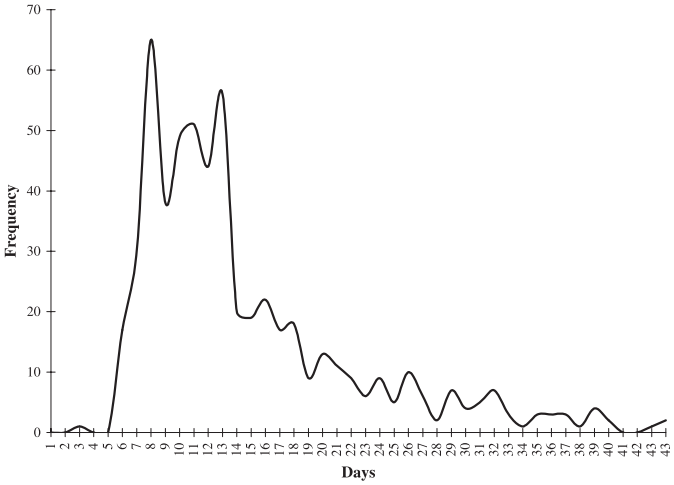

FIG. 2—*Frequency of DNA matches for days from crime reported to DNA match obtained.*

Results and Discussion

Previous work has classified DNA into different sources and so, firstly, the relative number of samples recovered, loaded, and matched for each source is shown in Table 1 (see Bond [4] for a definition of the different DNA sources).

Table 1 shows the numerically largest source of DNA recovered from crime scenes to be saliva which, for the offense types being considered here, would typically mean recovery of drinking vessels, bottles, cans, etc. The other main source of saliva (cigarette ends), whilst treated as a different source, is numerically the next largest source recovered. Both of these sources are typical of DNA recovery from items discarded by an offender at the crime scene. The next largest source is blood, which would typically be encountered through offenders cutting themselves whilst gaining entry to premises or a vehicle by forcing an entry. Cellular DNA is a general term for DNA material not easily attributed to any of the other sources and is also known as "contact" or "touch" DNA as it is typically recovered by swabbing a surface the offender is thought to have had contact with although no stain is visible. Finally, chewing gum (another source of saliva) is the least encountered DNA source.

The percentage of DNA material recovered that produces a profile suitable for loading onto the NDNADB (stages 1 to 2 in Fig. 1) reflects the ability of the CSE to recover DNA rich material from the crime scene. From Table 1, perhaps not surprisingly, blood produces a very efficient conversion of over 90% as it is rich in DNA from white blood cells (8). The three sources of saliva produced the next three most efficient conversions with cellular

TABLE 1—*DNA recovery and processing rates, January–December 2006.*

DNA Source	Percentage of Total Samples Recovered	Percentage of Samples Recovered Suitable for Loading on NDNADB	Percentage of Samples Loaded on NDNADB Producing a DNA Match
Blood	17.4	92.8	79.9
Cigarette ends	30.0	82.7	52.0
Saliva	33.3	43.1	57.3
Chewing gum	3.5	49.1	18.5
Cellular	15.8	20.5	53.0

NDNADB, National DNA database.

DNA, not surprisingly, the least efficient as it requires recovery from a potential contact area that contains no obvious DNA material. Obviously, the above conversions will be affected by the occasional recovery of material where DNA was originally present but has degraded and no longer produces a profile. That is, the CSE has no control over the quality of the sample other than to decide not to recover it.

The percentage of DNA material loaded that produces a DNA match (stages 2 to 3 in Fig. 1) reflects the ability of the CSE to recover material that is rich in the offender's DNA, provided the offender is on the database. This, therefore, requires the CSE to display an additional skill of being able to recognize what is likely to contain the offender's DNA rather than simply recovering items that are known to be DNA rich but might contain, say, the victim's DNA. Again, blood produces the most efficient conversion, as blood recovered from a crime scene can be more readily identified as alien to the scene and therefore more likely to belong to the offender than, say, a cigarette end. The value of blood as a DNA source to identify offenders has been identified previously (4) when it was termed as "non-mobile" DNA, which implied its recovery had more evidential value than "mobile" DNA (such as a cigarette end). The two main DNA sources of saliva (cigarette ends and saliva) and cellular DNA produce approximately the same levels of conversion (57.3–52%) whilst chewing gum produces a much lower conversion (18.5%).

The reason for chewing gum's low conversion rate lies in the location of its recovery at the crime scene. The majority of samples that were loaded onto the NDNADB were recovered either outside the crime scene (i.e., on the road next to a vehicle) or in communal areas of the crime scene (i.e., on the underside of an office desk). Thus, whilst the DNA source itself is DNA rich, the location has a pronounced effect on whether the DNA belongs to the offender or not.

It can be seen from Table 1 that, although the successful profiling of recovered cellular DNA is low (just over 20%), when it is successfully profiled its conversion to a DNA match is as good as more obvious sources of DNA such as cigarette ends.

Pearson's chi-squared test (9) showed a statistically significant difference between the conversions for blood in Table 1 compared with the other four DNA sources ($p < 0.01$). That is, the difference between the conversion figures for blood and the other four DNA sources is greater than would be expected by chance alone as the probability of this occurring by chance is <0.01.

Logistical Regression

In order to consider the combined influence of a number of predictors, in addition to the CSE's skill, on the efficiency of conversion of recovered DNA material into both profiles and matches, a logistical regression was performed using an equation of the form:

$$P(y) = \frac{1}{1 + e^{-(b_0 + b_1x_1 + b_2x_2 + \ldots.. + b_nx_n + \varepsilon)}} \quad (1)$$

where *P(y)* is the probability of y occurring given known values of x_i, b_0 is the y intercept and b_i is the regression coefficient of the corresponding variable x_i. ε represents a residual term (9).

Here, values of x (predictors) considered were:

- The skill, experience and accreditation of the CSE. Following appointment and initial training, CSEs undergo a 2-year training period culminating in accreditation as a Crime Scene Examiner. Each crime where DNA material was recovered was examined to see whether the CSE who examined the crime scene had reached the required standard and was accredited. For this predictor, *true* = accredited and *false* = not accredited.
- The offense type committed, categorized as either burglary or vehicle crime. Vehicle crime tends to provide a more self-contained crime scene for a CSE to examine and, therefore, might provide an easier opportunity for the CSE to evaluate what material is likely to contain offender's DNA. For this predictor, *true* = burglary offense and *false* = vehicle offense.
- The condition of the DNA material recovered. DNA samples were categorized into either "good" or "poor" samples based on the evaluation of the forensic service provider undertaking the DNA analysis. Sample conditions of "damp," "wet," or "dirty" were considered poor, whilst sample conditions of "dry," "frozen," or "clean" were considered good. For this predictor, *true* = good sample and *false* = poor sample (10).

These predictors were selected as the data were readily available for all offenses and also because it was felt that they represent a range of characteristics likely to influence the efficiency of the conversions discussed above.

The regression was performed twice for each of the five DNA sources, once with the probability *P(y)* taken to be whether or not a recovered sample produced a profile, and again with *P(y)* taken to be whether or not a profiled sample produced a match. Such a regression is well suited to this data as the outcome variable is a categorical dichotomy, as are the predictors (9).

Table 2 shows the results of the DNA recovery to profile regression in terms of Exp(B), which is an indicator of the change in odds of the outcome variable from a unit change in each predictor (9). For each dichotomous predictor, the unit change in the predictor is equivalent to the predictor changing from *false* to *true* or vice versa. That is, the value of Exp(B) shows, for each predictor, the odds of the outcome variable changing when the predictor changes from *false* to *true*. As the outcome variable is also dichotomous, Exp(B) is effectively showing the change in odds of producing a DNA profile from a recovered sample when the predictor changes from *false* to *true*.

Table 2 shows that, for all DNA sources, the accreditation of the CSE was statistically significant in influencing whether recovered samples were successfully converted to profiles loaded onto the NDNADB. For example, an accredited CSE is 5.6 times more likely to recover blood that produces a DNA profile than a nonaccredited CSE, 6.3 times more likely to recover saliva that produced a profile, etc. This demonstrates that the ability of the CSE to recover DNA rich material from the crime scene (stages 1 to 2 in Fig. 1) is significantly dependent on their accreditation.

Only cigarette ends showed significance for the offense predictor with burglary offenses 2.2 times more likely to produce a profile

TABLE 2—*Logistical regression model for each of the five DNA sources showing the values of Exp(B) for DNA samples successfully profiled from those recovered.*

	Predictor Exp(B)		
DNA source	CSE Accredited	Offense	Sample Condition
Blood	5.6*	Not significant	Not significant
Cigarette end	3.1*	2.2*	4.0*
Saliva	6.3*	Not significant	Not significant
Chewing gum	12.2*	Not significant	Not significant
Cellular	3.0*	Not significant	9.9*

CSE, Crime Scene Examiner.

*Significant difference at the 99% confidence interval ($p < 0.01$) using the model chi-square statistic.

TABLE 3—*Logistical regression model for each of the five DNA sources showing the values of the coefficients* b_0 *and* b_i.

	Coefficient b_i (SE)			
DNA source	b_0 (SE)	CSE Accredited	Offense	Sample Condition
Blood	1.0 (0.2)	1.72 (0.4)	Not significant	Not significant
Cigarette end	−1.9 (0.2)	1.14 (0.2)	0.78 (0.2)	1.4 (0.3)
Saliva	−0.6 (0.2)	1.84 (0.2)	Not significant	Not significant
Chewing gum	−0.94 (0.4)	2.5 (0.7)	Not significant	Not significant
Cellular	−4.2 (0.8)	1.1 (0.4)	Not significant	2.3 (0.7)

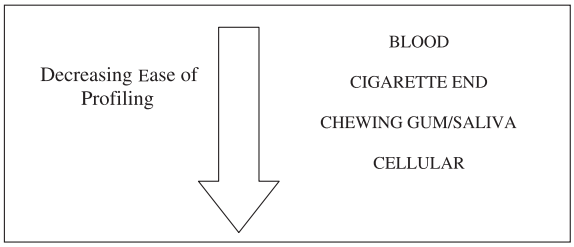

FIG. 3—*Representation of the decreasing ease with which DNA rich material can be recovered from a crime scene.*

than vehicle offenses. An examination of the location of cigarette ends at the crime scene revealed that those in vehicles tend to be recovered from ashtrays where there is a high risk of contaminating the DNA on the cigarette end (10). For burglary offenses, cigarette ends tend to be recovered singly, typically on a floor. With the other four DNA sources, there is not this same risk of offense dependent contamination.

Sample condition was only significant for cigarette end and cellular sources with these 4.0 and 9.9 times more likely respectively to produce a profile if the condition of the recovered DNA material was considered good (dry, frozen, or clean) rather than poor (damp, wet, or dirty). Whilst, as stated above, cigarette ends will be influenced by their location prior to recovery, the small amount of DNA material likely to be present on a cellular sample would be affected greatly by poor recovery or storage (A. Reid, personal communication; 24 March 2006). Other sources were recovered with samples classed as poor; however, the ease with which an abundance of DNA can be recovered from these sources appears to negate any adverse effect of poor recovery or storage.

Table 3 shows the coefficients calculated by the logistical regression, which may be used to construct Eq. (1). For example, the probability of obtaining a profile from a recovered cigarette end (1 = profile obtained, 0 = no profile obtained) may be calculated by setting the coefficients b_i equal to the values shown in Table 3 and then setting the predictor variables x_i equal to 1 or 0 depending on whether the calculation is being performed for that condition being true or false (CSE accredited = 1, CSE not accredited = 0, burglary offense = 1, vehicle offense = 0, sample condition good = 1, poor = 0).

Interestingly, the DNA profile to match regression (stages 2 to 3 in Fig. 1) produced no significance for any of the three predictors. For CSE accreditation, this implies that, whilst the recovery of DNA rich material is dependent on accreditation, once profiled, accreditation does not influence whether the DNA is likely to be that of the offender or not.

Conclusions

This study has considered the processing of DNA material recovered from crime scenes in terms of its conversion to a profile loaded onto the NDNADB and then the conversion of a profile into a DNA match, thus completing an analysis of the factors affecting all stages in the DNA process.

We have shown that the conversion of DNA material recovered from a crime scene to a DNA profile is significantly dependent on the accreditation of the CSE performing the recovery for all five DNA sources examined. This reflects the ability of the CSE to recover DNA rich material from the crime scene and is different to previous work (4) that examined the later stages of the DNA process. Whilst this current study has revealed that CSE accreditation influences the recovery of DNA rich material (stages 1 and 2 in Fig. 1), previous work has shown that it is the investigating police officer's accreditation that most influences whether the DNA match will successfully solve the crime (stages 4 and 5 in Fig. 1).

None of the predictors examined showed any significance in influencing the conversion of a DNA profile to a DNA match. Thus, once profiled, the CSE's ability to identify offender's DNA (as opposed to a victim's DNA) was not affected by their accreditation.

Other predictors were found to have an effect on the conversion of recovered DNA to a DNA profile although these were where significance might be reasonably expected through either easy sample degradation (such as a cigarette end in an ash tray) or through small amounts of DNA material being recovered (such as cellular DNA).

We propose that, in terms of successfully profiling DNA material recovered from a crime scene, there is a diminishing return based on the ease with which a CSE can recover samples likely to contain sufficient DNA material to profile, as illustrated in Fig. 3.

The most problematic of these five DNA sources is, undoubtedly, cellular which has a considerably less efficient conversion rate than the others. This is due to there being no obvious area to recover from (as would exist for a blood stain) or any obvious item to recover (such as a cigarette end or chewing gum). From April 2005 to March 2006 nationally, in the U.K., over 24,000 DNA cellular samples were submitted for profiling by U.K. police forces, which represents 30% of the total number of samples submitted for all DNA sources. The success rate of this cellular profiling was significantly less than that observed in this study (10%), which indicates that a substantial amount of money and resource is being expended by U.K. police forces and forensic service providers in (unsuccessfully) trying to obtain DNA profiles from cellular samples.

Failure to obtain DNA profiles through inexperience or poor crime scene management will, as has been reported previously for other stages in the DNA process, adversely affect the morale and job satisfaction of those involved in the DNA process. Following many years of investment by the U.K. government in DNA processing (11,12), perhaps it is now time to consider how best to optimize opportunities to solve crime with DNA within a limited budget.

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