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FOCUS ARTICLE

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The effectiveness of the current use of forensic DNA in criminal investigations in England and Wales

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Abstract

In this article, we consider the effectiveness of DNA analysis in criminal investigations. Through this investigative tool, unknown victims, suspects, and serial offenders have been identified. At the same time, wrongly charged and convicted individuals have been eliminated from investigations or released from custody following DNA testing. We know forensic DNA analysis is powerful in individual cases/certain crime types, but its aggregate contribution to criminal detections is low and questioned. There is little evidence to demonstrate its actual contribution. We examined the possible reasons for the low impact of forensic DNA, with some recommendations that may further maximize its utility. Available evidence demonstrates that there remains a need to ensure value for money in continued investment in forensic DNA analysis. An evaluation of trends in criminal activities and detection opportunities utilizing DNA evidence may help in identifying specific areas where DNA is most useful, and resources can be focused. Additionally, the potential of integrated multi-biometric analysis/systems and other evidence types should be explored.

This article is categorized under:

Forensic Biology > DNA Databases and Biometrics
Forensic Biology > Forensic DNA Technologies
Jurisprudence and Regulatory Oversight > Expert Evidence and Narrative

KEYWORDS

criminal investigation, DNA, effectiveness, forensic DNA, forensic DNA analysis

1 | INTRODUCTION

The analysis of DNA for human identification purposes has become an integral tool in identifying victims of atrocities; unidentified decedents; mass disaster victims; and individuals involved in police investigations. The scientific basis for DNA testing is the variability in autosomal, sex chromosome, and mitochondrial DNA (mtDNA) sequences among individuals. The types of forensic DNA analysis available include short tandem repeat (STR) typing, variable number tandem repeat typing, mtDNA analysis, single nucleotide polymorphism, and STR analysis using massively parallel sequencing technologies, DNA phenotyping, and DNA methylation analysis. The output of the different analytical techniques may be used in novel innovative search strategies, such as questioned-to-known profile comparisons, questioned-to-questioned profile comparisons, genetic genealogy investigation, phenotypic predictions, and familial searching to aid in the identification or association of persons and incident scenes. Other advances in forensic DNA analysis include the enhancement of the speed of analysis using instruments, such as rapid DNA systems (e.g., Applied Biosystems™ RapidHIT™ ID System), that permit testing at a test site, crime scene, or custody environment (Buscaino et al., 2018; Salceda et al., 2017).

Modern DNA profiling methods are strongly supported by robust scientific research data and continuous development of quality standards. These have ensured that the DNA evidence provided is accurate and results are most often highly reliable. The creation of online population-specific STR allele frequency databases, such as STRidER by the European Network of Forensic Science Institutes DNA Working Group (ENFSI DNA WG, n.d.), has allowed the calculation of the random match probability of matching DNA evidence to determine the significance of DNA results. Secondly, the development and validation of miniSTR kits, low copy number DNA testing, and DNA mixture analysis have allowed the analyses of degraded DNA samples, small quantities of DNA, and mixtures of biological material from multiple donors (Gill et al., 2015; Huffman, Hanson, & Ballantyne, 2021). Current research in forensic DNA and genetic analysis have focused on the reconstruction of the physical appearance of individuals—DNA phenotyping (Kayser, 2015), determination of the age of DNA donors using DNA methylation predictive models (Alsaleh & Haddrill, 2019), determination of the biogeographical ancestry of individuals (Pfaffelhuber, Grundner-Culemann, Lipphardt, & Baumdicker, 2020), and the estimation of the time of deposition of biological evidence (Alshehhi & Haddrill, 2019). These genetic tools are generally aimed at providing investigative leads by narrowing the pool of suspects or assisting with the prioritization of evidential material to support the progress of investigations.

The robust science and the evidential significance of DNA evidence in many criminal cases have established it as a "gold standard" (Lynch, 2003) in forensic science. Over 84 countries, including the United Kingdom, report utilizing forensic DNA analysis within the criminal justice system, and more than 70 countries operate a national forensic DNA database (Amankwaa, 2018; INTERPOL, 2016). In Europe, the linking of national DNA databases, through the 2008 Prüm Decisions, has allowed the transnational exchange of DNA data among European Union member states and the United Kingdom to enhance the fight against cross-border crime (Council of the European Union, 2018; Toom, Granja, & Ludwig, 2019). Yet, while forensic DNA analyses assist the police in solving difficult crimes (including "cold cases"), it contributes to a criminal justice outcome in less than 1% of recorded crimes in England and Wales (Wiles, 2017). England was the first country to use DNA analysis and the first to establish a national DNA database for policing purposes. This focus article reviews the factors that account for this low rate in England and Wales, with recommendations that may maximize the utility of forensic DNA analysis.

2 | CONTRIBUTION OF FORENSIC DNA ANALYSIS

While the value of DNA in individual cases, and some crime types, is demonstrable, the annual case resolution rate remains low for all recorded crime in England and Wales (with recorded crime representing roughly half of all the crimes committed according to the Crime Survey of England and Wales (CSEW) (ONS, 2020)). Several factors account for the low aggregate impact of forensic DNA analysis. Firstly, most crimes do not involve DNA evidence. Secondly, DNA evidence is not meaningful in cases where identity is not in question. Thirdly, police priorities/budget may affect scene attendance, collection and analysis of DNA, and follow-up of DNA "hits" on databases. Other factors include legislative issues, such as statutory limitations on sampling and use of DNA, practical issues concerning DNA transfer, persistence, and contamination, and a lack of systematic data on the effectiveness and efficiency of forensic DNA analysis in criminal investigations.

In investigations where DNA evidence may be relevant, DNA analysis has a range of applications. These can be categorized into four broad scenarios: (a) suspect/individual corroboration or elimination—crime stain-to-known person matches; (b) cold hit—identification of unknown suspect via crime stain-to-database/archived reference matches; (c) next-generation applications, such as familial searching, genealogy database investigations, and DNA phenotyping; and (d) linked crime hit—identification of linked offenses/serial offenders via crime stain-to-crime stain matches. These applications are illustrated with case examples below. Although many examples exist of the value of forensic DNA analysis, sometimes considered to be "priceless" when resolving an otherwise "unsolvable" crime (van der Beek, 2015), its aggregate value continues to be low. The reasons for this observation are discussed in the next section.

The first category of forensic DNA application can be illustrated with the Colin Pitchfork case in the 1980s, the first recorded case of DNA evidence used in a successful criminal investigation (BBC News, 2018). The case involved the rape and murder of two teenagers, Lynda Mann in 1983 and Dawn Ashworth in 1986. Richard Buckland, then aged 17, confessed to the murder of Dawn Ashworth. However, the results of the DNA tests on semen samples taken from the victims eliminated him as the perpetrator. The analysis indicated the victims were murdered by the same individual. The first crime-scene profile matched the second, but this profile did not match Buckland's DNA. After a mass screening of about 5,000 men in Leicestershire and a tip-off, the police identified Colin Pitchfork, whose profile matched both the crime scene profiles. He subsequently confessed to the crime and was sentenced to life imprisonment in 1988. A characteristic of this type of casework is the "direct comparison" of a questioned DNA profile to a known/reference DNA profile.

The second type of forensic DNA application is common in cases where there are no apparent suspects and the police have recovered biological material from the crime scene. A real-life example of this scenario is the case of Andrew Pennington who was convicted in 2018 (FIND Strategy Board, 2019). In 1988, the investigation of the rape of a 27-year-old woman in York resulted in no suspect being identified. A cold case review was conducted by the Cleveland and North Yorkshire Major Investigation Team, which found semen on the skirt of the rape victim. A DNA17 profile was obtained from the semen sample and uploaded in the NDNAD. A hit with DNA from Andrew Pennington was obtained after a search on the NDNAD in 2017, leading to his arrest. Mr Pennington's reference profile was on the NDNAD due to a previous unrelated case. He pleaded guilty to the rape offense and three counts of burglary which were linked following forensic investigations. He was jailed for 10 years in 2018, almost 30 years since the initial offense. In this type of application, "speculative searching" of a database is conducted to identify a potential suspect to progress an investigation. This may include sensitive strategies such as familial searching (FIND Strategy Board, 2019).

An example of the next-generation application of forensic DNA analysis is the Golden State Killer investigation. Between the 1970s and 1980s, the investigations of about 50 rapes and 12 murders in California went cold. A number of these crimes were linked via DNA analysis in the early 2000s revealing a similar modus operandi by the perpetrator. A search of the crime scene profile in the State DNA database found no hits. In 2018, the police uploaded the crime scene profile on the GEDmatch genealogy website which returned a near match. This intelligence led to Joseph DeAngelo, whose DNA was collected surreptitiously for comparison to the linked crime scene profiles. The results from the Sacramento County Laboratory of Forensic Science found a match between the crime scene profiles and DeAngelo's profile leading to his arrest. He pleaded guilty to the offenses in June 2020 (BBC News, 2020).

The three case examples above also illustrate the last category of DNA analysis applications involving the linking of multiple crimes to identify serial offenders. This may involve the direct comparison of separate crime-stain profiles or speculative searching in a database or archive of DNA profiles. The investigative strategy may be enhanced through mapping of the DNA information to other forensic evidence types or police intelligence, such as fingerprints, ballistic material, or criminal records, including information about the modus operandi of offenders. For example, an individual identified via DNA testing or database search, and multiple crimes linked via DNA may also be associated with other related or unrelated offenses where only finger marks or other evidential material were recovered. The non-DNA evidence/information from the initial DNA-related case may also be searched simultaneously in an intelligence database to detect any matches or link to the individual and/or offenses. Through the integration or combination of multiple evidence types and police-recorded crime data, it is possible to identify other unknown linked crimes and serial offenders beyond crime stain-to-crime stain DNA matches (De Moor, Vandeviver, & Vander Beken, 2018).

3 | MEASURING EFFECTIVENESS OF FORENSIC DNA ANALYSIS

Forensic DNA analysis can make a valuable contribution to criminal investigations. The value of forensic DNA has also been enhanced since the creation of national DNA databases in the 1990s and the introduction of transnational exchange of DNA data in the 2000s. The promise of preventing crime, and improving the chances of catching offenders, have fuelled the financial investment in, and development of, DNA capabilities and legislation/policies. Attempts to measure the impact of forensic DNA analysis have examined several outputs and outcomes of DNA related cases and DNA databases. Outcome measures are considered to offer better insights into the effectiveness of the use of forensic DNA than output measures, such as match rates and investigations aided (Bieber, 2006). The measures of effectiveness include:

1. Resolution of crime—assessed by the estimation of DNA detection rate and/or conviction rate.
2. Prevention/reduction of crime—assessed by analyzing the association between DNA regimes and crime rates.
3. Progress of investigations/investigations aided—assessed by identifying cold hits.
4. Performance of databases—assessed via the estimation of database match rates.
5. Deterrent effect—evaluated through qualitative surveys of offenders and criminal career research through estimation of recidivism rate.
6. Cost-savings—assessed through a cost–benefit analysis of financial investment into DNA analysis systems.
7. Societal-individual impact of the collection, retention, and use of DNA (Bieber, 2006; Briody, 2002, 2004, 2006; Doleac, 2016, 2017; Doleac, Landersø, Anker, & Sofie, 2016; Roman, Reid, Chalfin, & Knight, 2009).

The results of studies into the above effectiveness metrics generally indicate a potential for forensic DNA analysis to enhance the investigative capabilities of the police by identifying unknown suspects in cases involving DNA, such as murder, burglary, sexual assaults, and violent offenses; and reduce crime through the incapacitation and deterrence effects of DNA databases (Amankwaa & McCartney, 2019; Struyf, De Moor, Vandeviver, Renard, & Vander Beken, 2019). However, the wider context of the application of forensic DNA analysis is often missed in these evaluations (Amankwaa & McCartney, 2019). Further, our understanding of the factors that limit the use of DNA analysis is equivocal. This knowledge gap has led to overblown claims and unsupported beliefs of the capabilities of forensic DNA analysis among stakeholders, as demonstrated in several court cases (*Gaughran (Appellant) v Chief Constable of the Police Service of Northern Ireland (Respondent) (Northern Ireland)*, 2015; *Gaughran v The United Kingdom*, 2020; *R v Chief Constable of South Yorkshire Police (Respondent) ex parte LS (by his mother and litigation friend JB) (FC) (Appellant) and R v Chief Constable of South Yorkshire Police (Respondent) ex parte Marper (FC) (Appellant)*, 2004; *S and Marper v The United Kingdom*, 2008).

4 | FACTORS AFFECTING EFFECTIVENESS OF DNA ANALYSIS

While the scientific underpinnings of DNA analysis are robust, several factors hamper its application. A review of these factors is important because there are mixed views on the capabilities and limitations of DNA among the public and stakeholders, including forensic experts (Amankwaa, 2018; Machado & Silva, 2019; Skinner & Wienroth, 2019). Some studies have found concerns about the abbreviation of police detective work due to over-reliance on DNA results (McCartney, 2006). The match rate of the UK NDNAD, currently about 65.5% (FIND Strategy Board, 2020), is the main metric that is used to assess the performance of the database. While this output metric is important in assessing the potential effectiveness of the database, it does not represent the aggregate value of the use of DNA or databases in all criminal cases. For example, comments such as "…the database helps to identify a suspect in around 60 per cent of criminal cases" (Black, 2018, p. 164) are specious. The match rate of the NDNAD is only an estimate of the number of matches between a crime scene profile and reference profile per total number of crime scene profiles loaded in the NDNAD (FIND Strategy Board, 2019). Statistics provided by the UK Biometrics Commissioner indicate DNA contributes to criminal justice outcomes in just 0.3% of all crimes in England and Wales (Wiles, 2017). A detailed review of this issue has been provided in previous papers (Amankwaa & McCartney, 2019; Struyf et al., 2019). The aim of this focus paper is to elucidate the main reasons that may account for the low contribution of forensic DNA analysis to crime resolution. Presently, there is limited data to quantitatively evaluate the impact of the factors outlined below and further research is needed to investigate these issues (Wiles, 2017, 2020).

4.1 | Scope of DNA applications

Crime scene DNA profiles are one of the main drivers of the effectiveness of forensic DNA analysis (Wallace, 2006). The primary reason for the low aggregate value of forensic DNA analysis is the fact that only a fraction of crimes involves DNA evidence. Available data from the report of the Biometrics Commissioner shows that, of the 3.7 million crimes recorded by the police in 2016, only 11% of the crime scenes were examined by the police (Wiles, 2017). Of the common crimes that involve the use of DNA, the proportion of scenes examined was relatively higher than the overall percentage: 96.9% homicides, 80.3% domestic burglaries, 28.7% theft of vehicles, and 19.8% rapes.

The proportion of all reported crimes that produced DNA was 2.4%. About 63.5% homicides, 13.3% domestic burglaries, 11.3% theft of vehicles, and 7.8% rapes yielded DNA. Overall, only 1.8% of all crimes produced DNA that was analyzed by forensic scientists and only 0.5% of all crimes yielded DNA that was loaded in the NDNAD (Wiles, 2017). When broken down by the common DNA-related crime types, 8.4% of homicides, 1.4% domestic burglaries, 0.9% theft of vehicles, and 0.6% rapes had DNA linked to case outcomes (Wiles, 2017). A possible reason for the above statistics is that offenses, such as fraud, cybercrime, and theft are less likely to yield DNA. The FIND Strategy Board (2019) reports that these crime types contributed about 2% of all crime scene profiles loaded in the NDNAD. However, the CSEW shows that fraud (3.6 million), theft (3.2 million), and computer crimes (0.876 million) account for a large proportion of offenses experienced by adults (ONS, 2020). The types of offenses that are more likely to yield DNA include burglary, vehicle crime, and common offenses against the person, such as homicide, sexual, and violent crime (FIND Strategy Board, 2019). Thus, the nature of the crime, as well as scene attendance/examination and resource constraints, limits the application of forensic DNA analysis, which is viewed as a "panacea" for many crimes by some policymakers, scientists, and judges[1] (Meintjes-Van Der Walt, 2011).

4.2 | The probative value of DNA

Of the crimes that involve DNA evidence, identity may not be in question or the suspect/offender may have been identified by other means such as fingerprints, facial image, or witness/victim account (Bieber, 2006). For example, in an alleged domestic sexual assault, the identity of the suspect may not be material to the elements of the case, albeit DNA may be recovered from the victim. This scenario may also apply to non-stranger sexual offenses, assaults, and other offenses. In such cases, DNA may only be used to confirm the identity of the accused and/or establish the corpus delicti of the alleged incident, such as whether sexual intercourse or a violent attack has taken place. Another example is a burglary or violent offense where the police may recover the finger-mark of the perpetrator, which can be quickly searched in IDENT1 (the UK police fingerprint database) to determine identity. Though DNA may be collected from such scenes, it may not be relevant or probative to the progress or resolution of the case. Presently, it is not clear what specific role DNA evidence plays in the outcome of such cases and further research is needed to understand its specific contribution. A possible contribution, however, is the use of DNA evidence to identify further linked related or unrelated crimes.

In addition to the above scenarios, DNA transfer and persistence issues affect the use of forensic DNA analysis (Royal Society, 2017). Biological traces from an individual may be deposited at an incident scene before, during, or after an alleged crime has been committed. There is currently no robust methodology to determine the exact time of deposition of biological material (Alshehhi & Haddrill, 2019; Alshehhi, McCallum, & Haddrill, 2017). Further, the activity that resulted in the deposit of biological traces may be complex to determine—the so-called "activity-level" problem—that detecting a DNA trace and even identifying precisely where it was deposited, can still only rarely provide any useful information about what a person was doing when it was deposited. Research shows that biological traces can be deposited directly or indirectly, affecting the interpretation of DNA evidence (Szkuta et al., 2019; van Oorschot, Szkuta, Meakin, Kokshoorn, & Goray, 2019). A proportion of DNA-related cases where there is a match with an individual may, thus, be due to the presence of DNA unrelated to the case or background DNA or contamination at the scene or laboratory (EUROFORGEN, 2017; Rennison, 2012; Tully, 2020). The circumstantial nature of the DNA evidence, therefore, requires that there is other corroborating evidence or an assessment of the specific circumstances of the case (see *R v Jones (William Francis*) [2020] EWCA Crim 1021 (03 Aug 2020)) to progress or assist in resolving a case (FIND Strategy Board, 2019, p. 21).

4.3 | Policing priorities and budget

DNA matches generated from the NDNAD play a major role in the number of crimes resolved with the assistance of forensic DNA analysis. Recently, there has been a drop in the number of reference and crime scene profiles loaded in the NDNAD. This decrease is due to a cut in police budget and/or policing priorities (Wiles, 2020). Since the establishment of the NDNAD in 1995, the size of the database has risen from 42,593 DNA profiles (subject + crime scene) to more than 7 million profiles as of September 2020 (Home Office, 2020; National DNA Database Board, 2003). However, within the 2001/2002 to 2019/2020 period, the number of subjects and crime scene profiles loaded in the database has decreased, from 566,026 to 268,900 and 53,235 to 31,300, respectively (FIND Strategy Board, 2020; National DNA Database Board, 2003; Wiles, 2020). The main trigger for subject sampling and inclusion in the NDNAD is an arrest for a recordable offense. The significant fall in the annual subject profile uploads has been attributed to an increase in the use of alternatives of arrest, such as voluntary attendance and reform of police bail (Wiles, 2019). The decline in the annual crime scene load has been linked to changes in policing priorities and allocation of resources for criminal investigation, with a focus on serious incidents and cases that are likely to produce DNA (Wiles, 2020). The current match rate of the database suggests this trend may not have had an impact on the performance of the database. However, in theory, some opportunities to detect crime may have been missed because of the fall in profiles loaded onto the database.

4.4 | Statutory limitations leading to practical/technical complexities

The retention of DNA samples and profiles by the police has proved controversial. The European Court of Human Rights (ECHR) has examined the issue of DNA retention on several occasions, most notably in the case of *S and Marper v The United Kingdom* (2008), which found that the "blanket and indiscriminate" retention of DNA of individuals was disproportionate and thus breached the European Convention on Human Rights. This ruling led to a change in laws governing the use of DNA in the United Kingdom, leading to the introduction of the Protection of Freedoms Act 2012 (PoFA). The ECHR has again recently ruled disproportionate the retention of DNA in Northern Ireland (*Gaughran v The United Kingdom*, 2020), which may yet prompt more legislative restrictions (their laws being the same as England and Wales). One impact of the introduction of PoFA in England and Wales was the destruction of more than 7 million DNA samples and deletion of more than 1 million subject profiles from the NDNAD (Home Office & Brokenshire, 2013; MacGregor, 2014). The PoFA regime limits the retention of DNA samples and profiles collected from individuals arrested for a recordable offense. All DNA samples are required to be destroyed after generating a profile. A possible challenge with the destruction of the sample is that, at the investigative stage, it may not be possible to verify or investigate a match with advanced DNA typing technologies or the process may lead to adverse ethical or legal complications. For example, the police would have to identify and resample an individual (living or deceased) to verify a match or conduct further analysis, such as Y-STR analysis or autosomal STR typing with additional loci (Gill, 2014). These additional analyses may be crucial in cases involving DNA mixtures, for example, which can be difficult to interpret (Huffman et al., 2021). This limitation may result in delays at the investigative stage, affecting police follow-ups, and the efficiency of investigations.

Under the PoFA regime, DNA profiles of individuals without a conviction for a recordable offense must be deleted after the conclusion of an investigation or any proceedings. A maximum of 5 years of retention is allowed for non-convicted individuals arrested or charged with a qualifying or serious offense. The DNA profiles of convicted adults can be retained indefinitely. A detailed review of the implementation of the PoFA regime has been provided by Amankwaa and McCartney (2018). Although the match rate of the database has increased since this change, there have been concerns by stakeholders about the potential loss of some relevant hits from the database (MacGregor, 2016, pp. 38–39). Other statutory/policy related limitations include the use of voluntary attendance and bail conditions which have resulted in a decrease in the acquisition and use of subject profiles (Wiles, 2019). The extent of the impact of the statutory/policy limitations on the effectiveness of forensic DNA analysis remains unknown, and there have been calls by the Biometrics Commissioner and other stakeholders for an investigation into this issue (Wiles, 2017, 2018, 2019, 2020).

5 | CONCLUSION

Enhancing the utility of forensic DNA analysis is imperative to justify its financial and ethical costs (Amankwaa & McCartney, 2019; Skinner & Wienroth, 2019). For example, the DNA Expansion Programme (2000–2005) cost the Government and the police about £300 million (Forensic Science and Pathology Unit, 2005), and the annual cost of running the NDNAD is between £1.8 to 2 million (FIND Strategy Board, 2020). Both public security and civil liberty considerations continue to shape investment in this policing technology. However, our understanding of its aggregate and actual effectiveness and/or cost-effectiveness, and contribution to the resolution/prevention of crime is limited (Ludwig, 2016; Science and Technology Committee, 2016, p. 16; Walport, Craig, & Surkovic, 2015, p. 6; Wiles, 2017, pp. 13–14). Available evidence shows that while DNA analysis has contributed to successful investigations in many individual cases, its aggregate value to the resolution of all crime is low. In this focus paper, we reviewed the major reasons that may limit the effectiveness of forensic DNA analysis, including the scope of its application, significance or usefulness, priorities of the police and availability of resources, statutory/policy challenges, and technical issues. Currently, there is limited systematic and quantitative research on the extent of the impact of these factors on the effectiveness and efficiency of forensic DNA analysis. An understanding of the limitations may help identify specific strategies to improve the contribution of DNA analysis. Our review highlights a need to expand upon, and improve the examination of crime scenes for forensic DNA and collection of DNA samples from individuals. This should be informed by the evaluation of contemporary criminal activities to identify areas where DNA is most useful. Secondly, policies and legislation on the collection, retention, and use of DNA should be reviewed to ensure that both public security and civil liberties of individuals are adequately protected. Lastly, the review of the potential contribution of forensic DNA analysis suggests that the effectiveness of investigations may be enhanced via a combination of forensic DNA analysis and other biometrics or evidence types. This integrated/synergistic approach should be explored in future research to maximize the significance of DNA analysis.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Aaron Amankwaa: Conceptualization; investigation; methodology; project administration; writing-original draft; writing-review and editing. **Carole McCartney:** Conceptualization; data curation; formal analysis; investigation; methodology; supervision; writing-original draft; writing-review and editing.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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ENDNOTE

[1] Para 88 (*R v Chief Constable of South Yorkshire Police (Respondent) ex parte LS (by his mother and litigation friend JB) (FC) (Appellant) and R v Chief Constable of South Yorkshire Police (Respondent) ex parte Marper (FC) (Appellant)*, 2004.

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