MASTERS THESIS

IMPLICATIONS OF SECONDARY DNA TRANSFER & PUBLIC PERCEPTIONS ON THE NATIONAL DNA DATABASE OF SOUTH AFRICA

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DECLARATION

I, Polo Mapaballo Mokoma, hereby declare that this research study: *Implications of Secondary DNA Transfer & Public Perceptions on the National DNA Database of South Africa*, handed in for the qualification MSc at the University of the Free State, is my own independent work and that I have not submitted the same work for a qualification at/in another university. I also concede copyright of this work to the University of the Free State.

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Signature Date

FOREWORD

This research has been divided into two parts written in a series of articles. The part of the study detailed in the first article deals with the phenomenon of secondary DNA transfer and its implications to the use of DNA during criminal investigations.

The second and third articles make up the second part of the research. This part is a qualitative study aimed at determining the perceptions of the South African public regarding the National Forensic DNA Database of South Africa (NFDD) as well as the general knowledge of those individuals on the application of DNA as a criminal investigative tool. This part of the study will also be used to determine whether having more information on DNA and the DNA database as criminal investigative tools changes the perception of individuals regarding the subject.

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Lastly, I wish to show gratitude to my parents. Ma, this work is dedicated to you for all the struggles as a single mother and Ntate Nkopane, your spirit is what drove me to success! I love you both.

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ACRONYMS

AFIS- Automated Fingerprint Identification System

CE- Capillary Electrophoresis

CODIS- Combined Index system

DNA Act- Criminal Law (Forensic Procedures) Amendment Act, 2013

DNA- Deoxyribonucleic Acid

FSL- Forensic Science Laboratory

HLA- Human Leukocyte Antigen

LCN- Low Copy Number

LCN-DNA- Low copy number DNA

LNA- Locked Nucleic Acid

LT-DNA - Low template DNA

MPS- Massively Parallel Sequencing

NDNAD- National DNA Database

NFDD- National Forensic DNA Database of South Africa

NIST- National Institute of Science and Technology

PCR- Polymerase Chain Reaction

QA/QC- Quality Assurance/Quality control

RFLP-Restriction Fragment Length Polymorphism

SNP- Short Nucleotide Polymorphism

STR- Short Tandem Repeats

VNTR- Variable Number Tandem Repeats

CHAPTER 1: INTRODUCTION

1.1 Background to DNA testing for criminal investigative purposes

To clearly understand the role of DNA testing in criminal investigations, one has to first understand the history of identification or individualisation of people using biological systems.

1.1.1 Serological typing of blood

There are several blood grouping systems in existence but the most common is the ABO system described by Karl Landsteiner in 1901. Previously, it had been assumed that all blood was the same; however, in 1900 Karl Landsteiner discovered that blood from one person does not mix freely with blood from another person; instead agglutination might occur (Dean, 2005). This, he discovered, was due to the presence of some proteins (antigens) found on the surface of red blood cells and antibodies in the serum. He called the antigens A and B depending on which is expressed by the red blood cells and termed the blood groups as A and B respectively. He later included two more groups O, in which the red blood cells behaved as if they lacked the properties of A and B antigens, and AB which expressed both the A and B antigens. This discovery explained the often tragic consequences of blood transfusions. As is the case, the most common cause of death from a blood transfusion is a clerical error resulting in the transfusion of an incompatible type of ABO blood (Dean, 2005). In 1910, it was further discovered that these antigens, or lack thereof, were inherited. However, the mode of inheritance that would explain how a person’s blood type was determined was only described in 1924 (Dean, 2005). In 1940, Landsteiner along with his colleague Alexander Weiner discovered another red blood cell protein, the Rhesus factor (Rh factor) (Crow, 2010). This system, in combination with the ABO system, provided a means to identify individuals via their blood group. A combination of these two systems provided the first genetic tool used for distinguishing between individuals and applied to criminal investigations. The discrimination potential of the serological systems was however low as they relied on the expression of polymorphic proteins and the possibility of detecting a change in the physical property of such protein (Decorte *et al*., 1993). The ABO-Rh system was useful in the exclusion of an individual as a contributor of a crime scene sample but was limited once an inclusion had been made (Fourney, 2002).

By the 1980s a new system was added which provided more protein polymorphisms (Choo, 2007). Despite being a serological system, the Human Leukocyte Antigen (HLA) system is known to be the most polymorphic genetic system in humans (Choo, 2007) and was first introduced in forensic science for paternity testing in the late 1970s (Decorte *et al*., 1993). The most commonly used genes for forensic purposes were the class II genes of the HLA. DRB1 was mainly applied in paternity testing and DQA1 for forensic casework. The DRB1 is the most polymorphic of the HLA class II genes with a discrimination power of 98% and paternity exclusion probability of 80% (Decorte *et al.*, 1993). Due to the complexity of determining the alleles, it was not always easy to identify each genotype present in a mixture thus its application in forensic casework was limited. The DQA1 system was less complex hence suitable for forensic applications (Decorte *et al*., 1993).

In the mid-1980s, DNA technology was introduced in forensic science. This move was due to the fact that the most polymorphic sites in the human genome lie outside the amino acid coding regions (Decorte *et al*., 1993). This made a move from the use of protein polymorphisms to DNA polymorphisms. The first technique to be applied to DNA testing was Restriction Fragment Length Polymorphism (RFLP). With this technique, genomic DNA was treated with restriction enzymes which cut the DNA whenever a certain specific sequence of bases occurs generating a number of fragments (Panneerchelvam *et al*., 2003).

1.1.2 DNA Fingerprinting

In 1984, Alec Jeffreys discovered variable number tandem repeats (VNTR) or minisatellites and applied the RFLP technique to create a "DNA fingerprint" in the following year (Jeffreys *et al*., 1985). This technology was a large stride into the arena of forensic science because individualisation could be made with some certainty since the DNA fingerprint was individual specific (van Camp *et al*., 2007) and the profiles produced were reproducible even from dried blood stains (Decorate *et al*., 1993). The biggest problem with this technique was that it required a large amount of intact input DNA for a "fingerprint" to be useful posing a serious problem for forensic samples. In addition, this process was labour intensive and took a considerable amount of time to produce a result, a resource which is often not available in forensic casework. The resolution of mixtures also proved difficult (Decorate *et al*., 1993).

The invention of Polymerase Chain Reaction (PCR) in 1986 by Kerry Mullis (Mullis *et al*., 1986) improved the efficiency of DNA testing (Jeffreys *et al*., 1988) regardless of which system was used. Both HLA and VNTR analysis was improved with PCR because it enabled analysis of smaller amounts of DNA in less time. This made PCR-based methods preferable to their more labour intensive RFLP-based predecessors. In fact, the HLA-DQA1 system was the first commercially available forensic PCR kit (Decorate *et al*., 1993). Problems with the application of PCR on VNTRs led to the discovery of Short Tandem Repeats (STRs) or microsatellites in the late 1980's. With PCR analysis of VNTRs, shorter alleles were preferentially amplified. Consequently, the longest alleles tended not to be detected (Decorate *et al*., 1993). Microsatellites became a solution to the problem of VNTRs due to the smaller size of the region to be amplified hence could be detected efficiently.

1.1.3 STR and PCR

In the early 1990's, the forensic community migrated from the use of minisatellites to STRs for DNA analysis. With STRs and PCR, it became possible to successfully analyse degraded and trace DNA in a shorter amount of time (Decorate *et al*., 1993). The drawback to PCR technology is that the increased sensitivity heightens the problem of contamination during DNA analysis thus strict guidelines must be adhered to when using the method (Panneerchelvam *et al*., 2003). Due to the fact that STRs have fewer alleles than VNTRs, more loci were required to produce the same amount of information about the likelihood of two people sharing a profile compared to minisatellites (Smith *et al*., 1997). This led to the introduction of STR multiplex systems where many STR loci could be analysed simultaneously. These systems improved the efficiency and discrimination power of STR analysis and allowed for better application of DNA analysis to forensic casework (Gill, 2002). Together with the introduction of fluorescent labelling, automated sequencing technology and commercial STR kits, PCR-STR technology has become the preferred DNA typing technology in forensic laboratories. This technology has several advantages, namely; ease of interpretation of profiles, increased sensitivity, high discrimination, low cost, less time for analysis and better resolution of mixtures (Kashyap *et al*., 2004)

Over the years, improvements to DNA analysis using PCR technology have been made to increase the discrimination power and sensitivity of the analysis. To improve the discrimination power of STRs in the identification of individuals, more markers were developed. To study lineage and provide more discrimination in the identification of male persons, multiplex kits of the Y-chromosome markers (Y-STR) were developed (Butler, 2003; Daniels *et al*., 2004; Maynts-Press *et al*., 2007) and for female persons, mitochondrial DNA (mt-DNA) (Butler *et al*., 1998) and multiplex kits for X-chromosome markers (X-STR) are used (Szigbor *et al*., 2003). Using the gender marker (Amelogenin), a profile can be identified as either male or female (Sullivan *et al*., 1993) and once this distinction has been made then further analysis can then be carried out with the lineage markers. Single nucleotide polymorphisms (SNPs) perform better in the generation of genetic profiles from highly degraded samples as well as minute amounts of DNA due to their smaller size (Butler, 2003; Butler *et al*., 2007). A multiplex of SNPs has a high discrimination power that is efficient for analysis of degraded DNA. However, their reduced level of polymorphism as well as difficulty in mixture interpretation compared to STRs has hindered their routine use in forensic laboratories (Butler *et al*., 2007). Also, a huge investment towards improving the use of the consensus STR loci such as the validation of methods used, equipping laboratories, training personnel and efforts undertaken to gain admissibility into courts, has been made (Butler *et al*., 2007; Budowle *et al*., 2009). Introducing a new technology would disregard the investment already made on STR technology. The route taken to circumvent the shortfall of STRs and degraded DNA was to improve the existing system by re-engineering primers of the core STRs to reduce the length of the amplified flanking regions to produce "miniSTRs" (Butler *et al*., 2003). The miniSTRs have been multiplexed and have demonstrated improved performance in the analysis of degraded or inhibited DNA (van Oorschot *et al*., 2010). The best advantage of the miniSTRs is that comparison with profiles produced using standard STRs is still possible (Butler *et al*., 2003). It is expected that over time, more improvements to the current DNA analysis technology will be made to increase their efficiency but STR technology will not be replaced for the foreseeable future (Butler *et al*., 2007; Van Oorschot *et al*., 2010; Butler, 2012). Van Oorschot *et al*. (2010) make note of a few of the improvements made to STR technology above changing cycling conditions or primer sequence, namely; incorporation of locked nucleic acid (LNA) bases into the miniSTR primers, changing of master-mix components and the molecular mechanisms by which they interact, reducing the PCR volume, altering the type of DNA polymerase and addition of chemical adjuncts to improve amplification. Purification of the PCR amplicons, concentration of the PCR product, increasing injection time and/or voltage and using altered fluorophores are done to improve detection of the amplified product. All these improvements to the STR technology have greatly enhanced the analysis of trace DNA.

While Ge *et al.* (2014) acknowledge that STR technology will be used for a long while in the future; they state that more STR loci are required to provide better information to assist forensic investigations. Since the current Capillary Electrophoresis (CE) separation and detection technology is limited to analysis of only up to 30 STR loci which in turn limits the capacity of the markers for forensic application, they suggest Massively Parallel Sequencing (MPS) technologies as a viable alternative. Due to the high throughput, with MPS it is possible to type a battery of genetic markers including all forensically-relevant autosomal STRs, a set of Y-STRs and X-STRs, whole mt-DNA genome sequences and SNPs simultaneously. Analysis of this many markers means that higher accuracies, as well as resolution of mixtures would be feasible. The other benefit of MPS is that many thousands of samples can be processed simultaneously and best of all; the information produced can still be compared to the current STR data in the forensic databases. Currently, MPS has proved to be robust for typing of reference samples however, it is believed that more improvements to the technology will allow for increased sensitivity to analyse low quality and quantity of DNA (Ge *et al*., 2014).

1.1.4 Trace DNA Analysis

Van Oorschot *et al*. (2010) defines a trace DNA sample as any sample which falls below recommended thresholds at any stage of the analysis, from sample collection through to profile interpretation. This definition then includes what other writers term "touch" DNA, low template DNA (LT-DNA), low copy number DNA (LCN-DNA) and "low level" profile. As commonly as these terms are used interchangeably, van Oorschot *et al.* (2010) explain that each term is relevant at different stages within the process of DNA analysis. Touch DNA refers to the minute amounts of DNA collected and/or extracted; low template defines the minute amount of DNA material used at amplification stage; low copy number relates to the increased cycle number at amplification rather than the amount of DNA material and at interpretation phase, a profile is referred to as low level when the peak heights are below a validated threshold level.

In most forensic laboratories, the easiest and most commonly applied method to enhance the sensitivity of the standard PCR method is to increase the number of cycles from 28 to up to 34 (Gill, 2001; Kloosterman *et al*., 2003). The increased sensitivity of the LCN technique has allowed for the recovery of DNA from touched surfaces and the implication of this ability to forensic science is that the types of items of evidentiary value have increased (Gill, 2001). Previously, DNA testing was mainly utilised to solve serious crimes like homicide and rape but the ability to detect "touch DNA" has allowed for recovery and typing of DNA collected from evidence items recovered at scenes of volume crimes such as robberies, break-ins and hijackings. This means that DNA can be recovered from more evidence; from masks worn during a robbery to bite marks left on a victim of rape or homicide.

LCN-DNA analysis is not without problems however. With the increased number of PCR cycles come larger stutter peaks, allele drop ins and/or outs, heterozygote imbalance, locus drop outs and the occurrence of unknown allele peaks or contamination (Gill *et al*., 2000; Kloosterman *et al*., 2003; Forster *et al*., 2008). Contamination is a transfer of DNA after the crime event and it can occur at any point within the chain of custody (Gill, 2001). Contamination is not much of a problem when samples with high amounts of input DNA are dealt with but becomes a critical factor with LT-DNA analysis. Despite the fact that LCN-DNA analysis is now adopted by many forensic laboratories, the strength of evidence derived from this type of DNA analysis is decreased compared to the conventional DNA analysis methods. This is due to the uncertainties relating to the method of transfer and how and when the DNA was transferred (Gill, 2001) as well as the interpretation and reporting of the results obtained (Linacre, 2009). In their study, Foster *et al*. (2008) investigated other methods that can be used to enhance the 28 cycle PCR so that the problems resulting from an increased number of PCR cycles can be reduced. They concluded that by a combination of PCR product clean-up, concentration, increased sample loading as well as increased injection parameters, the same or better quality STR profiles could be produced from the 28-cycle PCR as those generated from a 34-cycle PCR.

1.2 DNA testing and the law

DNA testing in law enforcement is an undisputed asset. Forensic applications of DNA analysis are wide and cover a large spectrum of cases from criminal cases to missing persons' cases to wildlife cases. Since the first legal application of DNA profiling in an immigration case, in the United Kingdom (UK), by Alec Jeffreys in 1985 (Saad, 2005), DNA profiling has been used in criminal cases to solve serious crimes and, in recent times, volume crimes. The first criminal case solved through DNA profiling also served as the first case where this technology helped exonerate an innocent person. In 1986, Alec Jeffreys was called upon to assist the police with a double rape and murder case in Leicestershire. In that case, a suspect had confessed to one of the crimes, three years apart and DNA profiling linked the crimes but excluded the suspect in both of these crimes (Fourney, 2002). It was this success that prompted further use of DNA profiling in criminal investigations including cold cases, missing persons' cases, mass disaster cases, parentage cases and exonerations of those wrongfully convicted (Campbell, 2011). Research has suggested that even though there are many reasons for wrongful convictions, DNA is one of the most important tools utilised to prevent and uncover wrongful convictions. In fact, it has been determined that having access to DNA testing within the criminal justice system increases the likelihood of exoneration for murder and sexual assault by 6.93 times (Olney *et al*., 2014).

While acknowledging the benefits of DNA testing, it has to be mentioned that as the DNA profiling technology becomes more advanced, new problems are emerging. Previously, finding a person's DNA at the scene of crime implied presence at or near the scene of crime. Due to the existence of secondary or multiple DNA transfer, it can no longer be taken that one's DNA at any place means interaction with such an environment. With more studies conducted and concluding that secondary DNA transfer is possible, this phenomenon cannot be ignored. In the numerous studies conducted to determine the validity of the theory of multiple transfer of DNA, different conclusions have been reached regarding the significance of the phenomenon to criminal investigations depending on the method of analysis followed. Some researchers concluded that secondary DNA transfer has an impact on the routine analysis of DNA (Farmen *et al*., 2008; Aditya *et al*., 2011) while others concluded to the contrary (Ladd *et al*., 1999; Daly *et al*., 2012). Lawyers are increasingly proposing scenarios involving multiple transfer events as an explanation for the presence of a particular person's DNA at a crime scene (Goray *et al.*, 2010). This has thrown a curved-ball to the application of DNA in criminal investigations (see Chapter 2).

1.2.1 DNA databases

Over time, a need for comparison of profiles between cases and across jurisdictions drove the forensic community towards the use of consensus STR loci for generation of DNA profiles. This need for comparison also motivated for the establishment of national DNA databases in various countries.

The collection of profiles into a database has been an even better asset than just DNA analysis. A DNA database provides law enforcement with a scientific tool to supplement conventional investigative techniques. A DNA profile on its own is useful in cases where a suspect already exists, thus comparing the crime scene sample against the reference profile from the suspect is simple. In cases where conventional investigations have failed to yield a suspect, a profile derived from a crime scene sample is not useful and that is where the role of a database becomes significant. Databases are used successfully as investigative tools to identify serial offenders, link crimes and sometimes identify suspects where conventional methods fall short. Each time a new profile is loaded onto the database, it is automatically compared against existing profiles to yield a "hit" that can be used for intelligence purposes (Interpol, 2009). A basic DNA database consists of DNA profiles of convicted offenders and crime scene samples, the expansion of which may include profiles of suspects, arrestees, missing persons and volunteers depending on the legislated structure (Interpol, 2009). The UK set the ground in the establishment of a national DNA database in 1995 using a six STR loci multiplex followed by New Zealand and then the United States of America (US) in 1998 (Campbell, 2011). Many more countries have since followed suit in the establishment of their national databases and as of 2009, Interpol was aware of 120 countries that use DNA profiling as a criminal investigative tool (Interpol, 2009). The UK's NDNAD is the largest per capita while China and the US maintain two of the largest DNA databases in the world in terms of size. As at March 2014, the UK's NDNAD contained 5 716 085 reference profiles and close to five hundred thousand profiles from scenes of crimes representing approximately 9% of the country's population (UK, Home Office) while the Chinese and the US databases currently contain over 20 million and 12 million profiles respectively (Ge *et al*., 2014).

1.2.1.1 Benefits of DNA databases

The benefits of DNA databases are wide-ranging. With the databases, law enforcement agencies have been able to solve cases which would have otherwise remained a mystery. The ability of DNA databases to provide clues leading to the identification of suspects has made them invaluable in the fight against crime. The hits generated when a profile is run against existing profiles in a database often serve as crucial leads in a criminal investigation. This saves a lot of investigative hours and other resources allocated to the fight against crime. In addition to being a tool used to solve crime, DNA databases are also utilised in missing person cases as well as mass disaster cases. Using this tool, China has managed to identify and rescue 2455 trafficked children as of June 2013 and as at August 2012, the US has solved 3499 missing persons' cases (Ge *et al*., 2014).

DNA databases are said to serve as deterrents for future crime (Doleac, 2012). The argument that having one's profile captured into the database may prevent a person from future criminal activities for fear of being caught has been put forth as part of the reason for expansion of DNA databases by governments. Doleac (2012) noted that the effect of DNA profiling on recidivism varies with offenders' age and criminal history. The largest effect was observed on young offenders with multiple convictions and no effect was observed on older offenders with only one conviction. Bhati *et al*. (2014) also studied the deterrent effects of DNA databases and they determined that there was evidence of deterrence particularly for property crimes such as robbery and burglary. Bhati *et al*. (2014) further emphasised the probative value of DNA evidence in conviction of guilty offenders, identification of suspects as well as exoneration of those wrongfully convicted.

One other benefit of DNA databases is their potential to thwart cross-border criminality. Due to the fact that the national DNA databases of the different countries are built from the same core set of markers as set out and validated by the National Institute of Science and Technology (NIST), transfer and exchange of information on DNA databases between jurisdictions is possible. To expedite such exchange of information across jurisdictions, Interpol has also set up a DNA database, the DNA Gateway, through which the member countries can perform searches against profiles submitted by other states (Interpol, 2009). As at 2013, this database contained 140 000 DNA profiles contributed by 69 member states and the searches performed had resulted in 86 international hits (Interpol, 2014).

1.2.1.2 Controversies surrounding DNA databases

There is no doubt as to the significance and value of DNA databases in the criminal justice system however; there have been very justified concerns with regard to these tools. With the many success stories associated with the use of DNA databases come an almost equal amount of tales of the possible problems that could be borne by their application.

Campbell (2011) states that in the context of unconvicted individuals, the non-consensual collection of DNA encroaches on one's right to bodily integrity while storage of the DNA sample affects the right to privacy as well as the presumption of innocence. As well, with the increase in scope for inclusion to incorporate more crimes and/or arrestees, the number of profiles entered into the database has expanded the size of the DNA databases tremendously. With a larger database there is an increase in the match rate, meaning that there is a higher probability of obtaining a hit. However, a larger database also means a potential increase in adventitious hits which may result in miscarriages of justice. This has been the argument for and against the expansion of databases to include every citizen. The matter of adventitious hits due to the large size of a database can be circumvented by increasing the discrimination capability of the DNA test. Due to the fact that, ultimately, DNA evidence depends upon statistical probability, increasing the number of loci examined increases the discrimination power of the test in that the more the loci, the less the statistical probability that a random person other than the person whose profile matches that of the sample is the donor (de Wet *et al*., 2011). When the UK developed their DNA database, only six loci were used and this progressed to ten loci and currently sixteen loci and a sex marker are used (UK, Home Office). South Africa is also working towards a move from the 10-loci system to a 16-loci system (Heathfield, 2014). The negative implication of the move to multiplexes with more loci though is an increase in the financial burden associated with DNA analysis, a move that may not be afforded by smaller economies.

In his 2008 paper "The potential for error in forensic DNA testing (and how that complicates the use of DNA databases for criminal identification)", Thompson puts forth various ways in which DNA and associated databases can be fallible thus resulting in false incriminations. He covers a range of issues including coincidental matches resulting from partial and mixed profiles, statistics applied to the profile matches, erroneous matches due to contamination and inadvertent transfer of DNA or sample mislabelling or misinterpretation of results as well as intentional planting of DNA evidence at a scene of crime.

Other researchers have noted that DNA databases increase racial disparities as minor groups are often over represented in these databases (Simoncelli, 2006; Chow-White *et al*., 2011). In the UK's NDNAD, 7% of the profiles belong to black individuals; more than twice the size of the black population in the UK according to the 2011 population census (UK, Office of National Statistics). Similarly in the US, people of African origin are overrepresented in CODIS as a result of both widening the inclusion criteria as well as the existing racially skewed practices in other components of the criminal justice system (Levine *et al*., 2008; Chow-White *et al*., 2011). It is thus important to acknowledge that the issue of over-representation or under-representation of any one group is not necessarily a problem regarding the database as a tool but a problem of the entire criminal justice system. This unequal representation of races within the DNA database also means that expanding the database has a consequence of creating a universal coverage for certain races while almost entirely omitting others (Seringhaus, 2009).

An issue of concern also, is the accuracy of allelic frequencies utilized in match probability calculations of DNA databases (Thompson, 2008). There are differences in allele frequencies in different ethnic groups and these differences may influence the profile probability calculations. A match probability may be higher when a person is compared to their ethnic group than if compared to a different group or the whole population (Akram *et al*., 2012). However, due to the fact that in most cases, the allelic frequencies are determined using population databases in which the participants self-declare their ethnic group, it may be possible that the determined allelic frequency misrepresents a certain group (Buckleton *et al*., 2005).

An extension of the uses of DNA databases to include other applications such as familial searching has also raised more concerns regarding the application of DNA databases (Thompson, 2008). While familial searching has proved its value as an investigative technique through its successful application in various countries, the socio-legal-ethical concerns linked to its use cannot be ignored. There exists evidence that kinship analysis on a database increases the hit rate by 40% and there are clear examples where this type of search has resulted in the apprehension of criminals who would have otherwise eluded detection as well as cases where the innocent were exonerated (Rushton, 2010; DNAforensics). On the other hand, it must be accepted that with familial searching there is a higher possibility of adventitious links resulting in many false leads (Thompson, 2008; Rushton, 2010). Also associated with this type of database search is the potential to divulge unknown personal links thus affecting people's right to privacy. It is therefore important that the right balance between the pursuit of crime and people's rights be stricken to the effect that familial searching be employed only when all other investigative avenues have been exhausted and for those crimes considered serious or of a serial nature (Rushton, 2010; Myers *et al*. 2010).

Despite the fact that currently, the DNA profiles stored in the DNA database can only reveal a person's gender; there is a possibility that with improvements in technology and more research, linkage of the current STR markers to physical traits may be established. As it is, a DNA profile may reveal some genetic abnormalities (Heathfield, 2014). Granted that, the abnormalities are not obvious upon DNA profile interpretation however; DNA profiling is capable of revealing tri-allelic patterns at any one of the markers used (Heathfield, 2014). It is also worth mentioning that with the use of SNPs, it is possible to predict some physical traits that can be helpful in criminal investigations such as skin, eye and hair colour (Butler, 2012). The expanded capability of DNA testing through ancestry and phenotypic SNPs raises some ethical concerns however, it has been argued that no privacy of individuals is invaded since a person's externally visible characteristics are known thus cannot be considered private (Butler, 2012). Koops *et al*. (2008) state that while regulatory issues relevant to forensic genotyping are important, they must not be overestimated. It is however noted that forensic phenotyping must be carried out with strict guidelines and only when it contributes to the criminal investigation at hand.

1.2.1.3 Efficiency of DNA databases as criminal investigative tools

The efficiency of a database stems from the law that establishes it. The legislation provides for the most appropriate use of the database (Asplen, 2004) and differs from country to country. The DNA legislation prescribes for the administration and custody of the database, inclusion criteria for profiles and storage of both DNA samples and profiles. In some countries only convicted offender's profiles are entered into the database but not those of suspects (e.g. New Zealand, France); in some only convicted offenders with some prescribed sentence are entered (e.g. Netherlands, Sweden) and in some, a profile is entered into the database for suspects for any recordable offense (e.g. UK, Austria, Switzerland) (Jobling *et al*., 2004). Retention criteria also differ from country to country according to the severity of a crime (Netherlands) or outcome of a case (Finland) or some prescribed term by law. The size of each database thus depends on the criteria set out in the law for inclusion and retention of profiles. As a matter of fact, the reason behind the NDNAD's size is that a series of laws were introduced in the UK which systematically led to the expansion of the database. The Police and Criminal Evidence Act 1984 (PACE) allowed for the sampling of DNA from individuals charged with serious offenses. Then in 1994, the Criminal Justice and Police Act (CJPOA) established the NDNAD and routinised DNA collection by allowing collection of a non-intimate DNA sample without consent for any recordable offense. An amendment to the CJPOA in 2001 further allowed the police to permanently retain both the DNA sample and profile of all those sampled even if not convicted or cautioned for any crime (Johnson *et al*., 2003). These changes resulted in many people's profiles being included in the NDNAD, most of them innocent. This, however, has since been amended to limit the scope of inclusion as well as retention. Following the case of R vs S and Marper in the European Court for Human Rights where it was ruled that retention of a DNA profile after acquittal contravenes one's right to privacy, the UK amended its legislation to introduce retention periods according to the type of crime suspected (Wallace *et al*., 2014). The enactment of the Protection of Freedoms Act 2012 (PoFA) also resulted in the deletion of over a million DNA profiles belonging to people not convicted of any crime from the database in the year 2013/14 (UK, Home Office).

Technically, the more profiles a database contains, the higher the hit rate will be. With every new profile that is entered, the probability of obtaining a match increases, it is thus reasonable to assume that hit rates are correlated with improved effectiveness of the criminal justice system. Goulka *et al*. (2010) note the dangers of using either the database size or the match rate as measures for effectiveness of a DNA database. They argue that hit rates are output measures not outcome measures and a higher hit rate does not necessarily mean more offenders have been apprehended and prosecuted. This point is clearly illustrated when one looks at the UK database statistics. The NDNAD statistics from 1998 to 2012 clearly show that match rate is not the correct measure for efficiency of a DNA database (Wallace *et al*., 2014). With the increasing number of profiles kept in the NDNAD, one would have expected that more crimes would have been solved. This however has not been the case; in fact the increase in the size of the database seemed not to make any difference to what is termed DNA detections, meaning crimes where a match led to prosecution in a court of law. Fig. 1.1 shows that whilst there has been a steady increase in the size of the NDNAD from 2003 to 2012, the detection rate has remained more or less constant at 0.36% (Wallace *et al*., 2014).

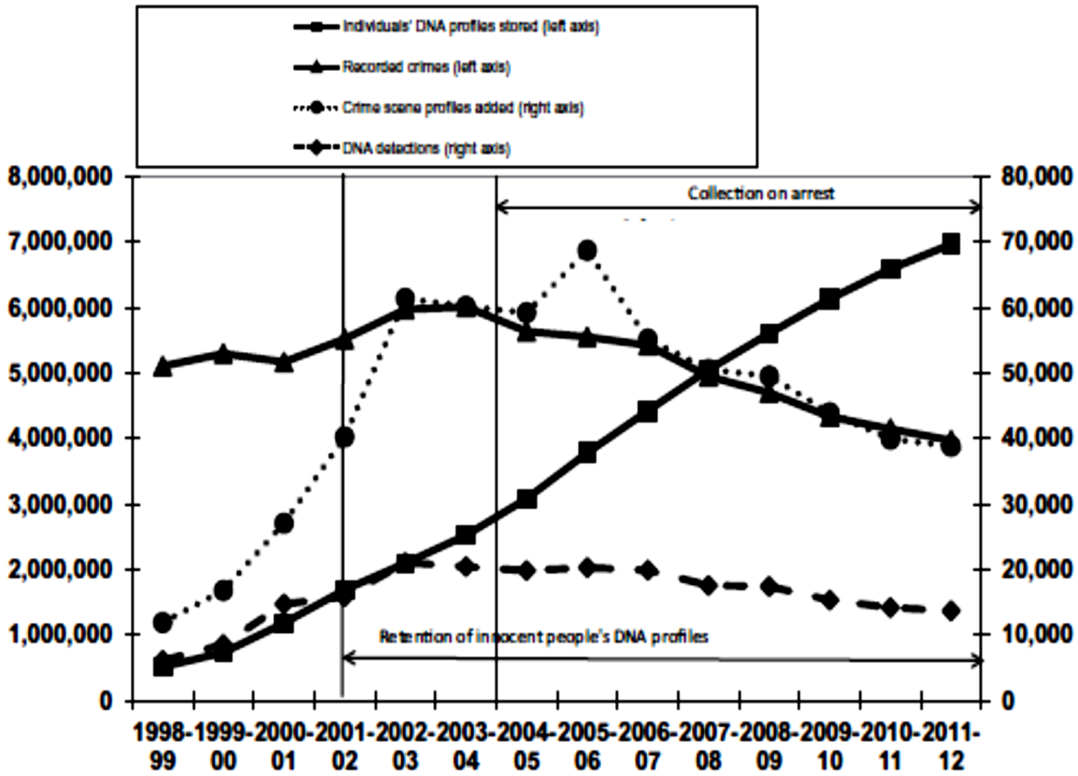

Figure 1.1 Crimes detected involving a DNA match, recorded crimes, individuals' DNA profiles stored on the UK's NDNAD and crime scene DNA profiles added per year from Apr 1998 to Mar 2012 (Wallace *et al*., 2014).

Goulka *et al*. (2010) also state that using size as a metric for database performance without also considering the concomitant trade-offs that might result from widening the net such as interference with people's rights of privacy and presumption of innocence, discrimination of minority groups as well as the cost implications of maintaining a large database is flawed.

Clearly, the value of a DNA database is determined by a proper balance between the benefits reaped and the trade-offs that result from its application in the criminal justice system. Due to the fact that DNA and DNA databases are applied in criminal investigations for the benefit of the citizens of a country, it is those same citizens who must determine the correct balance between crime prevention and possible draw-backs of having this technology in their lives. For this to occur citizens must be well informed on this technology as well as how it is applied and how it is to affect their daily lives. Thus far, all the studies conducted to collect the opinion of the general public or a specific group of individuals have yielded varying results depending on the group surveyed and the country where the study was conducted (Gamero *et al*., 2006; Gamero *et al*., 2007; Gamero *et al*., 2008; Curtis, 2009; Machado *et al*., 2011; Hoschild *et al.*, 2012; Stackhouse *et al*., 2010). What was similar though was the support that the use of DNA technology as a crime fighting tool had. In all these studies, the people surveyed indicated that

DNA technology is an asset that must be utilised to combat crime, the major differences in opinion appeared on issues relation to the question of whom to sample, retention of the physical DNA sample as well as the profile and custody of the DNA database (see Chapters 3 and 4).

The learnings from the NDNAD along with the Marper judgement have been used by other countries in drawing their DNA legislation. Other countries, including South Africa (SA), have used the UK's experiences when drawing their laws ensuring that the application of DNA databases as crime fighting tools are as efficient as possible.

1.2.2 DNA testing and the law in South Africa

The Criminal Law Act 51 of 1977 authorised the South African Police Service (SAPS) through the Forensic Science Laboratory (FSL) to perform criminal case work. The law allowed for sampling of biological material in the form of blood from people suspected of a crime strictly by qualified health professionals. This created a logistical nightmare to the execution of duties by the SAPS in a sense that consent was absolutely necessary and that could only be issued upon proof of probable cause. Even if consent was provided, it meant that the suspect had to be presented to the qualified health worker in a hospital or clinic for the drawing of blood or alternatively, the health worker had to collect the sample from a suspect where they are held. As a result, the use of DNA, or prior to the DNA era serological tests, for criminal investigative purposes was limited. With biological samples collected at scenes of crime and from suspects, South Africa started to build a DNA database consisting of two indices using a 10-loci system (PUB Programme, 2009). One of the challenges was that the law did not provide for comparison of a new profile against profiles in the database. The only comparison allowed was that of an existing suspect with crime scene profiles for a specific crime (PUB Programme, 2009). This in essence meant that if no suspect existed, then the crime scene profiles would not be very useful to investigators. It also meant that a suspect's profile could only be compared with crime scene profiles from a crime that would be the subject at that point hence DNA analysis was used to confirm whether the person in custody was indeed the perpetrator. This enabled many serial offenders to avoid detection for a considerable amount of time.

Realising the value of DNA in the criminal justice system along with the improvements in DNA analysis technology, an amendment bill to the Criminal Law Act, 1977 was proposed in 2008. The proposed legislation would allow for the expansion of the existing database and for comparative searches to be conducted. This would ensure the efficient use of DNA and the DNA database for forensic purposes.

Issues regarding human rights in other parts of the world resulted in a 4-year delay towards adoption of the amendment bill (Morris, 2013) which was finally enacted in 2014 and effected in January 2015. As Heathfield (2014) states, the passing of the Criminal Law (Forensic Procedures) Amendment Act, 2013 (DNA Act) signified the satisfying culmination of a persevering journey by the forensic community in South Africa.

1.2.3 The National Forensic DNA Database of South Africa (NFDD)

The Criminal Law (Forensic Procedures) Amendment Act 37 of 2013 prescribes the establishment, structure and administration of the National Forensic DNA Database (NFDD) of South Africa and sets out the inclusion and retention criteria for DNA profiles. According to this Act, the NFDD shall consist of six indices, namely; Crime Scene Index containing profiles from crime scene samples, Arrestee Index consisting of profiles of arrestees for all crimes, Convicted Offenders Index made up of profiles from convicted offenders for all crimes, Investigative Index consisting of profiles of people who assist with investigations but are not suspects or not directly involved, Elimination Index made up of profiles of people involved in the investigation of crimes and/or analysis of DNA samples including those employed at manufacturers of laboratory consumables and lastly, an index containing profiles of missing persons and unidentified human remains. The DNA Act allows for comparative searches to be conducted on profiles in all indices except those in the Investigative Index. This in effect means that all samples collected at scenes of crimes can be analysed and profiles searched against profiles in the database.

Familial searching is also allowed, however due to the issues that had arisen in other parts of the world regarding its application, the Act states clearly that whatever information obtained via familial searching must be treated with sensitivity. The Act also provides for the indefinite retention of DNA profiles of convicted offenders unless their conviction has been set aside or they have been pardoned. Different retention periods and conditions for profiles included in other indices have also been set. The maximum retention period for arrestee’s profiles is three years while that for minors, convicted or otherwise, is twelve months.

With the new DNA Act, the type of sample was changed from blood sample drawn by a medical professional to a non-intimate buccal swab that can be taken by police officers at a police station. This provided a means to circumvent the logistical hurdle that previously existed. With DNA sampling non-invasive, obtaining a sample and consent, where necessary, would be much easier and the risk of infection greatly reduced (Easteal, 1990). Provision for public awareness regarding the use of DNA and DNA database for criminal investigative purposes has also been made in the Act.

1.3 Aims and objectives of the study

With the implementation of the DNA Act, the use of DNA and DNA database for criminal investigative purposes is set to be routinized in South Africa. This study thus serves to address two issues:

1. Possible complications that may be introduced by the phenomenon of secondary DNA transfer to criminal investigations. Proving that the transfer of DNA material between persons and items they get in contact with during brief encounters is possible highlights the importance of crime scene conservation. It also brings added respect to QA/QC protocols that have been set as guidelines when handling forensically relevant biological material from collection through to analysis (Chapter 2).
2. Section 15T of the new DNA Act requires that the public be made aware of their rights regarding DNA collection as well as destruction of both sample and/or profiles. Public awareness programmes relating to the use of DNA in criminal investigation are thus not an option but an obligation under the South African law. This study was therefore conducted to put to test the level of knowledge and understanding as well as expectations of the participants on DNA and DNA database in the fight against crime. The collected views and opinions of the surveyed individuals regarding the application of DNA technology will provide solid evidence of support or rejection of the technology. With people showing support of the application of DNA and the DNA database as crime fighting tools, it makes it easier for politicians and legislators to fund the expansion and implementation of the database. Also, proving that having more information with regard to the application of this technology in criminal investigations has an effect on the view of individuals reinforces Section 15T of the Act (Chapters 3 and 4).

1.4 References

Akram, N.A., Forooqi, S.R. (2012) DNASF: A statistical package to analyse the distribution and polymorphisms of CODIS STR loci in a heterogenous population. *J Forensic Res*. 3 (9): 170.

Asplen, C. (2004) *The application of DNA technology in England and Wales*. [Online] U. S. Department of Justice. Available at: https://www.ncjrs.gov/pdffiles1/nij/grants/203971.pdf

Bhati, A., Roman, C.G. (2014) Evaluating and quantifying the specific deterrent effects of DNA databases. *Evaluation Review*. 38 (1): 68–93

Buckleton, J., Triggs, C.M., Walsh, S.J. (eds.) (2005) *Forensic DNA evidence interpretation*. Florida, USA: CRC Press.

Budowle, B., van Daal, A. (2009) Extracting evidence from forensic DNA analyses: future molecular biology directions. *BioTechniques.* 46: 339–350

Butler, J.M. (2003) Recent developments in Y-STR tandem repeat and Y-Single Nucleotide Polymorphism analysis. *Forensic Science Review*. 15: 91

Butler, J.M. (2012) *Advanced topics in forensic DNA typing: methodology*. Massachusetts, USA: Elsevier Inc.

Butler, J.M., Coble, M.D., Vallone, P.M. (2007) STRs vs SNPs: thoughts on the future of forensic DNA testing. *Forensic Sci Med Pathol*. 3: 200–205

Butler, J.M., Levine, B.C. (1998) Forensic applications of mitochondrial DNA. *Trends Biotechnol*. 16 (4): 158–62

Butler, J.M., Shen, Y., McCord, B.R. (2003) The development of reduced size STR amplicons as tools for analysis of degraded DNA. *J forensic Sci*. 48 (5): 1054–64

Campbell, L. (2011) “Non-conviction” DNA databases and criminal justice: a comparative analysis. *Journal of Commonwealth Criminal Law*. p. 55–77

Choo, S.Y. (2007) The HLA System: Genetics, Immunology, Clinical testing and Clinical implications. *Yonsei Medical Journal*. 48 (1): 11–23

Chow-White, P.A., Duster, T. (2011) Do health and forensic DNA databases increase racial disparities? *PLosMed* [Online]. 8(10): e1001100. Available from: doi:10.1371/journal.pmed.1001100

Crow, J.F. (2010) *DNA forensics: Past, present, and future* [Online]. Available from: http://www.promega.ca/~/media/files/resources/conference%20proceedings/ishi%2010/oral%20presentations/01crow.pdf?la=en.

Daniels, D.L., Hall, A.M., Ballentyne, J. (2004) SWGDAM developmental validation of a 19-locus Y-STR system for forensic casework. *J Forensic Sci*. 49 (4): 668-83

de Wet, S., Oosthuizen, H., Visser, J. (2011) DNA profiling and the law in South Africa. *PER/PELJ* [Online]. 14 (4). Available from: http://dx.doi.org/10.4314/pelj.v14i4.6

Dean, L. (2005) The ABO Blood Group. In: *Blood groups and red cell antigens* [Online]. Bethesda (MD): National Centre for Biotechnology Information (US). Available from: http://www.ncbi.nlm.nih.gov/books/NBK2267

Decorte, R., Cassiman, J. (1993) Forensic medicine and the polymerase chain reaction technique. *J Med Genes*. 30: 625–33

DNAforensics. (Undated) *Science of the future: Identifying criminals through their family members* [Online]. Available from: http://www.dnaforensics.com/FamilialSearches.aspx.

Doleac, J.L. (2012) *The effects of DNA databases on crime*. Stanford, CA 94305: Department of Economics, Stanford University.

Easteal, S. (1990) DNA fingerprinting by PCR amplification of HLA genes. In: Vernon, J. and Selinger, V. *DNA and Criminal Justice* [Online]. Australia: Australian Institute of Criminology. p.119-125. Available from: http://www.aic.gov.au/media_library/publications/proceedings/02/easteal.pdf

Forster, L., Thomson, J., Kutranov, S. (2008) Direct comparison of post-28-cycle PCR purification and modified capillary electrophoresis methods with the 34-cycle "low copy number" (LCN) method for analysis of trace forensic DNA samples. *Forensic Science International: Genetics* [Online]. 1: 415–417. Available from: http://dx.doi.org/10.1016/j.fsigen.2008.04.005

Fourney, R.M. (2002) *Forensic reality and the practical experience of DNA typing update* [Online]. International Society for the Reform of Criminal Law. Available from: http://www.isrcl.org/Papers/Fourney.pdf

Ge, J., Sun, H., Li, H., Liu, C., Yan, J., Budowle, B. (2014) Future directions of forensic DNA databases. *Croat Med J*. 55: 163–6

Gill, P. (2001) Application of low copy number DNA profiling. *Croat Med J*. 42: 229–232

Gill, P., Whitaker, J., Flaxman, C., Brown, N., Buckleton, J. (2000) An investigation of the rigor of interpretation rules for STRs derived from less than 100 pg of DNA. *Forensic Science International*. 112: 17–40

Goray, M., Mitchell, R.J., van Oorschot, R.A.H. (2010) Investigation of secondary DNA transfer of skin cells under controlled test conditions. *Legal Medicine*. 12: 117─120

Goulka, J., Matthies, C.F., Disley,E., Steinberg, P.S. (2010) *Toward a Comparison of DNA Profiling and Databases in the United States and England* [Online]. Santa Monica, CA: RAND Corporation. Available from: http://www.rand.org/pubs/technical_reports/TR918.

Heathfield, L.J. (2014) Policy required for entry of DNA profiles onto the National Forensic DNA Database of South Africa. *S Afr J Sci*. 110 (7/8)

Interpol. (2009) *Handbook on DNA data exchange and practice: Recommendations from the Interpol DNA Monitoring Expert Group* [Online]. Available from: www.interpol.int/content/download/.../7/.../HandbookPublic2009[2].pdf.

Interpol. (2014) *Fact Sheet: DNA Profiling* [Online]. Available from: www.interpol.int/en/News-and-media/.../Fact-sheets/DNA-Profiling/

Jeffreys, A.J., Wilson, V., Thein, L.S. (1985) Individual-specific 'fingerprints' of human DNA. *Nature.* 316 : 76-79

Jobling, M.A., Gill, P. (2004) Encoded evidence: DNA in forensic analysis. *Nature Review Genetics*. 5 (10): 739–51

Johnson, P., Martin, P., Williams, R. (2003) Genetics and Forensics: Making the National DNA Database. *Science Studies*. 16 (2): 22–37

Kashyap, V.K., Sitalaximi, T., Chattopadhayay, P., Trivedi, R. (2004) DNA profiling techniques in forensic analysis. *Int J Hum Genet*. 4 (1): 11–30

Kloosterman, A.D., Kersbergen, P. (2003) Efficacy and limits of genotyping low copy number DNA samples by multiplex PCR of STR loci. *International Congress Series*. 1239: 795–798

Koops, B., Schellekens, M. Forensic DNA phenotyping: Regulatory issues. (2008) *The Colombia Science and Technology Law Review*. 9: 158–202

Levine, H.G., Gettman, J.B., Reinarman, C., Peterson Small, D. (2008) *Drug arrests and DNA: Building Jim Crows's database* [Online]. Available from: http://www.councilforresponsiblegenetics.org/pageDocuments/0RRXBGGAEI.pdf

Linacre, A. (2009) Review of low template DNA typing. *Forensic Science International: Genetics Supplement Series*. 2: 549–550

Maynts-Press, K.A., Ballantyne, J. (2007) Performance characteristics of commercial Y-STR multiplex systems. *J Forensic Sci*. 52 (5): 1025–34

Morris, A.G. (2013) The DNA bill: Forensic science in the service of society. *S Afr J Sci* [Online]. p.109. Available from: http://dx.doi.org/10.1590/sajs.2013/a0043

Mullis, K., Faloona, F., Scharf, S., Saiki, R., Horn, G., Erlich, H. (1986) Specific enzymatic amplification of DNA in vitro: the Polymerase Chain Reaction. *Cold Spring Harb Symp Quant Biol*. 51 (1): 263–73

Myers, S.P., Timken, M.D., Piucci, L. M., Sims, G.A., Greenwald, M.A., weigand, J.J. et al. (2010) Searching for first-degree familial relationships in California's offender DNA database: Validation of a likelihood ratio- based approach. *Forensic Science International: Genetics* [Online]. Available from: doi:10.1016/jfsigen.2010.10.010

Olney, M. Bonn, S. (2014) An exploratory study of the legal and non-legal factors associated with exoneration for wrongful conviction: the power of DNA evidence. *Criminal Justice Policy Review*.

[Online]. p.1–21. Available from: http://cjp.sagepub.com/content/early/2014/02/13/0887403414521461

Panneerchelvam, S., Norazmi, M.N. (2003) Forensic DNA profiling and database. *Malaysian Journal of Medical Sciences.*10 (2): 20–26

Republic of South Africa. PUB Programme. (2009) Public understanding of Biotechnology: DNA profiling. [Online]. Available from: www.pub.ac.za

Rushton, S. (2010) *Familial searching and predictive DNA testing for forensic purposes: A review of laws and practices* [Online]. New Zealand: Victoria Law Foundation. Available from: http://dnaproject.co.za/new_dna/wp-content/uploads/2011/03/Report-Familial-Searching-and-Predictive-DNA-Testing-2010.pdf

Saad, R. (2005) Discovery, development, and current applications of DNA identity testing. *BUMC Proceedings*. 18: 130–133

Seringhaus, M.R. (2009) *Forensic DNA profiles: Database expansion, familial search and a radical solution* [Online]. Association for the Advancement of Artificial Intelligence. p.150–4. Available from: www.aaai,org

Simoncelli, T. (2006) Dangerous excursions: The case against expanding forensic DNA databases to innocent persons. *Journal of Law, Medicine & Ethics*. 390–397

Smith, G.B., Gordon, J.A. (1997) The admission of DNA evidence in state and federal courts. *Fordham Law Review*. 65 (6): 2465–2488

Sullivan, K.M., Mannucci, A., Kimpton, C.P., Gill, P. (1993) A rapid and quantitative DNA sex tests: fluorescence-based PCR analysis of X-Y homologous gene amelogenin. *Biotechs*. 15(4): 636–8, 640–1

Szigbor, R., Krawezak,M., Edelmann, J., Kuhlisch, E., Krause, D. (2003) Use of X-linked markers for forensic purposes. *Int J Legal Med*. 117: 67–74

Thompson, W.C. (2008) *The potential for error in forensic DNA testing (and how that complicates the use of DNA databases for criminal identification)* [Online]. New York: Council for Responsible

Genetics. Available from: http://www.councilforresponsiblegenetics.org/pagedocuments/h4t5eoyuzi.pdf

United Kingdom. Home Office. (2014) *National DNA Database: Annual Report 2013–2014* [Online]. United Kingdom: The Williams Lea Group. Available from: https://www.gov.uk/government/publications/national-dna-database-annual-report-2013-to-2014

United Kingdom. Office of the National Statistics. (2012*) Ethnicity and national identity in England and Wales 2011*. [Online] Available from: www.ons.gov.uk

van Camp, N., Diedrikx, K., Leuven, K.U. (2007) The expansion of forensic DNA databases and police sampling powers in the post-9/11 era: Ethical considerations on genetic privacy. *Ethical Perspectives.* 14 (3): 237–268

van Oorschot, R. A.H., Ballantyne, K.N., Mitchell, R.J. (2010) Forensic trace DNA: a review. *Investigative Genetics*. 1 (14)

Wallace, H.M., Jackson, A.R., Gruber, J., Thibedeau, A.D. (2014) Forensic DNA databases: Ethical and legal standards: A global review. *Egyptian Journal of Forensic Science*. [Online] Available from: http://dx.doi.org/10.1016/j.ejfs.2014.04.002

CHAPTER 2: IMPLICATIONS OF SECONDARY DNA TRANSFER TO CRIMINAL INVESTIGATIONS

Abstract

The increased sensitivity of deoxyribonucleic acid (DNA) profiling techniques have made it possible to obtain DNA profiles from touched objects. The concept of inadvertent DNA transfer is now an issue in the courts of law and its significance to cases is increasing. The issue of contamination during the processing of DNA evidence from the crime scene to the laboratory is a critical issue that throws a curved-ball in the presentation of DNA evidence in court. In this study, three experiments were designed to test for primary and secondary transfer of DNA. The results obtained confirm that DNA can be transferred from one person to the next and further onto the items they come in contact with. The efficiency of the transfer depends on the substrate touched, the shedder status of the individuals as well as their dexterity.

The implication of positive results is that quality assurance/control (QA/QC) protocols throughout the chain of custody must be vigilantly adhered to in order to minimise the occurrences of contamination through DNA transfer, whether primary, secondary or tertiary. This is especially important when dealing with minute amounts of DNA. Taking this scenario into consideration, it must be emphasised that DNA evidence derived by means of touch DNA has to be largely augmented by other evidence before it can be presented in court.

2.1 Introduction

Under normal circumstances, individuals shed thousands of skin cells daily, some more than others (Sangeeta *et al*., 2011). These deoxyribonucleic (DNA)-rich cells are transferred onto items which an individual comes into contact with and the amount of DNA deposited or transferred depends on several factors including the nature of the substrate contacted; the manner of contact as well as the timing between the transfer and the sampling of the DNA. Non-porous objects have been observed to be better primary substrates than porous substrates as DNA material readily transfers from a non-porous object onto the next object. On the other hand, porous objects as secondary substrates are better than non-porous objects as they facilitate transfer more readily than non-porous objects (Goray *et al*., 2010). Daly *et al*. (2012) investigated the effect of different substrates – glass, fabric and wood- on the amount of DNA transferred and found that glass yielded the least positive results of the three substrates tested due to its non-porous nature. It has also been observed that longer contact and more pressure or friction applied during contact facilitates transfer and adherence of DNA material onto a touched item (Ladd *et al*., 1999; Djuric *et al*., 2008; Goray *et al*., 2010). In their study, Djuric *et al.* (2008) concluded that hand-dominance is a factor in the amount of DNA that can be transferred onto touched surfaces due to the difference in the pressure applied at contact by the right or left hands depending on the dexterity of the individual. In addition, it has been observed that the shorter the time interval between contact and sampling the better the chance of DNA recovery from a touched item (Ladd *et al*., 1999). Arguments have been made that some people are naturally better shedders of skin cells than others hence the amount of DNA transferred between surfaces is also dependent on the shedder status of the particular individual involved in the contact (Farmen *et al*., 2008). The reasons for the difference in the ability of individuals to shed more skin cells than others are not yet known. It, however, must be stated that even for the so-called "good shedders", the status of shedding fluctuates depending on the factors stated above and personal habits that allow for the transfer of skin cells from one part of the body to the other (Kelley, 2010). Thus, the likelihood of obtaining a DNA profile from a touched object does not only depend on the shedder status of the individual, but also on the hand they used, the time elapsed between contact and sampling, the substrate involved and the activities of the individual involved in the contact prior to touching the object.

The phenomenon of recovering DNA from touched items was first reported by van Oorschot and colleagues in 1997. In the following decade, more research was conducted to examine various scenarios; from the feasibility of touch DNA itself (Djuric *et al*., 2008); to the impact of the different environmental conditions that affect the quantity and quality of DNA recovered (Farmen *et al*., 2008; Goray *et al*., 2010; Daly *et al*., 2012; Goray *et al*., 2012); to the impact of extraction methods and Polymerase Chain Reaction (PCR) techniques (Lowe *et al*., 2002; Bright *et al*., 2004; Forster *et al*., 2008; Aditya *et al*., 2011). Currently, DNA typing technologies have evolved and improved to the extent that less than 100 pg of input DNA can be used to obtain a full DNA profile (Lowe *et al*., 2002; Gill, 2002). Analysis of trace DNA or "touch" DNA is now the norm rather than the exception in forensic laboratories with interest growing as more and more high profile cases are being solved using this technology. It should be stated that touch DNA may be used only if it is of potential evidentiary value (Williamson, 2012). This means that the relationship between the victim and the suspect or the owner of the profile discovered at the crime scene must always be taken into account when collecting such evidence. The position where a sample is taken on the touched item is also important to note so that only the relevant sample is collected. Prioritising the sampling, such that items likely to yield sufficient quantities of DNA for analysis are taken first, is also key. Daly *et al.* (2012) suggested the sampling order for touch DNA regarding substrates should be from porous to non-porous objects in order to obtain samples that could yield the most useful profiles.

With trace DNA analysis, it is not possible to infer as to when the DNA was left at the crime scene or to the events that led to the DNA being deposited there. The trace could have been left before, during or after the crime in question and thus it is important to answer the question of how the suspect's DNA got to the scene of the crime, as there is always a possibility of transfer of an innocent person's DNA between individuals as well as to objects they have been in contact with. The drawback in the ability to analyse minute amounts of DNA is that the increased sensitivity of the methods employed will not only detect the DNA of interest to the case but will also detect very low level background DNA that would have otherwise not been detected under normal conditions (Gill, 2002; Goray *et al*., 2012). Contamination throughout the chain of custody is thus brought to the fore and the importance of control measures in the process of DNA analysis is highlighted. Vandewoestyne *et al*. (2011) investigated the possible sources of DNA contamination in a forensic laboratory and reported that most of the regularly used surfaces and equipment within the laboratory had some DNA contamination and thus can act as vectors for DNA transfer. They proposed that regular and stringent decontamination routines must be carried out to minimise this risk in the laboratory.

Through all the studies conducted to investigate touch DNA since 1997, the general consensus is that DNA transfer, whether primary or secondary, is possible and that it can be a factor during routine DNA analysis in a forensic laboratory especially when dealing with minute amounts of DNA. The significance, or implication, of secondary DNA transfer to a criminal investigation does depend on how the sample was collected, extracted and amplified; thus different conclusions have been reached depending on which processing technique was used. In their study, Aditya *et al.* (2011) concluded that Low Copy Number (LCN) DNA typing with miniSTRs yielded more interpretable profiles from touched items in comparison with profiles yielded through use of conventional STR typing methods employing the AmpF*l*STR Identifiler® PCR Amplification kit (Applied Biosystems, Foster City, CA, USA). Daly *et al.* (2012) concluded that secondary DNA transfer is not significant in routine forensic casework, having used a modified protocol of the QIAmp® DNA mini kit (Qiagen, Hilden, Germany) for extraction and the conventional 28 cycle PCR for amplification. On the other hand, Farmen *et al.* (2008) reported significant results from their study having used the Chelex® (Bio-Rad Laboratories, Hercules, CA, USA) method of extraction and the 34 cycle PCR for processing samples from touched items. The efficiency of touch DNA typing is thus dependent on the techniques employed for the process from sample collection to profile interpretation.

The objective of this study was then to investigate the phenomenon of secondary DNA transfer and its implications to criminal investigations using a modified protocol of the QIAmp® DNA mini kit (Qiagen, Hilden, Germany) for extraction and an optimised PCR protocol where the number of PCR cycles was increased to 32.

2.2 Materials and Methods

2.2.1 Sampling

Three experiments were conducted in total to test for primary and secondary DNA transfer with the assistance of two volunteers, one male and the other female. The volunteers' shedder status was unknown and they were advised to carry on with their routine prior to sampling for the experiments. Reference samples from the two volunteers were collected with buccal swabs to determine their reference DNA profiles. Glass was used as a substrate for transfer to emulate the worst-case scenario as it was found to be the least successful substrate in previous transfer studies (Daly *et al*., 2012). All the glassware used in the experiments was first cleaned with ordinary detergent followed by 5% bleach (Hypochlorite) solution and then autoclaved at 121 °C for 25 minutes. Sampling was carried out immediately after autoclaving. In all the experiments, the double swab method was used to collect the DNA sample whereby a moist swab followed by a dry one were used. Both hands of the volunteers were swabbed resulting in two samples per person and the experiments were repeated five times on different days.

In the first experiment designed to check for primary transfer, the volunteers shook hands using both hands for approximately 15 seconds (Fig. 2.1a) and then both hands for each individual were swabbed to collect DNA (Fig. 2.1b).

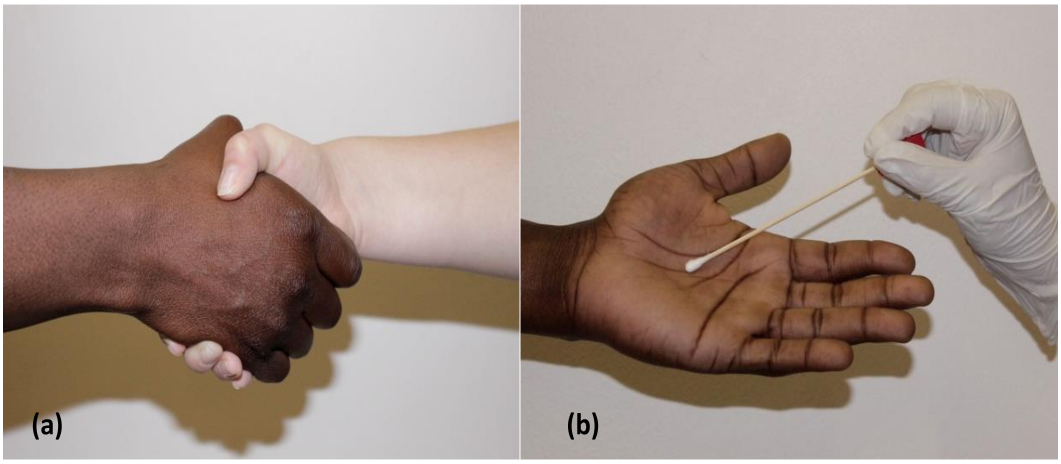

Figure 2.1: (a) Volunteers shaking hands for 15 sec and (b) both hands were swabbed to collect DNA

For the second experiment designed to test for transfer of DNA from person to person to object, the volunteers repeated the first experiment and then each individual immediately held a previously cleaned and sterilised glass bottle for approximately 30 seconds per hand (Fig. 2.2a). The bottles were then swabbed to retrieve the transferred DNA (Fig. 2.2b).

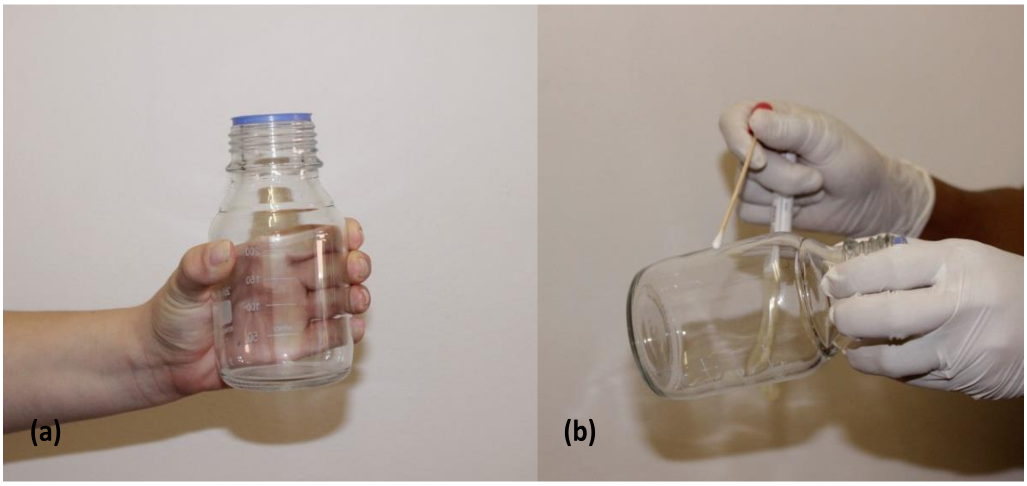

Figure 2.1: (a) Volunteers hold a clean glass bottle for 30sec after shaking hands and (b) the bottle double swabbed to collect DNA sample

In the third experiment to test for transfer of DNA from person to object to object, one of the volunteers donated a shirt that had been worn the previous day. The second volunteer, using gloved hands handled the shirt for approximately 30 seconds and then held a previously cleaned and sterilised glass bottle for approximately 30 seconds per hand as in experiment two. The bottles were then swabbed to obtain a DNA sample.

All the swabs collected throughout the three experiments were allowed to dry for 48 hours before extraction was carried out.

2.2.2 DNA Extraction and Quantification

DNA extraction was done using the QIAamp® DNA mini kit (Qiagen, Hilden, Germany) for all reference and test samples following the buccal swab spin protocol. For the reference samples, the manufacturer's instructions were followed. However, for the test samples the DNA was eluded in 25 µl elution buffer instead of the prescribed 150 µl. This was done to increase the concentration of the DNA extracted.

The amount of DNA extracted was quantified to determine the average amount of DNA obtained in the three experiments. Quantification was done with the Quantifier™ Human DNA Quantification kit (Applied Biosystems, Foster City, CA, USA) following the manufacturer's protocol employing the 7900HT RT-PCR System (Applied Biosystems, Foster City, CA, USA).

2.2.3 DNA Amplification and Fragment analysis

Human specific microsatellites and gender identification markers were used and the primer pairs included in the reactions are listed in Table 2.1. The PCR reaction mixture consisted of 6 µl of Kapa2G Robust HotStart ReadyMix (Kapa Biosystems, Boston, MA, USA) made up of 1x buffer containing 2 mM $MgCl_2$, 0.2 mM of each dNTP and 1U Kapa2G Robust HotStart DNA polymerase (Kapa Biosystems, Boston, MA, USA). To the readymix, 1 µM of each primer and 2 µl of 0─0.194 ng/µl DNA was added. Nuclease free water was added to make up a final PCR reaction volume of 15 µl. Positive and negative controls were included for quality assurance purposes. The PCR temperature cycles included 95 ºC for 11 minutes; 32 cycles of 94 ºC for 30 seconds, 63 ºC for 30 seconds and 72 ºC for 1 minute with a final extension step of 45 minutes at 60 ºC. The samples were stored at 10 ºC.

Table 2.1: STR and gender identification markers included in the PCR reactions

LOCUS NAME	**PRIMER SEQUENCE** **Forward (top row) & Reverse (bottom row)**	**Fluorescent Label** **(G5 filter set)**
TH01	GTGATTCCCATTGGCCTGTTC ATTCCTGTGGGCTGAAAAGCTC	VIC (Green)
vWA	GCCCTAGTGGATGATAAGAATAATCAGTATGTG GGACAGATGATAAATACATAGGATGGATGG	6 FAM (Blue)
D5S818	GGTGATTTTCCTCTTTGGTATCC AGCCACAGTTTACAACATTTGTATCT	NED (Yellow)
D8S1179	ATTGCAACTTATATGTATTTTTGTATTTCATG ACCAAATTGTGTTCATGAGTATAGTTTC	6 FAM (Blue)
Amelogenin	CCCTGGGCTCTGTAAAGAA ATCAGAGCTTAAACTGGGAAGCTG	VIC (Green)

* Krenke B.E., Tereba A., Anderson S.J., Buel E., Culhane S., Finis C.J. *et al*. (2002) Validation of a 16-locus fluorescent multiplex system. *J. Forensic Sci*. 47(4)

Fragment analysis was performed on the ABI PRISM® 3130 genetic analyser (Applied Biosystems, Foster City, CA, USA) and the sizing done using GeneMapper™ 3.0 software. Allele scoring was based on fragment size rather than the number of repeats due to the fact that a commercial kit was not used thus an allelic ladder was not available. The profiles produced were classified as full, partial or no result where a full profile would bear alleles of the touched person in all five markers used and a partial profile bear alleles in only one to four of the markers analysed. The resultant electropherograms were interpreted by three analysts individually and only the consensus alleles were recorded as true. As a guide, an arbitrary peak height threshold of 100 RFU was utilised and peaks that were less than 15% of the main alleles were considered as stutter peaks. The threshold was chosen based on validation studies performed in the laboratory and on previously published literature on contamination and Low Template (LT)/LCN DNA analysis (van Oorschot *et al*., 2005; Vandewoestyne *et al*., 2011).

Descriptive statistics as well as the t-values were used to compare the results obtained in the three experiments. The study was conducted with approval of the Dean of the Faculty of Natural and Agricultural Sciences and with the consent of the participants (Appendix 1).

2.3 Results and Discussion

2.3.1 Experiment 1: Primary transfer

Realtime PCR quantification indicated that the amount of DNA obtained from the swabs taken ranged between 0.015 ng/µl and 0.19 ng/µl. This total amount was contributed by both volunteers as shown by the mixed profiles obtained. Alleles belonging to both volunteers were observed at some or all loci for the different samples. Of the samples collected from both volunteers, 18% yielded full profiles of the person touched and 76% of the samples yielded partial profiles of that person. A full profile was defined by the detection of all the alleles of the touched person in all five loci analysed while a partial profile was defined as exhibiting alleles belonging to the touched person at less than five loci. These results confirmed that DNA can be transferred from one person to the next during brief encounters.

The larger fragment size (D8S1179) failed to amplify in a multiplex and was amplified in a singleplex with better success rate where alleles at this locus were then observed in 47% of the samples. This phenomenon where high molecular weight loci fail to amplify was also observed by Ladd *et al*. (1999) and Allesandrini *et al.* (2003) where up to 60.6% of locus drop-outs were observed. Interestingly, in this study, it was observed that the full profiles obtained were not from samples with the highest amount of DNA. In fact, one of the full profiles resulted from a sample with the least quantity of DNA obtained (0.015 ng/µl). This was an unexpected observation because with LCN analysis, a reasonable expectation would be that the higher the amount of DNA recovered, the better the chances of obtaining a full profile. In this case the quality of the DNA recovered may have played a bigger role than the quantity with the consequence that there was no direct link between quantity of DNA and the quality of the profile produced.

2.3.2 Experiment 2: Secondary transfer- person to person to object

The amount of DNA recovered in this experiment ranged between 0.005 ng/µl and 0.05 ng/µl. As expected, the average amount of DNA recovered from the primary transfer experiment was more than the amount recovered from this experiment ($p = 0.04$) as transfer introduces some DNA loss. In addition, due to the non-porous nature of glass, it was expected that less DNA would adhere onto the surface of the bottle when contact was introduced hence less DNA would be recovered from it. Based on the results of this experiment, it was thus determined that it is possible to detect DNA that was transferred from one person to another person and then onto an item that the second person touched.

Despite the minimal amount of DNA recovered, partial and mixed DNA profiles were obtained, from all the samples. Secondary DNA transfer was observed in the majority of the samples (89%) where partial profiles of the person who was touched but who did not touch the glass bottle were observed. This proved that DNA was transferred between the two volunteers during the handshake and then further onto the glass bottle touched. The most prominent profile observed in most of these samples was of the person who touched the glass directly except in one case where the most prominent profile came from the person who had never touched the glass bottle (Table 2.2). The results shown in table 2.2 indicate that even though after the volunteers shook hands and volunteer 1 handled the glass, the most prominent profile recovered from the glass belonged to volunteer 2 who had never touched it.

Table 2.2: Results demonstrating that the most prominent profile observed was not of the person who came in direct contact with the substrate.

Description	TH01	vWA	D5S818	D8S1179	Amelogenin
Volunteer 1	168/176	160/164	137/141	233	105/110
Volunteer 2	180	142/146	137	220/242	105
Result	180	142/146	137	No result	105/110

A similar result was obtained by Lowe *et al*. (2002) and Farmen *et al.* (2008), confirming that despite the expectation that the most prominent profile recovered from a substrate would be that of the person who touched it directly, it is possible to have results where the major contributor to a mixed profile would be a person who had never touched the substrate in question. The implication of such a finding to casework is that one person may be thought to have handled an object based on the fact that their profile seems to be the most dominant, while in fact their DNA was transferred secondarily from the person they had recently come in contact with. It must however be stated that, because sampling of the DNA from the touched object was carried out immediately, having a person's profile being more prominent than the person who actually touched an object would also mean that the two individuals ought to have been together at the scene of crime (Lowe *et al*., 2002;Daly *et al*., 2012). A possible implication of this in casework is that the person whose profile is observed, even if they were not directly responsible for a particular crime, could have been present at the time of crime in question and may have some information that could be useful to the investigation.

The results obtained also supported the conclusion made by Djuric *et al.* (2008) that hand dominance is a factor in the amount of DNA transferred onto touched items. Over 50% of the samples recovered from the dominant hand yielded more than half the alleles expected compared to the 38% recovered from the non-dominant hand. Also, a larger number of samples which yielded over 50% of the alleles belonging to the person who was not in contact with the glass came from our male volunteer. This could be attributed to the fact that the male individual might have applied more pressure than his female counterpart hence more friction applied that allowed for better adherence of DNA material onto the glass. This was not studied or analysed further hence male-female bias towards DNA transfer cannot be established. Other researchers however concluded that there is no male-female bias in the tendency to deposit or transfer DNA (Lowe *et al*., 2002; Farmen *et al*., 2008; Daly *et al*., 2012).

2.3.3 Experiment 3: Secondary transfer- Person to object to object

The average amount of DNA recovered in this experiment was lower than the amount recovered in experiments one and two (Table 2.3). This supports the conclusion made by Goray *et al.* (2010) that non-porous substrates, like glass in this case, are good primary substrates and poor secondary substrates. In this experiment, the clothing item was used as a primary substrate, which has been proven to be poor for that purpose as fabric facilitates adherence of DNA but not its transfer. Consequently, DNA was not easily obtained from the clothing item and transferred onto the glass. Even less DNA was able to adhere to the glass surface for it to be recovered by swabbing.

Table 2.3: Concentration of DNA (ng/µl) recovered in experiment 3

Sample #	1	2	3	4	5	6	7	8	9	10	Average
DNA Conc. (ng/µl)	0	0	0.00328	0.00365	0.00532	0	0	0	0	0.00208	**0.001433**

The amount of DNA recovered in this experiment was generally below the instrument's detection threshold for commercial kits according to the manufacturer (0.023 ng/µl) as well as to previous research (Daly *et al*., 2012). In 60% of the samples, the amount of DNA present was not detectable (Table 2.3). Fragment analysis was, however, performed successfully with interpretable results obtained. Partial profiles were obtained from 90% (n = 9) of the samples with the exception of one sample where a full profile was recovered. The profile however, did not match either of our volunteers nor the analyst. The profile may have belonged to some person, other than the donor/wearer, who may have handled, or come in to contact with the piece of clothing used for the experiments. These results also support the conclusion made by Poy and van Oorschot (2006) in their study where they demonstrated that gloves, while worn during examination of exhibits in forensic biology laboratories to protect the wearer from harmful agents as well as the exhibit from contamination by the wearer, can act as vectors for DNA transfer from one part of the exhibit to the other and/or tools utilized during examination.

The results observed in this experiment are contrary to the expectation in that there did not appear to be a direct relationship between the amount of DNA obtained and the type of profile observed. The peak intensity and the quality of the profile obtained from the sample which had the most amount of DNA (0.0053 ng/µl) (Fig. 2.3) were much lower than those observed from the sample which did not yield any quantification results (Fig. 2.4).

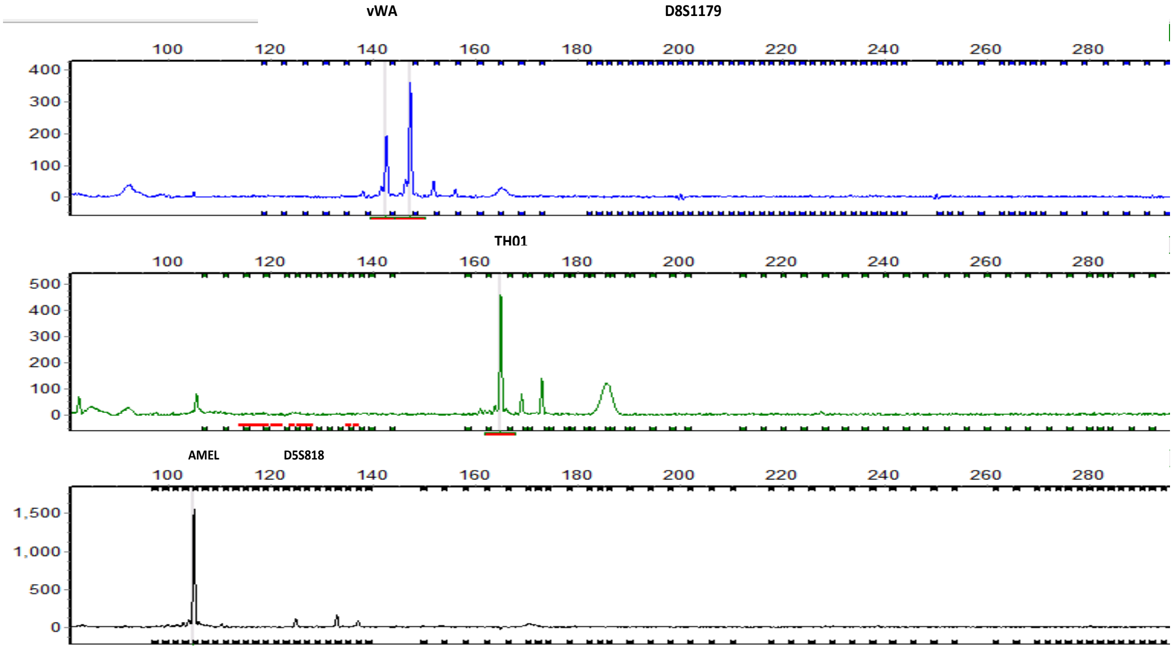

Figure 2.2: Profile obtained from sample with the largest amount of DNA

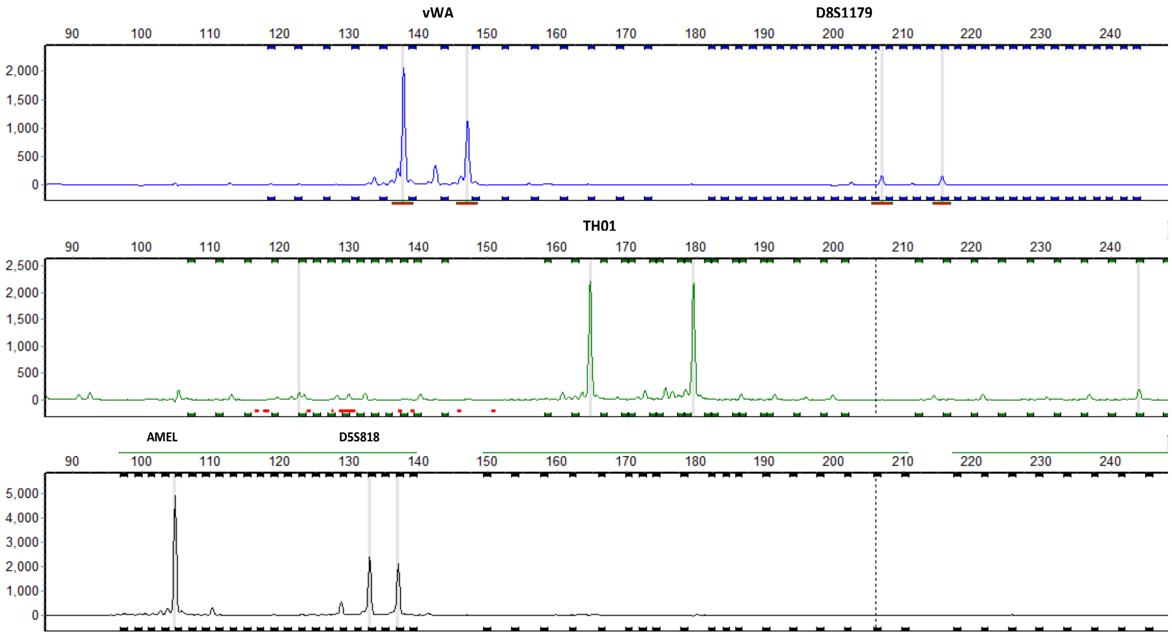

Figure 2.3: Profile obtained from one of the samples with no quantification results.

This leads to the conclusion that samples with a DNA amount that is below the detection threshold of an instrument should not be excluded for further analysis as it is possible to obtain useful profiles as, in some cases, the quality of the DNA may play a bigger role than its quantity. The results not only prove that secondary DNA transfer is possible, but also show that tertiary transfer may be possible. The unknown profile could be attributed to tertiary DNA transfer if it belonged to a person whose clothing was previously in contact with our donor's piece of clothing. Hand dominance was also apparent in these results where more alleles were recovered from bottles handled using the dominant hand compared to the non-dominant hand (average 71% compared to 57%). With regard to the amount of DNA recovered, there was no difference between the two hands ($p = 0.68$) hence hand-dominance did not seem to be a significant factor. This phenomenon was however not explored further in this study.

In both experiments two and three, the amount of DNA transferred and recovered was limited by the substrate chosen as well as the extraction protocol followed. Glass as a substrate has been proven to be poor thus it presents the worst-case scenario for DNA transfer and recovery. It is therefore anticipated that the success rate of a study involving a porous substrate would be higher than the rate observed in this study. This means that with porous substrates, the probabilities of obtaining full profiles that can be used in individualisation in similar circumstances are expected to be higher. The extraction protocol followed in this study included allowing the swabs used to collect the biological material to dry for 48 hours before extraction. van Oorschot *et al*. (2003) have shown that there is a difference in the amount of DNA extracted between dried and wet cotton swabs. Drying may facilitate stronger adhesion of the biological material onto the fibres of the swab leading to loss of DNA material at extraction. Drying of swabs was included in the protocol for this study to emulate forensic casework sampling as closely as possible. When swabs of biological material are collected at the scene of a crime, they are often not analysed immediately. It is often the case that these swabs are dried and kept in storage until such time that they are analysed. Due to the backlog for DNA analysis at most laboratories, it is thus likely that the swabs would be dried and stored for more than the 48 hours set for this study. It is also important to note that the type of cotton swabs used may have had an effect on the amount of DNA collected. Rocque *et al*. (2014) have shown that the efficiency of cotton swabs as DNA collection devices depends upon the tightness of cotton mesh. They proved that the looser the mesh of the cotton swab, the more efficient in both absorption and release of the DNA material. As well, it is expected that cotton swabs would be less efficient than their nylon-flocked counterparts in DNA collection as the latter have an increased surface area onto which the DNA material adheres (Santiago *et al*., 2013).

2.4 Conclusion

The results of this study show that innocent transfer of trace DNA can occur between individuals and the items they come in contact with; hence there may be a reasonable explanation as to the presence of a person's DNA at the scene of a crime. Through the research conducted, it is clear that the possibility of secondary DNA transfer, whether found on evidentiary items, or as a result of contamination throughout the chain of custody, cannot be ignored. In contrast to the conclusion reached by Ladd *et al.* (1999) that secondary DNA transfer cannot interfere with interpretation of profiles from casework, we believe that it can impact the interpretation of the results because of the mixed profiles obtained. Mixture analysis is complicated, more so with allelic and/or locus drop outs, spurious alleles, high background noise and stutter peaks (Naughton *et al*., 2011) as observed in this study.

2.5 References

Aditya, S., Sharma, A.K., Bhattacharyya, C.N., Chaudhri, K. (2011) Generating STR profile from "touch DNA". *Journal of Forensic and Legal Medicine*. 18: 295–298

Alessandrini, F., Cecati, M., Pesaresi, M., Turchi, C., Carle, F., Tagliabracci, A. (2003) Fingerprints as evidence for a genetic profile: Morphological study on fingerprints and analysis of exogenous and individual factors affecting DNA typing. *J Forensic Sci*. 48(3)

Bright, J., Petricevic, F.S. (2004) Recovery of trace DNA and its application to DNA profiling of shoe soles. *Forensic Sci. Int*. 145: 7–12

Daly, D.J., Murphy, C., McDermott, S.D. (2012) The transfer of touch DNA from hands to glass, fabric and wood. *Forensic Sci. Int. Gene*. 6: 41–46

Djuric, M., Varljen, T., Stanojevic, A., Stojkovic, O. (2008) DNA typing from handled items. *Forensic Sci. Int.: Genetics Supplement*. 1: 411–412

Farmen, R.K., Jaghø, R., Cortez, P., Frøyland, E.S. (2008) Assessment of individual shedder status and implication for secondary DNA transfer. *Forensic Sci. Int.: Genetics Supplement.*1: 415–417

Forster, L., Thomson, J., Kutranov, S. (2008) Direct comparison of post-28-cycle PCR purification and modified capillary electrophoresis methods with the 34-cycle "low copy number" (LCN) method for analysis of trace forensic DNA samples. *Forensic Science International: Genetics* [Online]. 1: 415–417. Available from: http://dx.doi.org/10.1016/j.fsigen.2008.04.005

Gill, P. (2002) Role of Short Tandem Repeat DNA in forensic casework in the UK–past, present, and future perspectives. *BioTechniques*. 32: 366–385

Gill, P., Whitaker, J., Flaxman, C., Brown, N., Buckleton, J. (2000) An investigation of the rigor of interpretation rules for STRs derived from less than 100 pg of DNA. *Forensic Sci. Int*. 112: 17–40

Goray, M., Mitchell, J.R., van Oorschot, A.H. (2012) Evaluation of multiple transfer of DNA using mock case scenarios. *Legal Medicine*. 14: 40–46

Goray, M., Mitchell, R.J., van Oorschot, R.A.H. (2010) Investigation of secondary DNA transfer of skin cells under controlled test conditions. *Legal Medicine*. 12: 117─120

Kelley, S. (2010) *Assessment of DNA transfer involving routine human behaviour* [Online]. Fort Worth, TX: University of North Texas Health Science Centre. Available from: http://digitalcommons.hsc.unt.edu/theses/98

Krenke, B.E., Tereba, A., Anderson, S.J., Buel, E., Culhane,S., Finis, C.J., *et al*. (2002) Validation of a 16-locus fluorescent multiplex system. *J Forensic Sci*. 47 (4)

Ladd, C., Adamovicz, S.M., Bourke, M.T., Scherczinger, C.A., Lee, H.C. (1999) A systematic ananlysis of secondary DNA transfer. *J Forensic Sci*. 44 (6): 1270─1272

Lowe, A., Murray, C., Whitaker, J., Tully, G., Gill, P. (2002) The propensity of individuals to deposit DNA and secondary transfer of low level DNA from individuals to inert surfaces. *Forensic Sci. Int*. 129: 25─34

Naughton, M., Tan, G. (2011) The need for caution in the use of DNA evidence to avoid convicting the innocent. *The International Journal of Evidence & Proof*. 15: 245─257

Poy, A., van Oorschot, R.A.H. (2006) Beware; gloves and equipment used during the examination of exhibits are potential vectors for transfer of DNA-containing material. *International Congress Series*. 1288: 556─558

Rocque MJ, Leake SL, Milon MP, Castella V (2014) The tightness of the cotton swabs meshing influences the chances of getting conclusive DNA profiles. *J Forensic Res*. 5(4): 234

Santiago, R., Caves, G., Nelson, M., Podini, D. (2013) *Cotton swabs vs. 4N6FLOQSwabs™: A comparative study for optimal recovery of simulated touch DNA* [Online].Washington, DC: The George Washington University. Available from: http://www.isfg.org

van Oorschot, R.A., Jones, M.K. (1997) DNA fingerprints from fingerprints. *Nature*. 387 (6635): 767

van Oorschot, R.A.H., Phelan, D.G., Furlong, S., Scarfo, G.M., Holding, N.L., Cummins, M.J. (2003) Are you collecting all the available DNA from touched objects?. *International Congress Series*. 1239: 803─807

van Oorschot, R.A.H., Treadwell, S., Beaurepaire, J., Holding, N.L., Mitchell, R.J. (2005) Beware of the possibility of fingerprinting techniques transferring DNA. *J Forensic Sci*. 50(6)

Vandewoestyne, M., van Hoofstat, D., de Groote, S., van Thuyne, N., Haerinck, S., van Nieuwerburgh, F. *et al*. (2011) Sources of DNA contamination and decontamination procedures in the forensic laboratory. *J Forensic Res*. 82

Williamson, A.L. (2012) Touch DNA: Forensic collection and application to investigations. *J Assoc Crime Scene Reconstr*. 18 (1): 1─5

CHAPTER 3: SOUTH AFRICAN PUBLIC'S KNOWLEDGE OF DNA AND ITS APPLICATION IN CRIMINAL INVESTIGATIONS

Abstract

This study was conducted to determine the level of knowledge regarding deoxyribonucleic acid (DNA) and its application in criminal investigations. The participants in this study were individuals whose occupations result in them often being first responders at crime scenes, or them being involved in criminal investigations in some way; including presenting, prosecuting and defending DNA evidence in court. The results show that the majority of these people were not particularly knowledgeable of DNA and/or a criminal DNA database and their functionality, even though they knew of their importance to solving criminal investigations. Seventy-nine percent (79%) of the respondents claimed to know that DNA is used for criminal investigations in South Africa (RSA) and were aware of some cases where this technology had been applied to solve criminal cases. Media, whether print or digital, was cited as the main source of this knowledge.

The results of this study indicate that people who should be in a position to protect evidence left at scenes of crimes are not aware of the importance of their conduct at these scenes or the implications of their interaction with physical evidence. A fair assumption can then be made that a typical member of the public is even less aware of their interaction with the crime scene and the consequences of their ignorance.

Limited knowledge of DNA and its application in criminal investigations by people who are first responders at crime scenes may have devastating consequences as their actions may lead to the evidence being compromised in some manner rendering it inadmissible in court.

3.1 Introduction

The use of DNA for criminal investigations has found wide application throughout the world with more and more cases being solved using this technology. Due to the ability of DNA evidence to link suspects to crime scenes, as well as victims, most believe that it is infallible and consider it to be the 'gold standard' of forensic science (Thomson, 2006). It must, however, be understood that the effectiveness of this 'gold standard' depends largely on how the forensic evidence was collected, preserved, analysed and interpreted. Often the weakest link in the presentation of DNA evidence in court is at the scene of crime during collection of the evidence. The manner in which the scene was handled and how the evidence was collected determines the strength of the evidence in court. Protection of the crime scene, as well as a properly documented chain of custody, means that the subsequently collected physical evidence can withstand the legal process in courts of law. Compromising DNA evidence at any point, from the time it was collected at the crime scene to its subsequent analysis at the forensic science laboratory, may render it inadmissible in court.

The issue of crime scene contamination often stems from ignorance as to the impact of the first responder's interaction with the forensic evidence at the scene and their level of competence in this regard. The first responder to any scene of crime is in fact, the most crucial person in terms of crime scene protection and preservation. In many cases however, the first responder is not aware of the consequences of their interaction with the physical evidence that may be in the area, some of which may have been left by the perpetrator. With this in mind, this study was conducted to determine what the people who are likely to be the first at a crime scene, as a result of their professions or occupations, know about DNA and its potential use in criminal investigations in South Africa and the source of their information. The information collected from this group of individuals will give indication as to the knowledge of the general public who are in fact the first people to interact with the crime scene. If these professionals have limited knowledge regarding DNA and its applications in criminal investigations, a fair assumption is that the general public will be even less knowledgeable.

Identifying the common sources of information from the respondents would provide an idea as to the type of information people are exposed to and how they perceive such information. It has been reported that people who watch fictional forensic science and/or crime television (TV) shows tend to believe they know more about forensic science tools and their applications, including DNA analysis, in criminal investigations than people who do not watch such shows (Schweitzer *et al.*, 2007). This "CSI effect" seems to affect people's expectations of the justice system and what it can and should deliver as it blurs the line between reality and fiction. The same expectations are the source of trust or mistrust in the scientific tools used for criminal investigative purposes and the justice system (Schweitzer *et al*., 2007).

3.2 Methodology

A generic questionnaire was designed to collect information regarding first responders' knowledge of the use of DNA and a DNA criminal intelligence database in the detection and resolution of crime (Appendix 3). The questionnaire consisted of questions with multiple answers where the respondent had to select the appropriate answer/s applicable to them. Open-ended questions were also included to allow the respondents to provide explanations for their responses. To ensure that questionnaire was of a standard level of comprehension, so that people of different backgrounds would find it easy to comprehend and answer twenty people of different social and educational backgrounds were requested to respond to the questionnaire and provide feedback on whether they clearly understood the questions prior to the start of the actual study. The initial respondents confirmed clear comprehension of the content of the questionnaire.

The information collected during the study provided insight into respondents' level of knowledge of DNA and/or its application in terms of crime resolution through the use of criminal intelligence DNA databases. The responses also provided information as to the source of the respondents' knowledge with regard to the application of this technology in South Africa.

Respondents to the questionnaire consisted of groups of individuals whose occupations exposed them to scenes of crimes and victims of crimes and included police officers, rape crisis centre workers, doctors, paramedics and public prosecutors. These individuals were given the questionnaire to self-administer while attending a DNA awareness workshop in Kimberly in the Northern Cape and Bloemfontein in the Free State province, South Africa. The attendees were requested to respond to the questionnaire before the workshop session commenced to make sure that the information collected was what they knew prior to the workshop. The DNA awareness workshop, developed by a non-governmental organisation The DNA Project in consultation with the forensic science division of the South African Police Services (SAPS), was aimed at providing an explanation on how DNA evidence can help solve crimes as well as the role a first responder plays in protecting and securing the scene of crime. Attendees were trained on the molecular nature of DNA, where it can be found in the human body, and the manner in which it could be left, by either the victim or the perpetrator, at a crime scene.

In addition, the process followed during the generation of a DNA profile at the forensic science laboratory (FSL), as well as the effectiveness of a criminal DNA database as a criminal investigative tool were discussed.

The criteria used for analysis of the responses obtained were based on gender, race, geographical area and level of education. These criteria were selected due to the perception that a person's knowledge of DNA would be linked to their prior access to information on this topic. Basic comparative statistics were employed to identify major differences in the responses provided by the various groups analysed. Correlation factor (r) and analysis of variance (ANOVA) between different groups were calculated to determine the differences in responses within the criteria of analysis.

The research was conducted with the approval of the Dean of the Faculty of Natural and Agricultural Science of the University of the Free State, Bloemfontein. The study was also carried out with the consent of each participant (Appendix 2).

3.3 Results and Discussion

A total of 265 responses were collected from four workshop sessions held in Kimberly and Bloemfontein. The demographics of the participants are presented in Table 3.1.

Table 3.1: Demographics of respondents to the questionnaire according to the criteria selected for analysis

Grouping	Number of respondents# (Proportion in sample, %)
Gender:	
Male	177 (67)
Female	86 (32)
Race:	
Black	163(62)
Caucasian	48 (18)
Coloured	45 (17)
Asian	3 (1)
Educational Background:	
High school and below	128 (48)
Undergraduate and above	122 (46)
Residential area:	
Urban	157 (59)
Semi-urban	26 (10)
Rural	38 (14)

#Some respondents did not select any available options hence the sum of respondents per grouping may not tally with the total number of responses obtained.

Due to the small number of questionnaires collected from Asian respondents, these were not included in any of the analyses.

The trend which emerged from this study is similar to what has been reported in other parts of the world like the United States of America (US) and New Zealand (Curtis, 2009; Hochschild *et al*., 2011) where people generally claimed to be knowledgeable about DNA and its forensic application even though they did not have any knowledge of how the technology was utilised. A little over half of the respondents (n = 152, 57%) said they knew what DNA was, but a considerably larger number (n = 209, 79%) said they knew that DNA was used in South Africa in criminal investigations (Table 3.2). Of the 152 individuals who said they knew what DNA and/or DNA database was, only a few (n = 57, 38%) actually provided relatively acceptable definitions of what they were. Most respondents mentioned typical sources of DNA at crime scenes, like bloodstains, semen and saliva, while other respondents simply stated that DNA is collected at crime scenes. The implication of these findings is that most people have heard of DNA being employed to solve criminal cases even though they had no knowledge of the molecular nature of DNA and how it could be deposited at a crime scene and subsequently analysed to link a perpetrator to the scene of crime. These results are consistent with those obtained in the US where Hochschild *et al*. (2011) reported that 53% of the 4291 respondents in their study claimed to be knowledgeable about the use of DNA and its use in law enforcement. Curtis (2009) reported that 96 of 100 respondents in her study claimed to know of the use of DNA in criminal investigations in New Zealand.

Of interest to note is that the least number of respondents knew of the purpose of a criminal DNA database (n= 91, 34%), but a larger number said they were aware of its existence in South Africa (n= 164, 62%), (Table 3.2). These results concur with those of the study conducted by Hochschild *et al.* (2011) where the group surveyed indicated that they were not particularly knowledgeable, nor totally ignorant, of the existence and function of a criminal intelligence DNA database.

The results indicate that both males and females responded similarly to the questions posed (r = 0.94) in terms of their knowledge of DNA and/or DNA database and whether the technology is used in South Africa for criminal investigations. There were slightly more females who knew of actual cases where DNA had played a role in crime resolution in South Africa. This may have been due to the fact that there were more females who, by their occupations as medical doctors, forensic pathology officers and rape crisis centre workers, encountered victims of rape and/or murder where DNA was routinely collected as part of the criminal investigation.

Table 3.2: Respondents' knowledge of DNA and its forensic application (Weighted responses according to the numbers surveyed per grouping)

	Do you know what DNA is?	Do you know what a DNA database is?	Do you know if DNA is used in SA?	Do you know if SA has a DNA database?	Are you aware of any cases where DNA played a role in arrest or conviction?	p-value
Total	**57%**	**34%**	**79%**	**62%**	**57%**	
Male	56%	36%	81%	63%	55%	0.93
Female	59%	30%	76%	59%	62%	
Black	50%	22%	75%	63%	58%	0.19
Caucasian	90%	79%	88%	60%	52%	
Coloured	47%	27%	80%	58%	58%	
High school	46%	24%	81%	67%	59%	0.91
Higher Learning	70%	48%	75%	57%	34%	
Urban	63%	43%	78%	62%	58%	0.27
Semi-urban	58%	31%	92%	62%	69%	
Rural	45%	13%	68%	50%	45%	

As shown in Table 3.2, it appeared that Caucasian respondents were more informed about DNA and criminal DNA Databases, than respondents of other races even though the variation between the races was not statistically significant ($p = 0.19$). The proportion of black and coloured respondents who answered "yes" to knowing what DNA and/or a criminal intelligence DNA database is, and their application in criminal investigations in South Africa were very similar. An opposite trend was reported in the US where, a larger proportion of black and multi-racial individuals seemed to know of DNA and its use in law-enforcement than other races surveyed. This may be due to the fact that in countries where DNA has long been applied as a criminal investigative tool through the use of a DNA database, it has been found that minority groups were over represented in the database (Kaye *et al*., 2003; Garnier, 2005; Chow-White *et al*., 2011) hence why a larger proportion of black and multi-racial individuals, who represent minority groups in these countries, seem to know more about this technology than the majority groups. In countries such as the US, the UK and New Zealand, neighbourhoods where minority groups reside are often raided and searched leading to more arrests and incarceration of individuals of these groups rather than of the Caucasian majority groups. This means that the DNA databases of such countries inevitably consists of larger numbers of profiles from minority groups than majority groups (Garnier, 2005; Chow-White *et al*., 2011) hence black and multi-racial individuals are likely to know of DNA technology application for crime detection through direct or indirect encounter in such countries.

In South Africa however, as much as the socio-economic status of the black and multi-racial populations is similar to that of other parts of the world, the difference is that these groups make up the majority of the population, not the minority, hence the expectation that individuals of all racial groups would know of DNA and its application in criminal investigations. In South Africa, due to the fact that previously the legal framework in the country did not include the routine utilisation of DNA for criminal investigative purposes, the majority of the population has not been exposed to the technology in any manner. That being said, the reasoning for why Caucasians, as a minority group in the country, would be slightly more knowledgeable than the other race groups on the use and application of this technology in crime detection and resolution may be a consequence of the advantages afforded to them during the apartheid era and their previously having more access to such information through school, work or media, rather than through some direct or indirect personal encounter. With the introduction of the new Criminal Law (Forensic Procedures) Amendment Act, 2013 (DNA Act) that became operational on 31 January 2015, which allows for routine use of DNA in criminal investigations, it can be expected that the black and multi-racial individuals in South Africa, who constitute the majority of the population, will be exposed to this technology more frequently. This will then mean that the knowledge or familiarity of the black and coloured populations with the application of DNA technology for criminal investigative purposes will increase.

The major differences in the knowledge base were observed in the educational grouping (r = 0.37). As can be expected, people with a higher level of education knew what DNA and DNA database were, but a larger percentage of people with lesser qualifications claimed to be aware of their application for criminal investigative purposes in South Africa (Table 3.2). This appears to be somewhat of a contradiction but it can be argued that highly educated people are knowledgeable on the actual subject matter even though they have not been exposed to crimes that may involve the use of DNA. These results also tally with the results based on race because of the 48 Caucasians involved in the study, 73% had post high school qualifications compared to the 39% of black and multi-racial respondents. This means that even though the black and multi-racial respondents are not particularly knowledgeable of DNA and/or databases because of their lower level of education, they are more exposed to actual crimes occurring that may involve DNA analysis. The higher exposure of these groups to such cases may be due to the fact that there is more crime in their neighbourhoods involving use of DNA. This is another point of departure between South Africa and other countries. In other parts of the world, it has been observed that over-policing and deliberate targeting of black and multi-racial neighbourhoods by the police results in more arrest and incarceration of these races giving the impression that there is more crime in such neighbourhoods than Caucasian neighbourhoods or that these races commit more crimes than their Caucasian counterparts (Kaye *et al*., 2003; Garnier, 2005; Schweitzer *et al*., 2007; Chow-White *et al*., 2011). In South Africa however, the reality is that there is more crime in black and multi-racial neighbourhoods and/or more crimes are committed by these races due to limited policing in these areas (Pelser *et al*., 2000; Altbeker, 2008). The fact that these races also make up the majority of the population precedes the larger arrest and incarceration figures when compared to those of Caucasians.

A lesser number of individuals from rural areas knew of DNA and its applications in criminal investigations. These results link directly with the results obtained according to educational background because of the 38 individuals who reside in rural areas, 27 (71%) had high school qualification or less. These results show that, people from rural areas are less informed or less aware of DNA applications in criminal investigations, along with cases where an arrest or conviction was made on the basis of DNA results. Several issues may be cited as reasons for this lack of knowledge. Firstly, it may be due to lack of access to information and/or interest in the subject. People in rural areas may not have access to the media, the Internet and other platforms of communication through which information can be relayed. Even if the information reaches such areas, DNA and its applications in criminal investigations are scientific and often people are less inclined to delve into scientific issues with a preconceived fear that they are difficult to comprehend, more so for people with a low level of education. Hence lack of information may not only rely on access to information, but also on ease of understanding of what is accessible. Due to a lack of education and the abstract nature of understanding DNA, and the fact that it is often impossible to actually see DNA with the naked eye, it may be difficult for individuals to understand what has been relayed to them resulting in lack of knowledge of either the subject matter or cases relating to the use of DNA.

Secondly, according to the crime statistics in South Africa and other countries, there are generally less crimes of a nature where DNA may be collected as evidence in rural areas than in urban areas (SAPS, 2014). Other researchers argue to the contrary that the extent of crime in urban and rural areas is similar but what differs is the impact of victimisation in rural areas borne by lack of access to social services and other support services such as clinics and police stations which render rural populations least able to deal with the impact of crime (Altbeker, 2008). Whichever the case may be, what is noted is that if a crime that may involve the use of DNA has occurred in a rural area, it is likely not to be reported and thus is not widely known by the general population. If and when these crimes are reported, lack of resources at these rural police stations such as trained crime scene investigators, equipment suitable for the collection of DNA samples, transportation to scenes of crimes, preservation and transportation of samples becomes a challenge and ultimately, the technology does not form part of the investigation in those cases even if it ought to have been. Other constraints such as the distance between the police station and the scene of crime also hinders the process of DNA collection as this means that the police are unable to secure the scene to avoid contamination in time. The effect of this is that the DNA evidence collected at such scenes may not withstand legal scrutiny in court.

Lastly, because rural populations are usually small in number and people know each other well, it is possible that conventional criminal investigative methods turn out to be efficient enough to yield viable leads to a case without the need for use of DNA. In their study, Pelser *et al.*

(2000) reported that 72% of victims of violent crime in the surveyed rural areas claimed to know their offenders either by name or sight.

Media whether print or digital, was cited as the main source of information regarding the use of DNA and/or a database and cases where DNA played a role in a criminal investigations in South Africa. Approximately 60% (n = 160) of the respondents said they heard of the cases from newspapers and/or television; a few knew of the cases from their work (Fig. 3.1). A similar response was recorded by Curtis (2009) in New Zealand where media was cited as the main source of information on the use of DNA for forensic purposes. These results emphasise the crucial role played by all types of media in the dissemination of information to the general public.

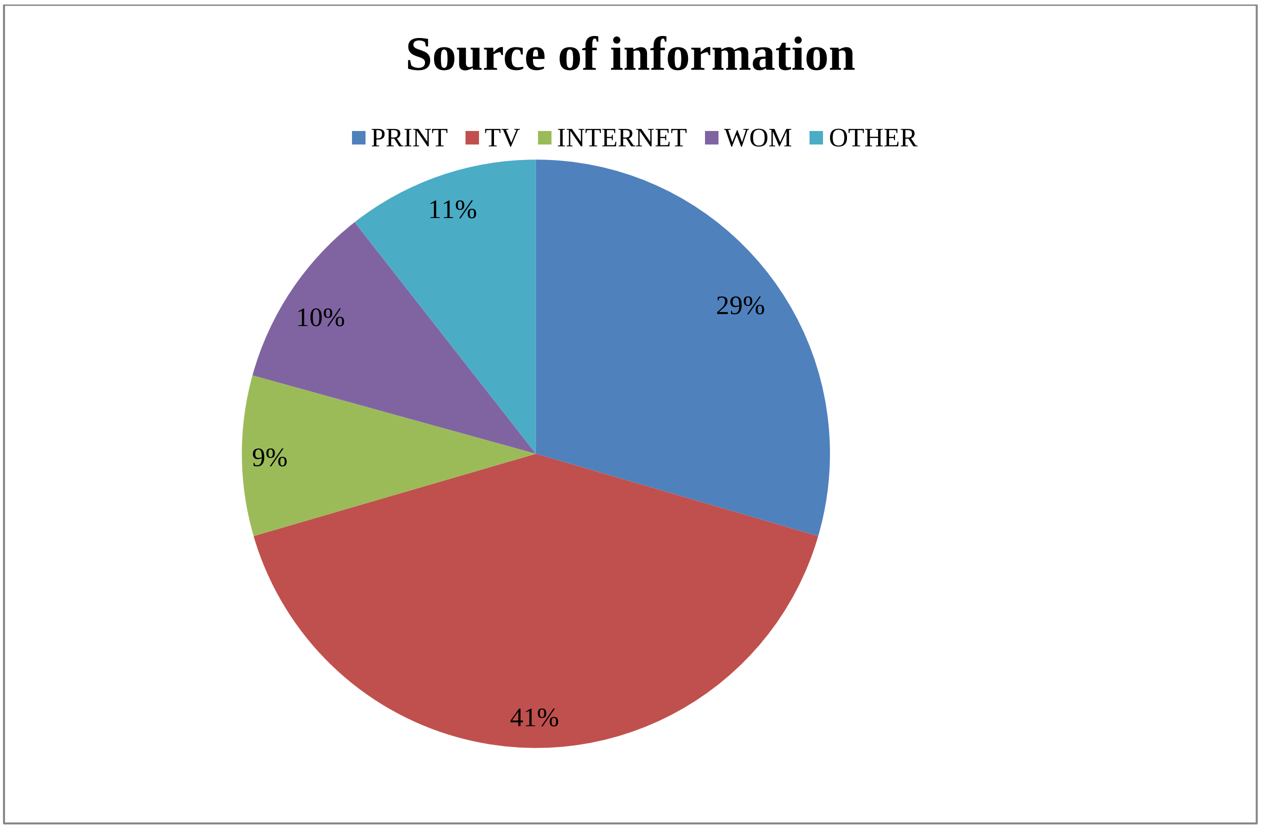

Figure 3.1: Sources of information regarding DNA

Television seems to be the biggest source of information regarding actual cases where DNA was applied to solve crimes. Even though the questionnaire was specific to criminal cases in South Africa, it can be assumed that some of the cases claimed to be known by some of the respondents occurred in other parts of the world and/or from the now popular forensic science television shows that people watch such as CSI, Solved and Law & Order to name a few. These shows may have contributed to the knowledge base that people have on DNA and its applications in forensics. This indicates that the "CSI effect" may exist, which could be one of the reasons why some respondents, especially those with a lower level of education, claimed to know of cases solved via DNA even though they were not particularly knowledgeable about what DNA is and how it is used as a criminal investigative tool. The issue of the "CSI effect" is still very much under scrutiny as some researchers believe that it is highly exaggerated and that people's perceptions of forensic science are not necessarily moulded by what they see on television in the form of forensic science shows (Sheldon *et al*., 2006). Schweitzer and Saks (2007) noted that while the "CSI effect" is a real issue, it does not particularly alter the outcome of a case. This phenomenon did not form part of the scope of this research but may need further investigation in South Africa.

3.4 Conclusion

It was determined by this study that generally, people understood that DNA and/or criminal intelligence DNA databases are important to criminal investigations, even though they did not particularly understand what DNA was, or the process undertaken to ensure the correct collection and analysis of forensic evidence. The limited knowledge of this group of individuals regarding the application of DNA in criminal investigations leads one to conclude that the general public has an even less knowledge and understanding of this subject.

Media, especially television, is the major source of information to the larger population and can thus be utilised as an awareness medium pertaining to what DNA is and how it can be used in criminal investigations as well as the role of first responders at crime scenes. This research has thus heightened the necessity of incorporating DNA awareness and crime scene preservation into training programmes for those professions or occupations where the individuals may often be first responders at crime scenes or attend to victims of crimes such as the groups surveyed in this study.

The implementation of the Criminal Law (Forensic Procedures) Amendment Act (2013) may change what has been observed in this study as more people are exposed to the application of DNA technology in South Africa through personal experience and/or media. It can also be expected that the "CSI effect" may be observed in all stakeholders - the public, law enforcement personnel, prosecutors, defence attorneys and judges, as the role of DNA evidence is heightened in criminal cases. This, however, should be investigated further.

3.5 References

Altbeker, A. (2008) Murder and robbery in South Africa: A tale of two trends. In: van Niekerk, A., Suffla, S. and Seedat, M. *Crime, violence and injury prevention in South Africa: Data to action*. Tygerberg, RSA: MRC-UNISA Crime, Violence and Injury Lead Programme. p.131–160.

Chow-White, P.A., Duster, T. (2011) Do health and forensic DNA databases increase racial disparities? *PLosMed* [Online]. 8(10): e1001100. Available from: doi:10.1371/journal.pmed.1001100

Curtis, C. (2009) Public perceptions and expectations of the forensic use of DNA. *Bulletin of Science, Technology and Society*. 29(4): 313–324

Garnier, G. (2005) Racial profiling: DNA forensic procedures & indigenous people in Victoria. *Current Issues in Criminal Justice*. 17(1): 47–68

Government Gazette. (2014) *Criminal Law (Forensic Procedures) Amendment Act 37 of 2013* [Online]. Cape Town: The Presidency. 52(583). Available from: http://dnaproject.co.za/new_dna/wp-content/uploads/2014/01/Act-37-of-2013.pdf

Hochschild, J.L., Sen, M. (2012) Race, DNA and Criminal justice: Linking public opinion to public policy. In: *Law and Society Annual Conference; June 2–5, 2011* [Online]; San Francisco, CA. Princeton University Press. Available from: http://dx.doi.org/10.4172/2157-7145.1000170.

Kaye, D.H., Smith M.E. (2003) DNA identification databases: Legality, legitimacy & the case for population-wide coverage. *Wis. L. Rev*. p.413–59

Pelser, E., Louw, A., Ntuli, S. (2000) *Poor safety: Crime and policing in South Africa's rural areas.* Pretoria: Institute for Security Studies. Monograph 47

Schweitzer, N.J., Saks, M.J. (2007) The CSI Effect: Popular fiction about forensic science affects the public's expectations about real forensic science. *Jurimetrics J*. 47: 357–364

Sheldon, D.E., Kim, Y.S., Barak, G.A. (2006) A study of juror expectations and demands concerning scientific evidence: Does the "*CSI* effect" exist? *Vanderbilt Journal of Entertainment and Technology Law*. 9(2): 331–368

South Africa. South African Police Service. (2014) *South African Crime Statistics* [Online]. Pretoria: South African Police Service. Available from: http://www.saps.gov.za/resource_centre/publications/statistics/crimestats/2014/crime_stats.php

The DNA Project. http://dnaproject.co.za

Thomson, C.W. (Jan/ Feb 2006) Tarnish on the "gold standard": Understanding recent problems in forensic DNA testing. *The Champion*. p. 10

CHAPTER 4: PUBLIC PERCEPTION ON THE NATIONAL FORENSIC DNA DATABASE OF SOUTH AFRICA (NFDD)

Abstract

Guillen et al. *(2000) stated that because any venture into human genetics can affect the whole community, it is only fair that the community itself and not only the scientists should debate and decide what it is prepared to accept or reject. The use of deoxyribonucleic acid (DNA) as a criminal investigative tool is one such venture. Due to the fact that the use of DNA for forensic casework has become routine in various jurisdictions across the globe, the engagement of the community which is to be affected is warranted. For this purpose, studies have been conducted in some countries to determine the perception of the general public, or a specific group of people, regarding the application of DNA in criminal investigation, specifically the DNA database as an investigative tool. Responses to similar questions in the referred studies were varied hence the need to conduct a South African study which would collect and report the perception and views of the South African public regarding the use of DNA technology for criminal investigative purposes.*

Over ninety percent of the people surveyed supported the existence of a DNA database in South Africa and said they would support the government's funding towards it. The majority (65%) supported the creation of a population-wide database without consideration to age or the type of crime involved. The respondents in this study showed the least concern for any of the purported dangers or disadvantages of a DNA database such as invasion of privacy, bio-surveillance as well as issues of consent and inclusion of minors. More concern was placed on ensuring that criminal elements are removed from communities. The results based on gender and race did not yield significantly different results from those of the whole group. The support of the database reflected by the public means that it will be easier for politicians and policy-makers to fund the application of DNA for forensic purposes by ensuring that proper legal framework as well as other resources are availed.

4.1 Introduction

The promulgation of the Criminal Law (Forensic Procedures) Amendment Act 37 of 2013 (DNA Act) in South Africa is set to bring a new era to criminal investigations in the country. This act provides for the establishment and/or expansion of a forensic DNA database to be used as a criminal investigative tool. Over the years, since the establishment of the first DNA database in the United Kingdom (UK) in the early 1990's, DNA databases have become standard tools in criminal investigations in different jurisdictions over the globe. With a DNA database, law enforcement agencies have been able to link crime scenes; link crimes to suspects; generate suspects where there were none; save a lot of investigative hours through the leads provided via cold hits, exclude the innocent and exonerate those wrongfully convicted. A database is also perceived to be a deterrent due to the increased chance of detection (Campbell, 2011). With these advantages, more and more countries are making an investment towards a forensic DNA database and South Africa is no exception.

As important as DNA databases are to criminal investigations, there are also some concerns regarding their use. It has been argued that the collection and storage of DNA and/or data from individuals, especially if not convicted of any crime, encroaches on several of their rights. Collection of DNA samples, especially without consent, interferes with the right to bodily integrity and the subsequent retention of the DNA and data derived from such DNA affects the right to privacy (Curtis, 2009; Campbell, 2011; Hochschild *et al*., 2012). It is said that the DNA collected and retained may be used for research without consent, bio-monitoring or other deceptive uses by the state or whoever gains access to the information such as familial searching, health assessments or paternity tests (Stackhouse *et al*., 2010). Refusal to grant consent for the collection of DNA, where applicable, is often misconstrued to mean guilt thus interfering with one's right of presumption of innocence (Curtis, 2009; Machado *et al*., 2011). Others have further stated that having one's profile kept in the forensic database means that the person is always treated as a suspect each time a search is made (Levitt, 2007) and that the mere existence of one's profile on the database stigmatises the individual (Stackhouse *et al*., 2010; Machado *et al*., 2011). It has also been found that the data kept in these DNA databases is racially and gender discriminative (Curtis, 2009). Even though DNA samples themselves are not racially biased, minority groups are often over-represented in DNA databases as a result of the bias in other components of the criminal justice system such as policing (Curtis, 2009; Hochschild *et al*., 2012; Onley *et al*., 2014). Hochschild and Sen (2012) noted that African Americans and Hispanics, who are minority races in the US, are disproportionately victimised by crime and over-policing while women are disproportionately victimised by sex-linked offences often perpetrated by males. Chow-White and Duster (2011) also state that because of the different policing practices in African American and Latino communities as opposed to Caucasian communities and the fact that laws are changing to include sampling of DNA from arrestees, the DNA databases held by law enforcement agencies are bound to consist of mostly those groups. Due to these facts, most profiles contained in the DNA database of the United States, CODIS, are of males of African and Hispanic origin. A similar trend has been noted in other parts of the world such as the UK. In fact, as at 2008, 40% of black men in the UK had their details on the national DNA database (NDNAD) (Stackhouse *et al.*, 2010) even though the proportion of black men in the entire country was less than 10%.

Opinions have differed greatly on both the relative benefits and harms of DNA databases (Hochschild *et al.*, 2012). What is clear though, is that this technology plays a crucial role in the criminal justice system. This role that DNA and DNA databases plays is often not the subject of dispute. Rather the issues that come into dispute revolve around the manner in which the DNA is taken and from whom it can be taken; the issue of retention of either the physical sample or profile generated and the duration of the retention of both, but not the technology itself. These arguments are typically made by those individuals whose occupations involve working with DNA evidence, whether as law practitioners who have to prosecute or defend clients; law enforcement officers who process the evidence, experts who provide testimony for or against the DNA evidence in question or human rights activists claiming to speak for or on behalf of the general public. Rarely does the public on whose behalf this technology is introduced or employed air their views. It is often presumed that the use of DNA and DNA databases as investigative tools enjoys the support of the general public on the grounds that all law abiding citizens would want criminals caught and thus the public is not engaged at a significant level (Levitt, 2007). This results in a situation where the public is not properly engaged by policy and law makers on this issue.

When laws are made in countries, the public is often awarded the opportunity to submit comments on a bill before it is passed. Despite this opportunity, very few members of the public actually get to submit those comments or opinions. Often this is done by individuals, or bodies, whose views regarding that particular legislation and/or subject would already be established. The rest of the public find themselves in a position where a law may be passed and/or technology being introduced into their lives without them having proper understanding of the law and/or the technology. The same holds true for the DNA Act which has recently been promulgated and effected in South Africa. Submissions were made to parliament mostly in support of the proposed bill, but were the views expressed a reflection of those of the general South African public? Guillen *et al.*(2000) stated that because any venture into human genetics can affect the whole community, it is only fair that the community itself and not only the scientists should debate and decide what it is prepared to accept or reject. This builds trust between the public and institutions that serve them. Introducing a technology that will be an integral part of the society, such as DNA technology, requires understanding expectations and views of the public. In an attempt to achieve this, studies have been conducted in other regions of the world to source the opinion of the public, or a certain group of people within the society, on the use of DNA and DNA databases (Gamero *et al*., 2006; Gamero *et al*., 2007; Gamero *et al*., 2008; Curtis, 2009; Stackhouse *et al*., 2010; Machado *et al*., 2011; Hochschild *et al*., 2012). Responses to similar questions in the referred studies have varied depending on who formed the subject of the study as well as the country where the study was conducted. This led to the decision to conduct a similar study in South Africa.

This study was thus aimed at determining the perception of South Africans on the use of DNA technology as a criminal investigative tool, specifically the use of the forensic DNA database. The results will provide guidance to law and policy makers of the country as to how much this technology is value enabling them to make an appropriate investment towards the forensic DNA database in terms of resources allocated to it. Research conducted in the US has shown that people's views regarding DNA change with a better understanding of what DNA is and how it is applied in the criminal justice system (Hochschild *et al*., 2012). The secondary objective of this study was thus to determine if having more information would change the respondents' perceptions on forensic DNA applications.

4.2 Methodology

This study was conducted simultaneously with the one aimed at determining the knowledge of the public on DNA and its forensic applications in South Africa (Chapter 3). A two part generic questionnaire of standard level of comprehension was designed to collect information regarding the knowledge and use of DNA and DNA database as criminal investigative tools as well as opinion regarding this application. The first part of the questionnaire dealt with knowledge of DNA and its forensic application and the results have been captured and discussed in Chapter 3. The second part of the questionnaire dealing with the respondents' opinion on the use of DNA for forensic applications forms the subject of this chapter.

The questionnaire consisted of structured questions with a Likert scale (Malhotra, 2006) where the respondents were given statements which they could select one of the options ranging from strongly agree to strongly disagree. The questions were tailor-made to collect responses pertaining to issues of existence and support of the use of DNA technology, custody of and access to the database, consent for sampling and inclusion of DNA profiles into the database, as well as retention of both DNA samples and profiles. These issues were identified as important and sources of the most controversy with regards to DNA databases according to research conducted in other parts of the world (Gamero *et al*., 2006; Gamero *et al*., 2007; Gamero *et al*., 2008; Curtis, 2009; Stackhouse *et al*., 2010; Machado *et al*., 2011; Hochschild *et al*., 2012). The issues in reference also form part of the new DNA legislation in South Africa hence why it is critical that the perception of South Africans on them be captured.

A group of individuals whose occupation exposed them to scenes of crimes and victims of crimes attending a DNA awareness workshop in Kimberly and Bloemfontein South Africa were given the questionnaire to self-administer. The DNA awareness workshop, developed by a non-governmental organisation, The DNA Project, in consultation with the forensic science division of the South African Police Services (SAPS), was aimed at providing an explanation on how DNA evidence can help solve crimes as well as the role a first respondent plays in protecting and securing the scene of crime. Attendees were trained on the molecular nature of DNA, where it can be found in the human body and the manner in which it could be left, by either the victim or the perpetrator, at a crime scene. In addition, the process followed during the generation of a DNA profile at the forensic science laboratory (FSL), as well as the effectiveness of a criminal DNA database as a criminal investigative tool were discussed. A few highlights of the contents of the DNA Act were covered, as well as bringing the attendees into full view of the current status of South Africa with regards to DNA and its applications in criminal investigations. To determine the effectiveness of the training and the impact of the supposedly new-found knowledge on their views, the group was requested to fill in the questionnaire again at the end of the workshop to provide a before and after scenario.

The analysis of the questionnaires was done based on gender and race. Basic comparative statistics were employed to identify major differences in the responses provided by the groups. Correlation factor (r) and p-values (t-test and ANOVA) between different groups were calculated to determine the differences in responses within the criteria of analysis.

The research was conducted with the consent of the participants (Appendix 2) and with the approval of the Dean of the Faculty of Natural and Agricultural Science of the University of the Free State, Bloemfontein.

4.3 Results & Discussion

A total of 265 responses were collected from four workshop sessions held in Kimberly and Bloemfontein. In terms of gender, the majority of the respondents were male (n= 177) and considering race, the majority were black (n=163). The least represented race was Asian with only three (3) respondents and these were not included in any of the analyses.

4.3.1 Support for use of DNA for criminal investigative purposes

The trend for these results was similar for the different analysis criteria employed. That is, the trend exhibited by the combined result from all the respondents was similar to that exhibited by the individual groups per analysis criteria. The majority of the group (82%, n=218) had strong feelings (91% in all agreed) towards the establishment of a DNA database in South Africa feeling that it may serve as a deterrent for further criminal activity (70% agreed) (Fig. 4.1). Over 80% of the respondents trusted DNA analysis as a reliable method for identification of perpetrators of crime and showed support for the government's funding of the use of DNA analysis as a tool to fight crime. Hochschild and Sen (2012) noted a similar trend in the US based on polls conducted since 1998; that, in general, even though people know little about forensic DNA testing, its use as a crime fighting tool is supported. In this study over 80% of people of all races were in support of the government funding for more extensive use of DNA for criminal investigative purposes but also felt that its use in the criminal justice system must be regulated.

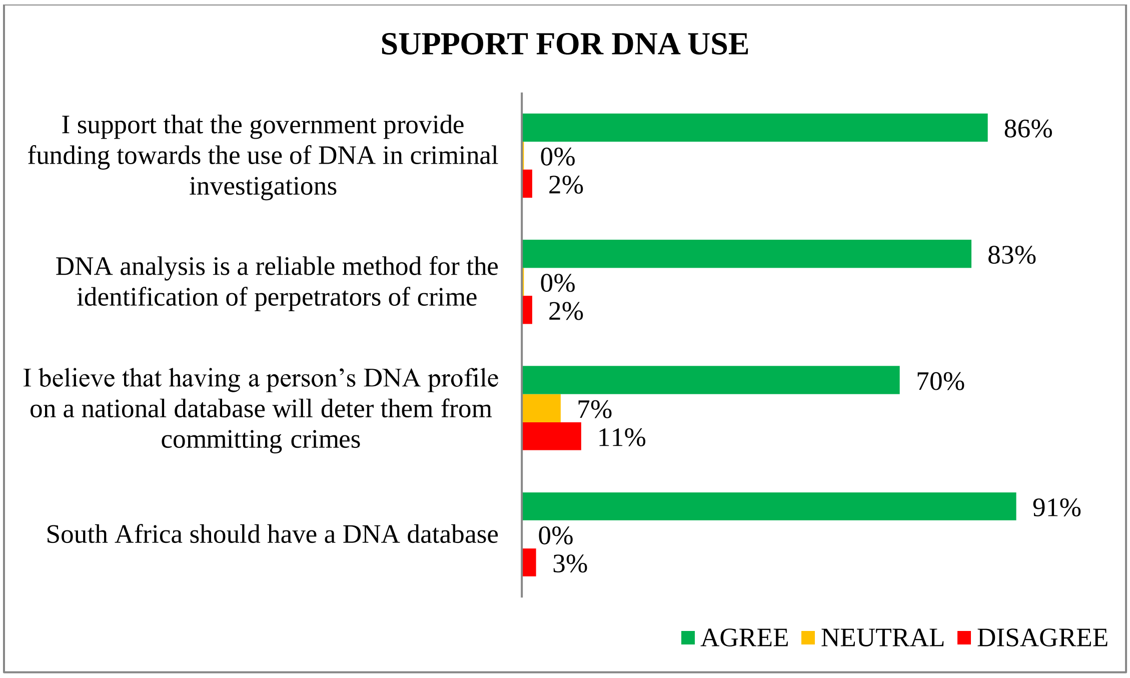

Figure 4.1: Responses to questions in relation to support of the use of DNA for criminal investigations

The application of DNA for criminal investigative purposes seemed to enjoy the support of all genders and races. With that being noted, it is important to also note that females were less enthusiastic than their male counterparts with regards to the reliability of DNA analysis as a means of identifying perpetrators of crimes as well as with the deterrent effects of the DNA database (Table 4.1). According to the demographics of this study, there were more females who by their professions would have encountered cases where DNA played or ought to have played a role in the identification and conviction of a perpetrator of a crime but fell short for some reason. The mistrust reflected here may well not be on the DNA technology itself but rather on the capabilities of the people who are tasked with analysis of DNA from sample collection through to laboratory analysis. On the other hand, Caucasians seemed to be more enthusiastic than all other groups about the forensic applications of DNA. The reason for this enthusiasm may be because the majority of the Caucasian respondents had post high school qualifications (73%) and thus may have a better grasp of the capabilities of DNA technology as a crime fighting tool.

Table 4.1: Support for the use of DNA in criminal investigations according to gender and race (Weighted responses; only proportion of people who agree with given statements)

	MALE	FEMALE	BLACK	CAUCASIAN	COLOURED
South Africa should have a DNA database	93%	87%	90%	94%	96%
I believe that having a person's DNA profile on a national database will deter them from committing crimes	72%	67%	71%	71%	69%
DNA analysis is a reliable method for the identification of perpetrators of crime	88%	73%	81%	96%	78%
I support that the government provide funding towards the use of DNA in criminal investigations	89%	81%	85%	92%	84%

4.3.2 Inclusion of profiles into the database

Results regarding who to include in a DNA database were contradictory (Fig. 4.2). The majority (80%) of the respondents felt that DNA samples must be taken on arrest for any crime inferring that neither the age, type of crime nor conviction for a crime should be a factor on whose profiles are included in the database. In fact, 65% of the group supported the notion of a population-wide DNA database through collection of DNA at birth while only 17% were against it. Almost three quarters (74%) of the respondents showed willingness to provide a DNA sample for inclusion into the national database (Fig. 4.2). The reasons for why the majority of respondents in this study supported a nationwide DNA database were not explored but may be similar to those stated in other studies (Stackhouse *et al*., 2010; Machado *et al*., 2011). In these studies, the respondents felt that the only way a DNA database can be effective and eliminate any bias and stigmatisation is for it to be all inclusive containing profiles of every individual in the country regardless of age, crime involved or conviction. A differing result regarding inclusion into the database was reported by Curtis (2009) where less than 30% of the respondents were in support of a nationwide database or inclusion of all new-born's profiles in the database. Despite the lack of support for a nationwide database, the majority (81%) of the people interviewed in that study were willing to provide their DNA for inclusion in the database similar to the results obtained in this study (75%) and other studies (Hoschild *et al*., 2012). What is clear though, is that the concerns raised by civil rights and liberty organisations such as GeneWatch who speak strongly against the idea of a universal DNA database are not shared by participants of this study.

Interestingly, when a specific reference was made to age and type of crime as basis for inclusion, a slightly different result was obtained. The majority still maintained that age should not be a factor for consideration in who to include in the database however, only 38% agreed that the type of crime should not have any bearing on whom to include in the database. In Spain, Gamero *et al.* (2006) reported that only 35% of the respondents agreed to inclusion of suspects in the database compared to the 80% who thought that people who were found guilty of serious offenses must be included. In New Zealand, Curtis (2009) observed that only 40% of the respondents felt that suspects for any crime must be included in the database compared to well over 90% of the respondents who agreed that profiles of individuals convicted of serious offenses such as sexual and violent offenses must be included in the database.

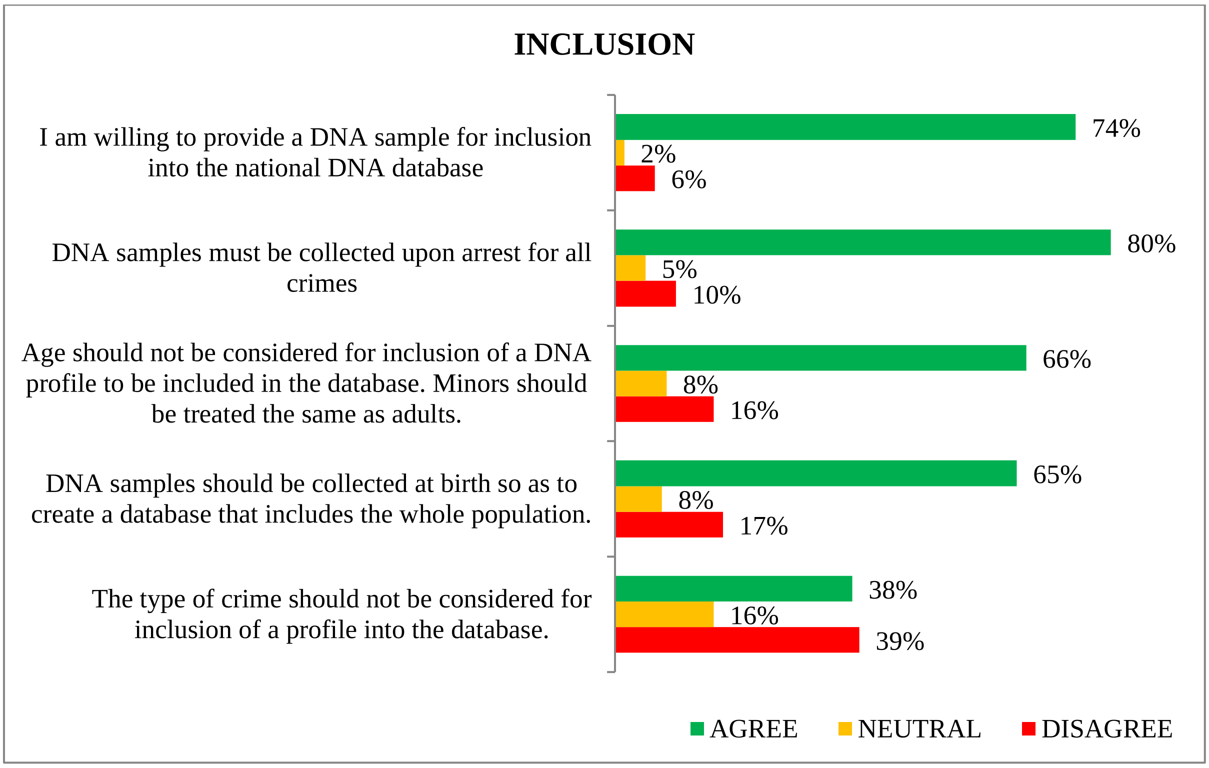

Figure 4.2: Responses to the questions pertaining to inclusion of DNA profiles onto the national DNA database

When the respondents were provided with an opportunity to be more specific as to which crimes they thought warranted inclusion in the database, murder and rape were chosen as the top two according to 85% and 84% of the respondents respectively while the least number of respondents (38%) felt driving offences warranted inclusion (Table 4.2). The same trend was also reflected in the results by gender and race. Of interest to note though is that for women, rape was the number one crime that warranted inclusion in the database whereas murder was the number one crime for men. These results seem to support the observation that females are victimised by sexual crimes (Hochschild *et al.*, 2012) while males often fall victim to murder (Altbeker, 2008). In fact, according to the United Nations Office on Drugs and Crime

(UNODC) (2015), the global male homicide rate is almost four times higher than that of females and as at 2002, the murder rate of South African males was 6.4 times more than that of males in other parts of the world (Altbeker, 2008). Research also shows that more females are likely to be sexually assaulted than males. In the US, 91% of rape cases are of females compared to 9% of males (National Sex Violence Resource Centre, 2015) and global statistics show that female rape prevalence is over four times higher than that of males (13% vs 3%) (Stemple, 2009). These figures are however suspected to be underestimated as very few cases of male sexual assault are reported especially in developing countries (Paterson, 2013).

Another interesting point is that there was a significant difference in opinion between races ($p = 0.03$).The proportion of Caucasians who felt that any particular crime must be included in the database was higher than all the races while the proportion of blacks who felt the same way was generally lower than other races. This may be borne by the fear and constant awareness that Caucasians in South Africa seem to have of crime. According to Valji *et al.* (2004), there is a racialised discourse of crime that misrepresents Whites (Caucasian) as predominant victims of crime while conversely portraying Blacks as primary perpetrators of crime. This perception that Whites seem to be predominant victims of crime was shown in Harris and Radaelli (2007) where 20% of Whites claimed to have personally been victim of crime compared to the 9% of Blacks and Coloureds. It would thus appear that the fear of crime apparent in this population group is justified. The notion that fear of crime in the country is predominantly ‘white fear’ has however been disproved by surveys conducted by the Human Science Research Council on South African social attitudes focusing on fear of crime not actual crime (Roberts, 2008). According to these surveys, while in the 1990s Whites were more fearful of crime than other races, the situation changed from 2000 and as at 2007 Blacks and Indians were more fearful of crime than other races. This may well be supported by the fact that there are more policing efforts, by the police as well as community policing forums, in white neighbourhoods than neighbourhoods of other races. Also the socio-economic status of Whites is well above that of other races such that they can afford the ‘extra protection’ in the form of security systems in their homes, firearms and/or other means (Simpson, 1998).

4.3.3 Consent for DNA sampling

A little over half of the respondents felt that consent was necessary for a DNA sample to be collected from suspects and arrestees but not from convicted individuals as they felt that an individual convicted of a crime has diminished rights and collecting their DNA will not infringe on their rights and privacy (Fig. 4.3). Most of the respondents (48%) felt that the collection of a DNA sample was not an infringement of any person's privacy, convicted or otherwise. This compares to the 26% who felt DNA collection is an infringement of people's privacy. Similar to the results obtained in this study, the majority of people in the study conducted by Curtis (2009) felt that consent is not necessary for collection of a DNA sample. Clearly, people are more concerned about eliminating criminal elements from their communities even if it means not exercising some of their rights. A differing observation was made by Gamero *et al*. (2007) where 57.4% of the respondents were against a database consisting of profiles of all citizens without consent but the figure lowered to 47.6% if the citizens were to provide consent.

The results by gender were almost identical ($r = 0.91$). Even though statistically insignificant ($p = 0.89$), there were differences in responses by race. Close to 70% of Caucasians felt that no consent was necessary for sampling DNA from convicts as compared to less than 50% of Blacks and Coloureds. More Blacks than other races believed that the collection of DNA is an infringement of an individual's privacy, even if convicted of a crime. This apparent discomfort about DNA sampling for black people may stem from the inherent fear of this group of being treated unfairly or mistrust of the criminal justice system. Simpson (1998) states that after apartheid, not only did the new government inherit many state institutions, including the police, justice system and correctional services all of which form the criminal justice system, but has also inherited the legacy of mistrust associated with them. It is that legacy of mistrust that may explain how the black respondents feel about a possible invasion of their privacy.

Table 4.2: Crimes that warrant DNA sampling for inclusion in the forensic database (weighted responses)

	MURDER	RAPE	ROBBERY	BURGLARY	FIRE ARM OFFENSES	DRUG OFFENSES	DRIVING OFFENSES	KIDNAPPING	p-VALUES
Total	**85**	**84**	**63**	**57**	**52**	**55**	**38**	**61**	
Race									
Black	82	79	59	52	47	49	34	57	0.16
Caucasian	98	98	83	75	77	79	48	88	
Coloured	89	96	58	60	49	53	42	56	
Gender									
Male	91	89	69	62	59	59	41	66	0.03
Female	78	80	53	50	40	49	36	55	

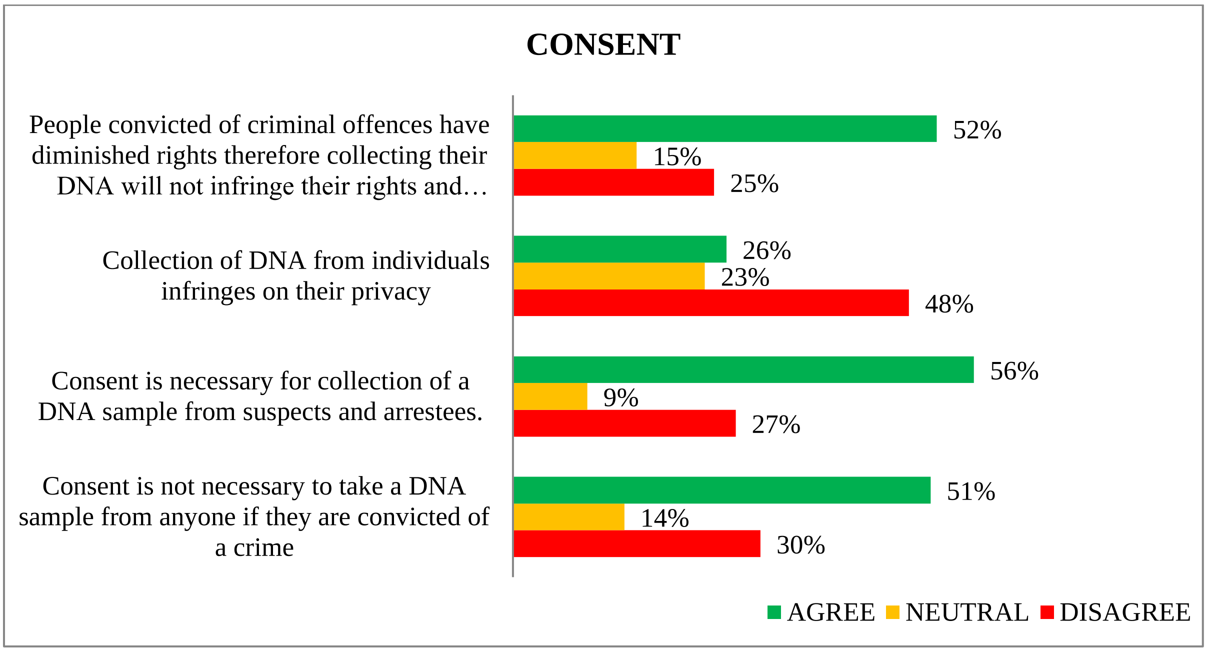

Figure 4.3: Responses of the group pertaining to consent

4.3.4 Retention & removal of profiles

A large majority of the group felt that both DNA samples and profiles should be retained indefinitely. Prior studies (Curtis, 2009) show that the retention of DNA profiles is less of a bone of contention than that of the sample from which a profile was derived. In contrast to the profiles, DNA samples contain a wealth of genetic information that is personal to the individual such as predispositions to addiction, sicknesses and certain behaviour, as well as relationships which may not be in the public domain. This creates uncertainty in people as to what other purposes that information may be used for by the state or anyone who gains access to it. This concern was also noted by researchers in other studies about perceptions on forensic applications of DNA (Stackhouse *et al*., 2010; Machado *et al*., 2011). The respondents in those studies were not concerned with indefinite retention of their details on the database; in fact, they supported the permanent retention of profiles of all citizens as they felt that it will assist in solving more crimes as well as eliminating victimisation by law enforcement agencies. Of concern to them was the potential misuse of such data by the state or other parties and/or being framed for crimes they did not commit should their DNA be planted at scenes of crimes.

The feelings of some of the individuals changed once some conditions were suggested on retention of profiles such as an acquittal or a time frame (Fig. 4.4). Well over 70% of the respondents supported the indefinite retention of both samples and profiles but when a specific question was asked whether the samples and profiles should be kept after acquittal only 46% felt that they should be retained. The reason for this change in opinion was not solicited from the respondents however, the implication is that to the respondents, DNA is collected to facilitate investigation of a specific crime and once that crime or case has been solved, there would be no need for retention of a profile or sample. Different responses have been noted in other studies regarding the issue of profile retention after acquittal. The respondents in Stackhouse *et al.* (2010) and the study conducted by Wales Gene Park/Techniquest (2007) felt that profiles should be kept indefinitely even if the individual was acquitted of a crime. On the other hand, Gamero *et al.* (2006) reported that 79.85% of respondents supported retention of DNA profiles belonging to people found guilty of serious offences. This figure changed to less than 50% when the question was asked of people who were suspects but not finally charged.

The suggestion of a possibility of introducing a time frame for retention gave contradicting results, where only 31% of the respondents felt that no such time frame for retention of profiles should be stipulated. More males than females supported permanent retention of profiles in the database. This is not a surprising observation considering the fact that fewer females than males thought that having a person's profile captured in the DNA database will serve as a deterrent. The results by race exhibited a similar trend for all races where the majority of individuals supported permanent retention of profiles and samples. Some people, however, changed their perception when asked whether to retain after acquittal or if a time frame must be provided for retention. Caucasians were more enthusiastic about permanent retention than other races. Unlike the other races, the majority of Caucasians still felt that acquittal must not play a role on whether to retain profiles in the database or not and that no prescriptions of time must be stipulated. The reason for this may be simply that they believe retaining profiles indefinitely would somehow expedite case resolution so that criminal elements are put behind bars and/or that it will serve as a deterrent for crime.

The results obtained seem to support the conclusion made by Hochschild and Sen (2012) that people lack a good understanding of DNA and its forensic applications despite their support of it. This was demonstrated by the responses obtained when the respondents were requested to suggest appropriate retention times for those crimes they felt warranted retention of DNA samples or profiles in the database. In some cases, the respondents suggested retention times of profiles for as little as 24 hours while the other extreme was permanent retention of DNA samples and profiles for all crimes and ages.

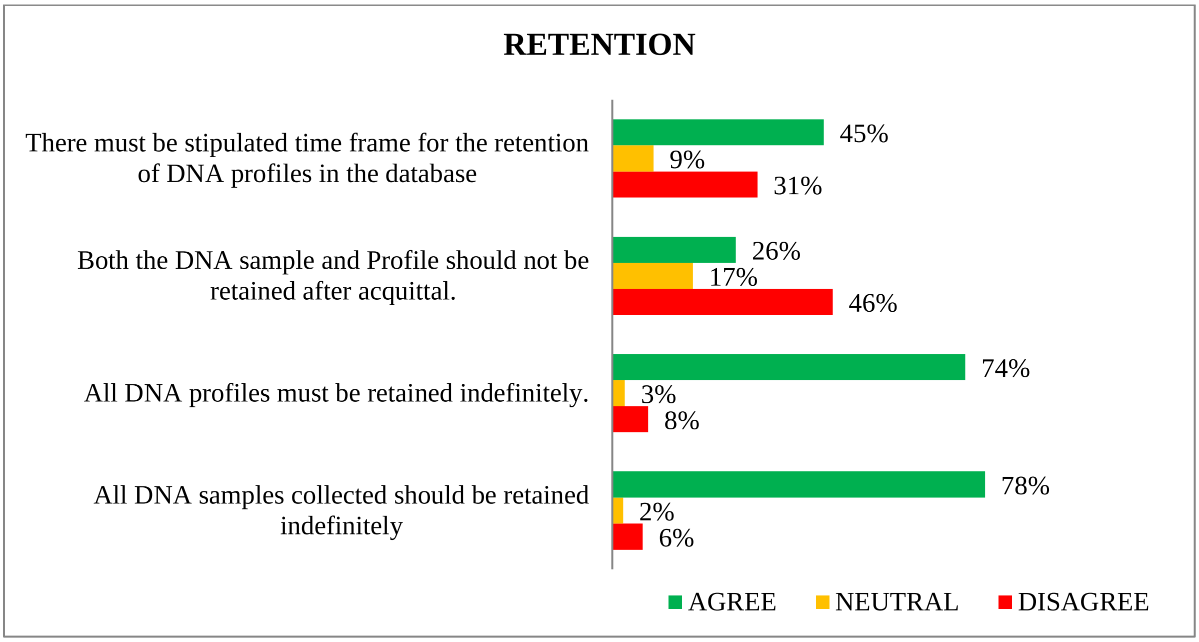

Figure 4.4: Responses pertaining to retention of DNA samples and profiles

It appeared that the respondents were not aware of or thinking of the practicality of retaining both profiles and samples indefinitely. As a matter of fact, the more the profiles in a database the better the chances of getting "hits" thus expediting solution to crimes but this also means that the cost of performing searches and maintaining the database will also increase. In their paper, Konings *et al.* (2011) discuss the feasibility of having an all-inclusive DNA database, weighing the investment that is required against the benefits expected. In that paper, they quote the head of the Netherlands Forensic Institute where he stated that it would cost his country approximately 1.65 billion Euros to set up a DNA database of the Dutch population and estimated that with current resources available to them, it would take approximately 330 years. Already, the expected cost of implementing the Criminal Law (Forensic Procedures) Amendment Act in South Africa is estimated to be around 1.2 billion Rands (Hartley, 2013) and retaining each tested sample indefinitely will require storage facilities adding more strain to the limited resources available for crime prevention. The respondents were also not mindful of the possible implications of indefinite retention of profiles or DNA samples on civil liberties of individuals especially those not convicted of any crime.

When asked if profiles of under-aged individuals should be removed after a certain period, 40% of the respondents felt that under-aged persons must be treated the same way as adults, so whatever the law prescribes on retention of profiles must apply to all citizens. Interestingly, the results according to gender were similar. The majority of both males and females felt that profiles of under-aged individuals must not be removed from the database at all. Over half of

Caucasians thought that under-aged profiles must be retained indefinitely while almost the same proportion of Coloureds felt that they must be treated the same way as adults.

4.3.5 Custody and administration of the DNA database

The majority of the group (65%) felt that the South African Police Service (SAPS) should be responsible for collection of DNA samples but a lesser number (51%) felt that they should be in custody of the National Forensic DNA Database (NFDD). According to 72% of the respondents, the Forensic Science Laboratory (FSL), which is the institution performing the analysis of DNA samples, should be independent of the SAPS and 67% thought it must also be the custodians of the database (Fig. 4.5).

These results show a clear understanding by the respondents that the SAPS are responsible for crime investigation and therefore in a better position to obtain samples than anyone else. As in other parts of the world, there is lesser trust in the police when it comes to the actual sample analysis as well as custody of the database so much so that people feel the FSL must not be part of the SAPS but be an autonomous entity. Similar feelings were captured by Curtis (2009) in New Zealand and Gamero *et al.* (2008) in Spain where the majority of people felt that the police should not be the custodians of the DNA database suggesting alternative independent institutions. Similarly, Machado *et al*. (2011) noted the same trend where the respondents in their study were supportive of the existence and use of a forensic DNA database but a clear mistrust of the police or state was evident. The respondents in that study were fearful that the police were capable of planting evidence to incriminate individuals. In the US, the majority of people showed trust towards both the government and private companies in collecting DNA samples in the same manner (Hochschild *et al*., 2012). The implication is that the trust was not placed on the institutions but rather on the capabilities of the individuals that would be performing the task of collecting DNA samples.

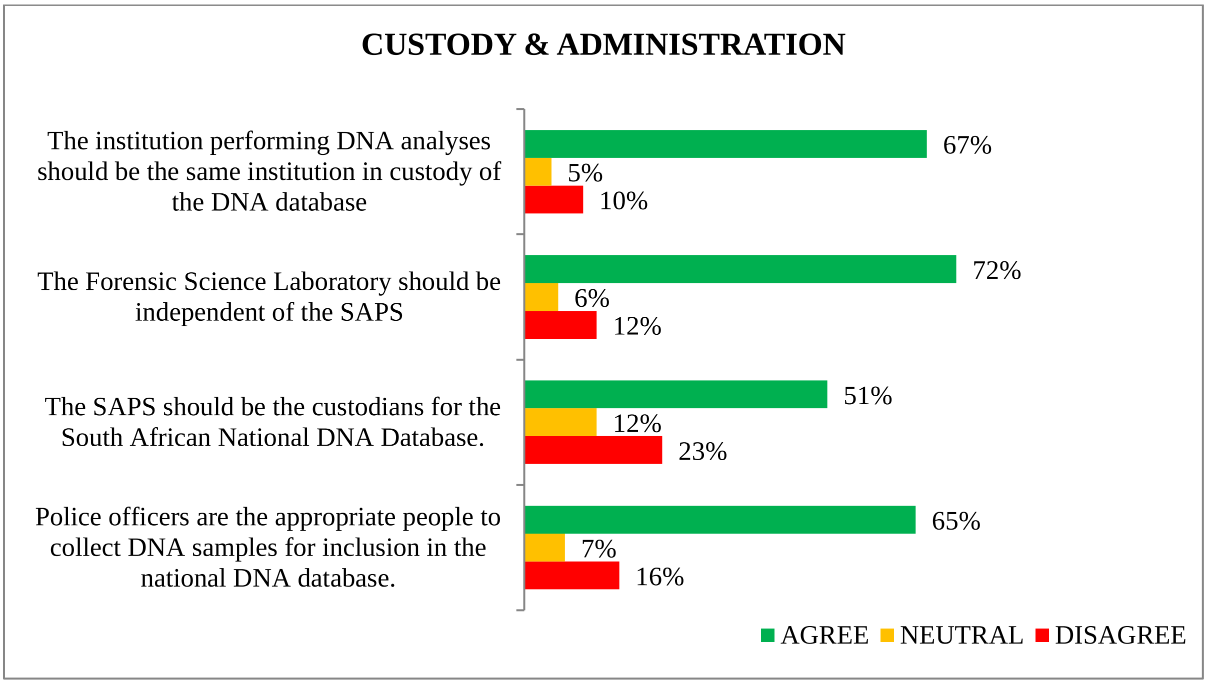

Figure 4.5: Responses pertaining to custody of the national DNA database

The results pertaining to custody of the database were similar across the analysis criteria. To note is the fact that as much as the majority supported the notion of the NFDD being in custody of the SAPS across all criteria, over 40% in all groups were either not in support of or indifferent to the idea. In fact, less than 50% of the females agreed to it while Caucasians were the least enthusiastic about police officers sampling for DNA for inclusion in the database. This shows some level of mistrust in the police's capabilities to handle DNA sampling by this group. The questioning of the police's capabilities when it comes to DNA sampling may not be a surprising result considering the fact that most of the respondents in this study were either working closely with law enforcement officers when carrying out their daily duties or they were law enforcement officers themselves, thus privy to some knowledge of the capabilities of the people who would be responsible for DNA sample collection. Gamero *et al.* (2008) noted that support for any of the government security agencies as custodians of the database decreased as the level of education of the surveyed individuals increased. This may also be another reason for the observation regarding Caucasians' lack of support for the SAPS as custodians of the database. Over 70% of the Caucasian respondents in this study were in possession of higher education qualifications. Interestingly, unlike what has been noted in the US, more Blacks (68%) in this study showed more trust in the police's capabilities for DNA sampling than other races. According to Hochschild and Sen (2012) almost 50% of the black respondents in the US showed little or no trust in the government on the issue of DNA collection.

4.3.6 Access and privacy of data included in the database

There seemed to be a lesser concern as to what follows the collection of profiles if they are to be used for the purposes of fighting crime. Most of the respondents (61%) felt that it is necessary to obtain a court order before a search on the DNA database could be carried out (Fig. 4.6). Close to 80% of respondents in Gamero *et al*.(2008) thought that the judges and courts of law are the appropriate entities to have access to data held in the DNA database meaning that anyone who requires access to such data must do so through the court of law. A large number of respondents (83%) supported the linking of the DNA database with the existing fingerprint database (Automated Fingerprint Identification System-AFIS) and the exchange of profiles between countries to fight cross border crime (79%) but a smaller number (51%) agreed with the use of profiles for research without consent (Fig. 4.6). It appears that the respondents were not mindful of the contradiction in their responses in that linking the DNA database with the fingerprint database means that when a search is made to the fingerprint database, which does not require a court order; it inevitably means it is also being done on the DNA database. This may mean that unlawful searches of the DNA database would be carried out each time a fingerprint search is made on AFIS, a technicality that would render the DNA database ineffective.

There seemed to be no fear linked to the sharing of the information on the DNA database with other governments and there was no concern apparent for any possible misuse of the data collected. It may be that the participants were not aware of any of the possible misuses of the data contained in the database or that they were more concerned about combating crime to the extent of ignoring any other possible uses of such data kept in the database. This is an interesting point because, in other studies (Curtis, 2009; Stackhouse *et al*., 2010; Machado *et al*., 2011), the respondents were fearful of the possible lack of security for the data kept on the database thus worried about who would gain access to it. The concerns ranged from fear of being framed for a crime to fear of third parties such as insurance companies and future employers gaining access to this information and using it to discriminate against individuals. While the participants in the study by Curtis (2009) were in full support of the use of DNA for forensic purposes, the majority also raised concerns about privacy (63%) as well as possible misuse (60%). This is a clear illustration that what may be a concern in one part of the world in not necessarily a concern in another.

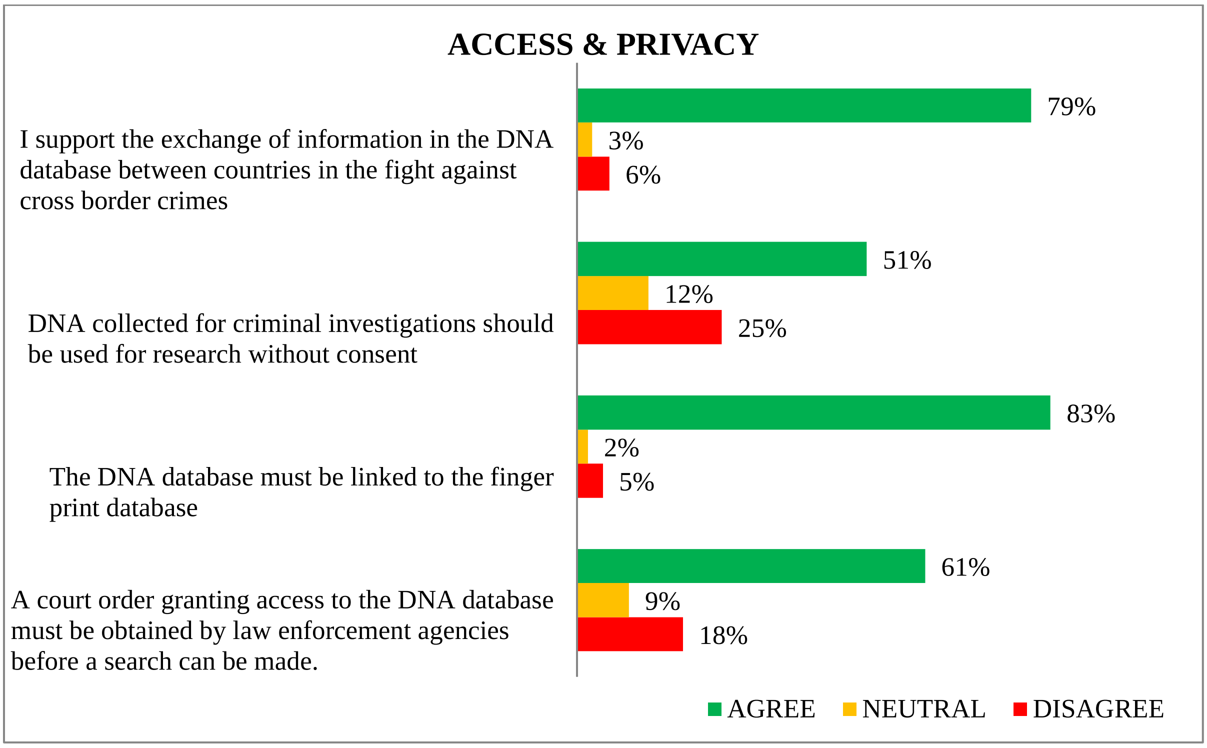

Figure 4.6: Responses regarding access & privacy to information in the DNA database

A similar trend was noted for all groups per analysis criteria. Caucasians showed more support for the linking of the DNA database with the fingerprint database as well as exchange of information on the DNA database across countries than other races.

Worthy to note is that the opinions herein expressed, regarding inclusion and retention of profiles as well as administration of the national forensic DNA database, seem to be to a large extent in line with the current stipulations of the DNA Act. According to the act, DNA samples are to be collected on arrest for all crimes without consent. The profiles from arrestees are to be retained for a maximum of three years while those of convicted offenders are to be retained indefinitely. The point of departure between the law and the perceptions in this study is regarding minor's profiles and the collected samples. While the majority of respondents felt that both samples and profiles be retained indefinitely and that minors' profiles be treated the same as those of adults, the law requires that all samples collected be analysed within 30 days of collection and destroyed within 90 days of analysis. It also states that DNA profiles belonging to minors must not be retained beyond twelve months, regardless of conviction.

4.4.7 Comparison of perceptions before and after training

The results obtained at the end of the workshop when the respondents had more information regarding the use of DNA and DNA databases as criminal investigative tools did not differ significantly from the original results obtained prior to the training (r = 0.96). After the workshop, a slightly higher number of individuals, though not significant, felt that South Africa should have a forensic DNA database (97% vs the original 91%). As well, a slightly larger number of individuals felt that neither age nor the type of crime should be considered for inclusion of a profile into the database. Of interest was that with a better understanding of how a DNA database works, more people felt that both the sample and profile should not be retained after acquittal (26% vs 41%). These results correspond to the results obtained in a similar study conducted in the UK in 2007 (Wales Gene Park and Techniquest). The observation in that study was also that people's perceptions were not significantly changed by having more information. Changes were noted on only a few issues regarding who to include in the database. In that study, as with this study, more people agreed to inclusion of arrestees into the database as well as the existence of a population-wide DNA database after the workshop session than before.

It must be acknowledged that due to their professions, the respondents in this study were likely to be pro-law enforcement and thus would be inclined to select responses that would be along their line of work. This means that these results may not be a true reflection of the perception by the general public but only that of a certain group of individuals. In their study, Gamero *et al.* (2006) and Gamero *et al.* (2008) noted that the most differences in opinion were observed between professions, this however was not explored in the present study. With this being noted, the results may have not been influenced at all considering that other studies (Stackhouse *et al*., 2010; Machado *et al*., 2011) have been conducted where the opinions of actual offenders in prisons or people who had their profiles already included in a DNA forensic database were collected and they were also in support of the existence of a DNA database. In these studies, the majority of respondents supported the existence of a DNA database because they felt that it may prevent the practice of law enforcement officers of "rounding up the usual suspects". With the ex-offender's profile in the database, eliminating them as suspects would be easier and quicker rather than this offender being treated as a suspect simply because they are a known criminal.

4.5 Conclusion

The results of this study show that the use of DNA and/or a DNA database for criminal investigative purposes enjoys the support of the majority of participants. Clear differences in opinion are reflected when some aspects of DNA database are discussed and per these results, the most controversial aspects of the DNA database are regarding consent and retention of profiles. What cannot be disputed however is that putting criminals behind bars is far more important to the people than their concerns regarding the potential invasion of privacy or any other right thought to be affected by having a profile on the DNA database.

The results have also shown that with more information about DNA and its forensic application, there is a change in perception, however slight. This means that in order for people to give an opinion on the application of DNA for forensic purposes, they must first be aware of its existence and all the surrounding social and ethical issues. It is only then that they can draw their own conclusions and opinions regarding the subject (Stackhouse *et al*., 2010).

Comparing what the South African legislation on application of DNA for forensic purposes stipulates and the results obtained in this study, one is drawn to conclude that the DNA Act in the current form is adequate to serve as the legal framework governing the application of DNA in criminal investigations. It is however important to state that due to the skewed and small sample size used for this study, it is possible that the views captured here do not reflect the views of the general public. It is therefore suggested that a larger study, that would capture the perceptions of more people according to different groups such as professions, age groups and geographical regions throughout the country, be conducted.

4.6 References

Altbeker, A. (2008) Murder and robbery in South Africa: A tale of two trends. In: van Niekerk, A., Suffla, S. and Seedat, M. *Crime, violence and injury prevention in South Africa: Data to action*. Tygerberg, RSA: MRC-UNISA Crime, Violence and Injury Lead Programme. p.131–160.

Campbell, L. (2011) "Non-conviction" DNA databases and criminal justice: a comparative analysis. *Journal of Commonwealth Criminal Law*. p. 55–77

Chow-White, P.A., Duster, T. (2011) Do health and forensic DNA databases increase racial disparities? *PLosMed* [Online]. 8(10): e1001100. Available from: doi:10.1371/journal.pmed.1001100

Curtis, C. (2009) Public perceptions and expectations of the forensic use of DNA. *Bulletin of Science, Technology and Society*. 29(4): 313–324

Gamero, J., Romero, J., Peralta J., Carvalho, M., Vide, M., Corte-Real, F. (2006) The opinion of the Spanish population with regard to the procedural situation of individuals that would justify the storage of their DNA profiles in a national database. *International Congress Series*. 1288: 774–776

Gamero, J., Romero, J., Peralta, J. Corte-Real, F., Guillén, M., Anjos, M. (2008) A study of Spanish attitudes regarding the custody and use of forensic DNA databases. *Forensic Science International: Genetics*. 2: 138-149

Gamero, J., Romero, J., Peralta, J., Carralho, M., Corte-Real, F. (2007) Spanish Public Awareness regarding DNA profile Databases in Forensic Genetics: What type of DNA profiles should be included. *J Med Ethics*. 33: 598–604

GeneWatch UK. http://www.genewatch.org

Gullien, M., Lareu, M. V., Pestoni, C., Salas, A., Carracedo, A. (2000) Ethical-legal problems of DNA databases in criminal investigation. *Journal of Medical Ethics*. 26: 266–271

Harris, M., Radaelli, S. (2007) Paralysed by fear: Perceptions of crime and violence in South Africa. *SA Crime Quarterly*. 20: 1–6

Hartley, W. (2013) ANC *says costs can be cut for new DNA database* [Online]. Available from: http://www.bdlive.co.za/national/2013/08/01/anc-says-costs-can-be-cut-for-new-dna-database.

Hochschild, J.L., Sen, M. (2012) Race, DNA and Criminal justice: Linking public opinion to public policy. In: *Law and Society Annual Conference; June 2–5, 2011* [Online]; San Francisco, CA. Princeton University Press. Available from: http://dx.doi.org/10.4172/2157-7145.1000170.

Konings, L., van Rossum, B. (2011) Should we record the DNA profiles of the entire Dutch population in a DNA database?. *Erasmus Journal of Medicine*. 1(2): 47–49

Levitt, M. (2007) Forensic databases: Benefits and ethical and social costs. *British Medical Bulletin*. 83: 235–248

Machado, H., Santos, F., Silva, S. (2011) Prisoners' expectations of national forensic DNA database: Surveillance and reconfiguration of individual rights. *Forensic Science International* [Online]. Available from: doi:10:1016/j.forsciint.2011.02.020

Malhotra, N.K. (2006) Questionnaire Design and Scale Development. In: Grover, R. and Vriens, M. *The Handbook of Marketing Research: Uses, Misuses, and Future Advances*. Thousand Oaks, CA: SAGE Publications, Inc. p.84-95.

Olney, M., Bonn, S. (2014) An exploratory study of the legal and non-legal factors associated with exoneration for wrongful conviction: the power of DNA evidence. *Criminal Justice Policy Review*. p.1-21

Paterson, K.K. (2013) *A Competition of suffering: Male vs. female rape* [Online]. Available from: http://www.womenundersiegeproject.org/blog/entry/a-competition-of-suffering-male-vs.-female-rape.

Roberts, B. (2008) *Age of hope or anxiety? The dynamics of fear of crime in South Africa* [Online]. Available from: http://www.hsrc.ac.za/uploads/pageContent/3333/2008marAge%20of%20hope%20or%20anxiety.pdf

Simpson, G. (1998). Urban Crime and Violence in South Africa. In: Petty, C. & Brown, M. (eds). *Justice for Children, London: Save the Children* [Online]. Available from:

http://www.csvr.org.za/old/index.php/publications/1524-urban-crime-and-violence-in-south-africa.html

Stackhouse, R., Anderson, C., Shaw, A.M., Iredale, R. (2010) Avoiding the "usual suspects": young people's views of the national DNA database. *New Genetics Society*. 29(2): 149-166

Stemple, L. (2009) Male rape & human rights. *Hastings Law Journal*. 60: 605–47.

The DNA Project. http://dnaproject.co.za

United Kingdom. Wales Gene Park and Techniquest. (2007) *The National DNA Database: The Public's views*. UK: Wales Gene Park and Techniquest.

United Nations. (2013) *UNODC Global study on homicide*. United Nations publication, Sales No. 14.IV.1.

United States of America. National Sexual Violence Resource Centre. (2015) *Statistics about sexual violence* [Online]. Available from: http://www.nsvrc.org/

Valji, N., Harris, B., Simpson, G. (2004) Crime, security and fear of the other. *SA Reconciliation Barometer*. 2(1)

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

With the implementation of the DNA Act, and as more crimes are solved through the application of DNA technology, it can be safely assumed that South Africans' interest in the technology will increase. Based on the results reported in Chapter 3 of this research, it is clear that the majority of people are not familiar with the applications of DNA and how it works for various reasons. It is therefore important to engage the public and increase their knowledge base on how DNA works and the benefits of the technology in serving the society. Raising public awareness on DNA will also help decipher the myths often accompanying the application of this technology for forensic purposes. Also, crime generally has an impact on communities and understanding the role that DNA and DNA databases can play in solving and preventing crime by the general population will encourage communities to support the government's investment and commitment towards this technology as reflected by the results of the study reported in Chapter 4.

It is also important to note that for DNA analysis to be effective as a crime fighting tool, all requirements for production of reliable results must be met. These include proper testing facilities and equipment that meet the minimum requirements set internationally for DNA analysis, well trained personnel capable of collecting, processing and analysing DNA as well as interpreting and reporting results. de Wet *et al.* (2011) highlight the importance of QC/QA compliance in the laboratory along with a well-documented chain of custody for DNA evidence to hold up in court. Building a solid community of forensic scientist is thus encouraged. van Oorschot *et al.* (2010) notes that there is a need for improved initial and ongoing training; proficiency testing and bench marking for people involved in DNA testing if success rates are to be improved. According to Olckers *et al.* (2013), unlike other professions, the forensic science profession is currently not organised or regulated in South Africa. They propose for a body that would formally organise and assist forensic scientists in the form of an academy of forensic science. The responsibility of the South African Academy of Forensic Sciences (SAAFS) would be to enforce ethics for practising forensic scientists, provide a forum for peer-review, see to the development of the profession in the country, assist the criminal justice system through access to a register of credible forensic scientist as well as provide transparency to the legal professionals and the public. It is thus expected that along with the increased application of DNA and DNA databases in criminal investigations, the forensic science profession in the country will also grow and become organised. With the existence of a robust forensic science community, it is expected that research into this field will be enhanced in order for the country to keep up with advances in technology.

The legal and regulatory framework for the application of DNA for forensic purposes must be clear to enable efficiency. The legal framework has to stipulate and prescribe the requirements needed to present DNA evidence in court especially when there are serious technical issues attached to it as with trace DNA analysis. As an example regarding the presentation of DNA evidence in court, de Wet *et al.* (2011) mention the use of a section 212(4) affidavit per the Criminal Procedures Act of 1977 (South Africa) as a means of submitting expert DNA evidence. The question that is highlighted here is that, as much as the law seems to permit such submission to the court, is it appropriate for DNA evidence? With more application of DNA evidence in criminal procedures, the submission of such affidavits in court may require review to allow for proper cross examination in such cases. The results presented in Chapter 2 bring the issue of DNA transfer to the fore. Clearly, the legitimacy of this phenomenon cannot be ignored and indeed DNA transfer is increasingly becoming an issue in court. It is therefore reasonable to expect an opinion on transfer from a DNA expert witness and such type of evidence will most likely require the expert to be physically present in court.

All the social, technical and legal issues mentioned herein are not possible without political will. It is through the politicians that laws, amendments thereto, and policies regarding the forensic application of DNA (not to the exclusion of other forensic sciences) in South Africa to fight crime can be applied successfully.

References

de Wet, S., Oosthuizen, H., Visser, J. (2011) DNA profiling and the law in South Africa. *PER/PELJ* [Online]. 14 (4). Available from: http://dx.doi.org/10.4314/pelj.v14i4.6

Olckers, A., Blumenthal, R., Greyling, A. (2013) Forensic science in South Africa: Status of the profession. *Forensic Science International: Genetics Supplement Series*. 4: 146–147

van Oorschot, R. A.H., Ballantyne, K.N., Mitchell, R.J. (2010) Forensic trace DNA: a review. *Investigative Genetics*. 1 (14)

APPENDIX 1: INFORMATION DOCUMENT & CONSENT FORM FOR GENETIC RESEARCH FOR THE STUDY TITLED: IMPLICATIONS OF SECONDARY DNA TRANSFER AND THE PUBLIC PERCEPTIONS ON THE NATIONAL DNA DATABASE OF SOUTH AFRICA

We are planning a research project on the feasibility of extraction secondary transferred DNA from a touched object. We request your permission to collect a buccal swab and to use your DNA that we isolate from your buccal sample as a reference sample.

The findings of this study will not have direct bearing on any genetic characteristics since only markers located in the non-coding region of the DNA will be used.

You are free to refuse consent and you do not have to give reasons for doing so.

Privacy and Confidentiality

To ensure the privacy and confidentiality of your genetic information, your buccal sample will be marked with a code and not your name. Researchers working on this project will therefore be able to identify the sample, but not any other scientists working in the laboratory.

Results of research

Feedback on genetic research will be provided to you if requested.

Family members

Information about family members, in addition to that provided by you, is not required for this research.

Your genetic material and information will not be released for other uses other than research without consent, unless required by law.

Storage of buccal swab/DNA

Your genetic material and information will be disposed of at the end of this study, once the sample storage and record-keeping requirements of good research practice have been met.

Do you have any sensitivity on how your swab/DNA should be disposed of? If so, what are they?

____

These will be recorded and taken into account at the time of disposal.

We can dispose of your genetic material even after the research has started since the samples are stored in an identifiable form.

Voluntary Participation

You do not have to agree to take part in this research and you are free to withdraw from the research at any time.

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Signature of participant:	Signature of researcher
Name :	Name:
Date:	Date

APPENDIX 2: INFORMATION AND CONSENT FORM FOR PARTICIPATION IN THE STUDY TITLED: IMPLICATIONS OF SECONDARY DNA TRANSFER AND THE PUBLIC PERCEPTIONS ON THE NATIONAL DNA DATABASE OF SOUTH AFRICA

Dear Participant

The aim of this study is to establish the level of awareness and knowledge of and compile views of the South African public from various socio-economic backgrounds, regarding the National Forensic DNA database (NFDD). The objective is to get the opinion of the public about the establishment, the management (custody), the inclusivity and the use of the National DNA database in the country and the promulgation of the necessary legislation and even find the level of understanding of DNA and its forensic applications.

You will be interviewed following a generic questionnaire designed to enquire as to your knowledge of DNA and DNA database and their applications in criminal investigations and also to collect your views and opinion regarding the DNA database and the use of DNA in forensic investigations. No personal information will be required just general information that will assist in the analysis of the data collected; even this information will be treated with strict confidence. The information collected will be used solely for this research and the results may be published in a scientific journal.

If you require any more information regarding the study, please contact the researcher Polo Mokoma on 082 215 7879.

Thank you for your cooperation

I hereby give my **CONSENT** to participate in this research study as described. I fully understand that my participation in this study is completely voluntary, and if I decide to withdraw, no negative repercussions will follow. I also understand that the data collected in this study may be published in a scientific journal, but that personal information of any of the participants will **NOT** be made available.

________________________ _____________________

Signature Date

APPENDIX 3: OPINION QUESTIONNAIRE ON THE NATIONAL FORENSIC DNA DATABASE OF SOUTH AFRICA

The purpose of this survey is to determine the opinion of the South African public regarding the DNA database and its use as a crime fighting tool.

Section One: Personal Details

Please select an answer applicable to you.

1. Gender
- ☐ Male
- ☐ Female

2. Race
- ☐ Black
- ☐ Caucasian
- ☐ Asian
- ☐ Coloured

3. Province of residence
- ☐ Free State
- ☐ Gauteng
- ☐ Western Cape
- ☐ KZN
- ☐ Eastern Cape
- ☐ Limpopo
- ☐ Northern Cape
- ☐ Mpumalanga
- ☐ North West

4. Is your area of residence urban or rural
- ☐ Urban
- ☐ Rural
- ☐ Semi- urban

5. Highest education level
- ☐ No schooling
- ☐ Primary
- ☐ High School
- ☐ Higher Learning-Undergraduate
- ☐ Higher Learning-Graduate
- ☐ Higher learning-Postgraduate

6. Profession/Occupation:__________________

7. Age group

☐ 18-30 years

☐ 31-40 years

☐ 41- 50 years

☐ >50 years

8. Are you a parent?

☐ Yes

☐ No

9. Have you ever been arrested for or convicted of a crime

☐ Yes

☐ No

10. If you have answered yes to 9 above, please provide the details of the crime.

____

____

____

Section Two: DNA and its forensic applications

1. Do you know what DNA is?

☐ Yes

☐ No

2. Do you know what a DNA Database is?

☐ Yes

☐ No

3. If you have answered yes to one or both of the questions above, please explain what you know.

____

____

____

____

4. Where did you get the information in question 3 above?

____

5. To your knowledge, is DNA currently used in criminal investigations in South Africa?

☐ Yes

☐ No

6. To your knowledge, does South Africa have a DNA database?

☐ Yes

☐ No

7. Are you aware of any cases in South Africa where DNA and or DNA database played a vital role in an arrest or conviction?

☐ Yes

☐ No

8. If you answered yes to 7 above, please state where you heard the information from. Select the applicable answer.

☐ Print media (Newspaper, magazine)

☐ TV

☐ Internet

☐ Word of mouth

☐ Other *(specify)* ________________________

☐ Not applicable

Section Three: DNA Database

PART A: Below are statements regarding DNA and the DNA database, please indicate a response that most describes how you feel and/or think.

Strongly agree

Agree

Neutral

Disagree

Strongly disagree

	Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1.	South Africa should have a DNA database	**1**	**2**	**3**	**4**	**5**
2.	Police officers are the appropriate people to collect DNA samples for inclusion in the national DNA database.	**1**	**2**	**3**	**4**	**5**
3.	Consent is not necessary to take a DNA sample from anyone if they are convicted of a crime	**1**	**2**	**3**	**4**	**5**
4.	Consent is necessary for collection of a DNA sample from suspects and arrestees.	**1**	**2**	**3**	**4**	**5**
5.	The type of crime should not be considered for inclusion of a profile into the database.	**1**	**2**	**3**	**4**	**5**
6.	DNA samples should be collected at birth so as to create a database that includes the whole population.	**1**	**2**	**3**	**4**	**5**
7.	Age should not be considered for inclusion of a DNA profile into the database. Minors should be treated the same as adults.	**1**	**2**	**3**	**4**	**5**
8.	DNA samples must be collected upon arrest for all crimes	**1**	**2**	**3**	**4**	**5**
9.	All DNA samples collected should be retained indefinitely	**1**	**2**	**3**	**4**	**5**
10.	All DNA profiles must be retained indefinitely.	**1**	**2**	**3**	**4**	**5**
11.	Both the DNA sample and Profile should not be retained after acquittal.	**1**	**2**	**3**	**4**	**5**
12.	There must be stipulated a time frame for the retention of DNA profiles in the database	**1**	**2**	**3**	**4**	**5**

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
13. I believe that having a person's DNA profile on a national database will deter them from committing crimes	**1**	**2**	**3**	**4**	**5**
14. A court order granting access to the DNA database must be obtained by law enforcement agencies before a search can be made.	**1**	**2**	**3**	**4**	**5**
15. The SAPS should be the custodians for the South African National DNA Database.	**1**	**2**	**3**	**4**	**5**
16. The Forensic Science Laboratory should be independent of the SAPS	**1**	**2**	**3**	**4**	**5**
17. DNA analysis is a reliable method for the identification of perpetrators of crime	**1**	**2**	**3**	**4**	**5**
18. Collection of DNA from individuals infringes on their privacy	**1**	**2**	**3**	**4**	**5**
19. I am willing to provide a DNA sample for inclusion into the national DNA database	**1**	**2**	**3**	**4**	**5**
20. People convicted of criminal offences have diminished rights therefore collecting their DNA will not infringe their rights and privacy.	**1**	**2**	**3**	**4**	**5**
21. The DNA database must be linked to the finger print database	**1**	**2**	**3**	**4**	**5**
22. DNA collected for criminal investigations should be used for research without consent	**1**	**2**	**3**	**4**	**5**
23. The institution performing DNA analyses should be the same institution in custody of the DNA database	**1**	**2**	**3**	**4**	**5**
24. I support that the government provide funding towards the use of DNA in criminal investigations	**1**	**2**	**3**	**4**	**5**
25. I support the exchange of information in the DNA database between countries in the fight against cross border crimes	**1**	**2**	**3**	**4**	**5**

PART B: To the questions that follow, please choose all responses that apply to you

1. What crimes warrant the taking of a DNA sample for inclusion into the database?
   - ☐ Murder
   - ☐ Rape/sexual assault
   - ☐ Robbery(incl. hijacking)
   - ☐ Burglary(incl. autotheft)
   - ☐ Possession of fire arms and ammunition
   - ☐ Drug-related offences
   - ☐ Driving related offences
   - ☐ Kidnapping(incl. human trafficking)
   - ☐ Other(specify)___________________
   - ☐ None

2. For which crimes do you think, DNA profiles of offenders should be retained?
   - ☐ Murder
   - ☐ Rape/sexual assault
   - ☐ Robbery(incl. hijacking)
   - ☐ Burglary(incl. autotheft)
   - ☐ Possession of fire arms and ammunition
   - ☐ Drug-related offences
   - ☐ Driving related offences
   - ☐ Kidnapping(incl. human trafficking)
   - ☐ Other(specify)___________________
   - ☐ None

3. For the answers selected in 2, how long must the profiles be retained? Please suggest a time period which you deem appropriate on the space in provided:
   - ☐ Murder ____
   - ☐ Rape/sexual assault____
   - ☐ Robbery(incl. hijacking)_______________________________________
   - ☐ Burglary(incl. auto theft)______________________________________
   - ☐ Possession of fire arms and ammunition_________________________
   - ☐ Drug-related offences____
   - ☐ Driving related offences_______________________________________
   - ☐ Kidnapping (incl. human trafficking)_____________________________
   - ☐ Other(specify)_______________________ _________________________
   - ☐ None

4. At which age should profiles of underage offenders be removed, if at all, from the database?
   - ☐ 16 years

☐ 18 years

☐ 21 years

☐ Must be treated same as adult offenders

☐ Not at all

Section 4: Additional Comments

Please provide any other opinion you may have regarding the use of DNA and DNA database for criminal investigations in South Africa.

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BIBLIOGRAPHY

Aditya, S., Sharma, A.K., Bhattacharyya, C.N., Chaudhri, K. (2011) Generating STR profile from "touch DNA". *Journal of Forensic and Legal Medicine*. 18: 295─298

Akram, N.A., Forooqi, S.R. (2012) DNASF: A statistical package to analyse the distribution and polymorphisms of CODIS STR loci in a heterogenous population. *J Forensic Res*. 3 (9): 170.

Alessandrini, F., Cecati, M., Pesaresi, M., Turchi, C., Carle, F., Tagliabracci, A. (2003) Fingerprints as evidence for a genetic profile: Morphological study on fingerprints and analysis of exogenous and individual factors affecting DNA typing. *J Forensic Sci*. 48(3)

Altbeker, A. (2008) Murder and robbery in South Africa: A tale of two trends. In: van Niekerk, A., Suffla, S. and Seedat, M. *Crime, violence and injury prevention in South Africa: Data to action*. Tygerberg, RSA: MRC-UNISA Crime, Violence and Injury Lead Programme. p.131–160.

Asplen, C. (2004) *The application of DNA technology in England and Wales*. [Online] U. S. Department of Justice. Available at: https://www.ncjrs.gov/pdffiles1/nij/grants/203971.pdf

Bhati, A., Roman, C.G. (2014) Evaluating and quantifying the specific deterrent effects of DNA databases. *Evaluation Review*. 38 (1): 68–93

Bright, J., Petricevic, F.S. (2004) Recovery of trace DNA and its application to DNA profiling of shoe soles. *Forensic Sci. Int*. 145: 7─12

Buckleton, J., Triggs, C.M., Walsh, S.J. (eds.). (2005) *Forensic DNA evidence interpretation*. Florida, USA: CRC Press.

Budowle, B., van Daal, A. (2009) Extracting evidence from forensic DNA analyses: future molecular biology directions. *BioTechniques.* 46: 339–350

Butler, J.M. (2003) Recent developments in Y-STR tandem repeat and Y-Single Nucleotide Polymorphism analysis. *Forensic Science Review*. 15: 91

Butler, J.M. (2012) *Advanced topics in forensic DNA typing: methodology*. Massachusetts, USA: Elsevier Inc.

Butler, J.M., Coble, M.D., Vallone, P.M. (2007) STRs vs SNPs: thoughts on the future of forensic DNA testing. *Forensic Sci Med Pathol*. 3: 200–205

Butler, J.M., Levine, B.C. (1998) Forensic applications of mitochondrial DNA. *Trends Biotechnol*. 16 (4): 158–62

Butler, J.M., Shen, Y., McCord, B.R. (2003) The development of reduced size STR amplicons as tools for analysis of degraded DNA. *J forensic Sci*. 48 (5): 1054–64

Campbell, L. (2011) “Non-conviction” DNA databases and criminal justice: a comparative analysis. *Journal of Commonwealth Criminal Law*. p. 55–77

Choo, S.Y. (2007) The HLA System: Genetics, Immunology, Clinical testing and Clinical implications. *Yonsei Medical Journal*. 48 (1): 11–23

Chow-White, P.A., Duster, T. (2011) Do health and forensic DNA databases increase racial disparities? *PLosMed* [Online]. 8(10): e1001100. Available from: doi:10.1371/journal.pmed.1001100

Crow, J.F. (2010) *DNA forensics: Past, present, and future* [Online]. Available from: http://www.promega.ca/~/media/files/resources/conference%20proceedings/ishi%2010/oral%20presentations/01crow.pdf?la=en.

Curtis, C. (2009) Public perceptions and expectations of the forensic use of DNA. *Bulletin of Science, Technology and Society*. 29(4): 313–324

Daly, D.J., Murphy, C., McDermott, S.D. (2012) The transfer of touch DNA from hands to glass, fabric and wood. *Forensic Sci. Int. Gene*. 6: 41─46

Daniels, D.L., Hall, A.M., Ballentyne, J. (2004) SWGDAM developmental validation of a 19-locus Y-STR system for forensic casework. *J Forensic Sci*. 49 (4): 668-83

de Wet, S., Oosthuizen, H., Visser, J. (2011) DNA profiling and the law in South Africa. *PER/PELJ* [Online]. 14 (4). Available from: http://dx.doi.org/10.4314/pelj.v14i4.6

Dean, L. (2005) The ABO Blood Group. In: *Blood groups and red cell antigens* [Online]. Bethesda (MD): National Centre for Biotechnology Information (US). Available from: http://www.ncbi.nlm.nih.gov/books/NBK2267

Decorte, R., Cassiman, J. (1993) Forensic medicine and the polymerase chain reaction technique. *J Med Genes.* 30: 625–33

Djuric, M., Varljen, T., Stanojevic, A., Stojkovic, O. (2008) DNA typing from handled items. *Forensic Sci. Int.: Genetics Supplement*. 1: 411─412

DNAforensics. (Undated) *Science of the future: Identifying criminals through their family members* [Online]. Available from: http://www.dnaforensics.com/FamilialSearches.aspx.

Doleac, J.L. (2012) *The effects of DNA databases on crime*. Stanford, CA 94305: Department of Economics, Stanford University.

Easteal, S. (1990) DNA fingerprinting by PCR amplification of HLA genes. In: Vernon, J. and Selinger, V. *DNA and Criminal Justice* [Online]. Australia: Australian Institute of Criminology. p.119-125. Available from: http://www.aic.gov.au/media_library/publications/proceedings/02/easteal.pdf

Farmen, R.K., Jaghø, R., Cortez, P., Frøyland, E.S. (2008) Assessment of individual shedder status and implication for secondary DNA transfer. *Forensic Sci. Int.: Genetics Supplement.*1: 415─417

Forster, L., Thomson, J., Kutranov, S. (2008) Direct comparison of post-28-cycle PCR purification and modified capillary electrophoresis methods with the 34-cycle "low copy number" (LCN) method for analysis of trace forensic DNA samples. *Forensic Science International: Genetics* [Online]. Available from: http://dx.doi.org/10.1016/j.fsigen.2008.04.005

Fourney, R.M. (2002) *Forensic reality and the practical experience of DNA typing update* [Online]. International Society for the Reform of Criminal Law. Available from: http://www.isrcl.org/Papers/Fourney.pdf

Gamero, J., Romero, J., Peralta J., Carvalho, M., Vide, M., Corte-Real, F. (2006) The opinion of the Spanish population with regard to the procedural situation of individuals that would justify the storage of their DNA profiles in a national database. *International Congress Series*. 1288: 774–776

Gamero, J., Romero, J., Peralta, J. Corte-Real, F., Guillén, M., Anjos, M. (2008) A study of Spanish attitudes regarding the custody and use of forensic DNA databases. *Forensic Science International: Genetics*. 2: 138-149

Gamero, J., Romero, J., Peralta, J., Carralho, M., Corte-Real, F. (2007) Spanish Public Awareness regarding DNA profile Databases in Forensic Genetics: What type of DNA profiles should be included. *J Med Ethics*. 33: 598–604

Garnier, G. (2005) Racial profiling: DNA forensic procedures & indigenous people in Victoria. *Current Issues in Criminal Justice*. 17(1): 47–68

Ge, J., Sun, H., Li, H., Liu, C., Yan, J., Budowle, B. (2014) Future directions of forensic DNA databases. *Croat Med J*. 55: 163–6

GeneWatch UK. http://www.genewatch.org

Gill, P. (2001) Application of low copy number DNA profiling. *Croat Med J*. 42: 229–232

Gill, P. (2002) Role of Short Tandem Repeat DNA in forensic casework in the UK─past, present, and future perspectives. *BioTechniques*. 32: 366─385

Gill, P., Whitaker, J., Flaxman, C., Brown, N., Buckleton, J. (2000) An investigation of the rigor of interpretation rules for STRs derived from less than 100 pg of DNA. *Forensic Sci. Int*. 112: 17─40

Goray, M., Mitchell, J.R., van Oorschot, A.H. (2012) Evaluation of multiple transfer of DNA using mock case scenarios. *Legal Medicine*. 14: 40─46

Goray, M., Mitchell, R.J., van Oorschot, R.A.H. (2010) Investigation of secondary DNA transfer of skin cells under controlled test conditions. *Legal Medicine*. 12: 117─120

Goulka, J., Matthies, C.F., Disley,E., Steinberg, P.S. (2010) *Toward a Comparison of DNA Profiling and Databases in the United States and England* [Online]. Santa Monica, CA: RAND Corporation. Available from: http://www.rand.org/pubs/technical_reports/TR918.

Government Gazette. (2014) *Criminal Law (Forensic Procedures) Amendment Act 37 of 2013* [Online]. Cape Town: The Presidency. 52(583). Available from: http://dnaproject.co.za/new_dna/wp-content/uploads/2014/01/Act-37-of-2013.pdf

Gullien, M., Lareu, M. V., Pestoni, C., Salas, A., Carracedo, A. (2000) Ethical-legal problems of DNA databases in criminal investigation. *Journal of Medical Ethics*. 26: 266–271

Harris, M., Radaelli, S. (2007) Paralysed by fear: Perceptions of crime and violence in South Africa. *SA Crime Quarterly*. 20: 1–6

Hartley, W. (2013) *ANC says costs can be cut for new DNA database* [Online]. Available from: http://www.bdlive.co.za/national/2013/08/01/anc-says-costs-can-be-cut-for-new-dna-database.

Heathfield, L.J. (2014) Policy required for entry of DNA profiles onto the National Forensic DNA Database of South Africa. *S Afr J Sci*. 110 (7/8)

Hochschild, J.L., Sen, M. (2012) Race, DNA and Criminal justice: Linking public opinion to public policy. In: *Law and Society Annual Conference; June 2–5, 2011* [Online]; San Francisco, CA. Princeton University Press. Available from: http://dx.doi.org/10.4172/2157-7145.1000170.

Interpol. (2009) *Handbook on DNA data exchange and practice: Recommendations from the Interpol DNA Monitoring Expert Group* [Online]. Available from: www.interpol.int/content/download/.../7/.../HandbookPublic2009[2].pdf.

Interpol. (2014) *Fact Sheet: DNA Profiling* [Online]. Available from: www.interpol.int/en/News-and-media/.../Fact-sheets/DNA-Profiling/

Jeffreys, A.J., Wilson, V., Thein, L.S. (1985) Individual-specific 'fingerprints' of human DNA. *Nature.* 316 : 76-79

Jobling, M.A., Gill, P. (2004) Encoded evidence: DNA in forensic analysis. *Nature Review Genetics*. 5 (10): 739–51

Johnson, P., Martin,P., Williams, R. (2003) Genetics and Forensics: Making the National DNA Database. *Science Studies*. 16 (2): 22–37

Kashyap, V.K., Sitalaximi, T., Chattopadhayay, P., Trivedi, R. (2004) DNA profiling techniques in forensic analysis. *Int J Hum Genet*. 4 (1): 11–30

Kaye, D.H., Smith M.E. (2003) DNA identification databases: Legality, legitimacy & the case for population-wide coverage. *Wis. L. Rev*. p.413–59

Kelley, S. (2010) *Assessment of DNA transfer involving routine human behaviour* [Online]. Fort Worth, TX: University of North Texas Health Science Centre. Available from: http://digitalcommons.hsc.unt.edu/theses/98

Kloosterman, A.D., Kersbergen, P. (2003) Efficacy and limits of genotyping low copy number DNA samples by multiplex PCR of STR loci. *International Congress Series*. 1239: 795–798

Konings, L., van Rossum, B. (2011) Should we record the DNA profiles of the entire Dutch population in a DNA database?. *Erasmus Journal of Medicine*. 1(2): 47–49

Koops, B., Schellekens, M. Forensic DNA phenotyping: Regulatory issues. (2008) *The Colombia Science and Technology Law Review*. 9: 158–202

Krenke, B.E., Tereba, A., Anderson, S.J., Buel, E., Culhane,S., Finis, C.J., *et al*. (2002) Validation of a 16-locus fluorescent multiplex system. *J Forensic Sci*. 47 (4)

Ladd, C., Adamovicz, S.M., Bourke, M.T., Scherczinger, C.A., Lee, H.C. (1999) A systematic ananlysis of secondary DNA transfer. *J Forensic Sci*. 44(6): 1270─1272

Levine, H.G., Gettman, J.B., Reinarman, C., Peterson Small, D. (2008) *Drug arrests and DNA: Building Jim Crows's database* [Online]. Available from: http://www.councilforresponsiblegenetics.org/pageDocuments/0RRXBGGAEI.pdf

Levitt, M. (2007) Forensic databases: Benefits and ethical and social costs. *British Medical Bulletin*. 83: 235–248

Linacre, A. (2009) Review of low template DNA typing. *Forensic Science International: Genetics Supplement Series*. 2: 549–550

Lowe, A., Murray, C., Whitaker, J., Tully, G., Gill, P. (2002) The propensity of individuals to deposit DNA and secondary transfer of low level DNA from individuals to inert surfaces. *Forensic Sci. Int*. 129: 25─34

Machado, H., Santos, F., Silva, S. (2011) Prisoners' expectations of national forensic DNA database: Surveillance and reconfiguration of individual rights. *Forensic Science International* [Online]. Available from: doi:10:1016/j.forsciint.2011.02.020

Malhotra, N.K. (2006) Questionnaire Design and Scale Development. In: Grover, R. and Vriens, M. *The Handbook of Marketing Research: Uses, Misuses, and Future Advances*. Thousand Oaks, CA: SAGE Publications, Inc. p.84-95.

Maynts-Press, K.A., Ballantyne, J. (2007) Performance characteristics of commercial Y-STR multiplex systems. *J Forensic Sci*. 52 (5): 1025–34

Morris, A.G. (2013) The DNA bill: Forensic science in the service of society. *S Afr J Sci* [Online]. p.109. Available from: http://dx.doi.org/10.1590/sajs.2013/a0043

Mullis, K., Faloona, F., Scharf, S., Saiki, R., Horn, G., Erlich, H. (1986) Specific enzymatic amplification of DNA in vitro: the Polymerase Chain Reaction. *Cold Spring Harb Symp Quant Biol*. 51 (1): 263–73

Myers, S.P., Timken, M.D., Piucci, L. M., Sims, G.A., Greenwald, M.A., weigand, J.J. et al. (2010) Searching for first-degree familial relationships in California’s offender DNA database: Validation of a likelihood ratio- based approach. *Forensic Science International: Genetics* [Online]. Available from: doi:10.1016/jfsigen.2010.10.010

Naughton, M., Tan, G. (2011) The need for caution in the use of DNA evidence to avoid convicting the innocent. *The International Journal of Evidence & Proof*. 15: 245─257

Olckers, A., Blumenthal, R., Greyling, A. (2013) Forensic science in South Africa: Status of the profession. *Forensic Science International: Genetics Supplement Series*. 4: 146–147

Olney, M. Bonn, S. (2014) An exploratory study of the legal and non-legal factors associated with exoneration for wrongful conviction: the power of DNA evidence.

Criminal Justice Policy Review [Online]. p.1–21. Available from: http://cjp.sagepub.com/content/early/2014/02/13/0887403414521461

Panneerchelvam, S., Norazmi, M.N. (2003) Forensic DNA profiling and database. *Malaysian Journal of Medical Sciences.*10 (2): 20–26

Paterson, K.K. (2013) *A Competition of suffering: Male vs. female rape* [Online]. Available from: http://www.womenundersiegeproject.org/blog/entry/a-competition-of-suffering-male-vs.-female-rape.

Pelser, E., Louw, A., Ntuli, S. (2000) *Poor safety: Crime and policing in South Africa's rural areas.* Pretoria: Institute for Security Studies. Monograph 47

Poy, A., van Oorschot, R.A.H. (2006) Beware; gloves and equipment used during the examination of exhibits are potential vectors for transfer of DNA-containing material. *International Congress Series*. 1288: 556─558

Republic of South Africa. PUB Programme. (2009) Public understanding of Biotechnology: DNA profiling. [Online]. Available from: www.pub.ac.za

Roberts, B. (2008) *Age of hope or anxiety? The dynamics of fear of crime in South Africa* [Online]. Available from: http://www.hsrc.ac.za/uploads/pageContent/3333/2008marAge%20of%20hope%20or%20anxiety.pdf

Rocque MJ, Leake SL, Milon MP, Castella V (2014) The tightness of the cotton swabs meshing influences the chances of getting conclusive DNA profiles. *J Forensic Res*. 5(4): 234

Rushton, S. (2010) *Familial searching and predictive DNA testing for forensic purposes: A review of laws and practices* [Online]. New Zealand: Victoria Law Foundation. Available from: http://dnaproject.co.za/new_dna/wp-content/uploads/2011/03/Report-Familial-Searching-and-Predictive-DNA-Testing-2010.pdf

Saad, R. (2005) Discovery, development, and current applications of DNA identity testing. *BUMC Proceedings*. 18: 130–133

Santiago, R., Caves, G., Nelson, M., Podini, D. (2013) *Cotton swabs vs. 4N6FLOQSwabs^{TM}: A comparative study for optimal recovery of simulated touch DNA* [Online].Washington, DC: The George Washington University. Available from: http://www.isfg.org

Schweitzer, N.J., Saks, M.J. (2007) The CSI Effect: Popular fiction about forensic science affects the public's expectations about real forensic science. *Jurimetrics J*. 47: 357–364

Seringhaus, M.R. (2009) *Forensic DNA profiles: Database expansion, familial search and a radical solution*. Association for the Advancement of Artificial Intelligence. p.150–4. Available from: www.aaai,org

Sheldon, D.E., Kim, Y.S., Barak, G.A. (2006) A study of juror expectations and demands concerning scientific evidence: Does the "*CSI* effect" exist? *Vanderbilt Journal of Entertainment and Technology Law*. 9(2): 331–368

Simoncelli, T. (2006) Dangerous excursions: The case against expanding forensic DNA databases to innocent persons. *Journal of Law, Medicine & Ethics*. 390–397

Simpson, G. (1998). Urban Crime and Violence in South Africa. In: Petty, C. & Brown, M. (eds). *Justice for Children, London: Save the Children* [Online]. Available from: http://www.csvr.org.za/old/index.php/publications/1524-urban-crime-and-violence-in-south-africa.html

Smith, G.B., Gordon, J.A. (1997) The admission of DNA evidence in state and federal courts. *Fordham Law Review*. 65 (6): 2465–2488

South Africa. South African Police Service. (2014) *South African Crime Statistics* [Online]. Pretoria: South African Police Service. Available from: http://www.saps.gov.za/resource_centre/publications/statistics/crimestats/2014/crime_stats.php

Stackhouse, R., Anderson, C., Shaw, A.M., Iredale, R. (2010) Avoiding the "usual suspects": young people's views of the national DNA database. *New Genetics Society*. 29(2): 149-166

Stemple, L. (2009) Male rape & human rights. *Hastings Law Journal*. 60: 605–47.

Sullivan, K.M., Mannucci, A., Kimpton, C.P., Gill, P. (1993) A rapid and quantitative DNA sex tests: fluorescence-based PCR analysis of X-Y homologous gene amelogenin. *Biotechs*. 15(4): 636–8, 640–1

Szigbor, R., Krawezak,M., Edelmann, J., Kuhlisch, E., Krause, D. (2003) Use of X-linked markers for forensic purposes. *Int J Legal Med*. 117: 67–74

The DNA Project. http://dnaproject.co.za

Thompson, W.C. (2008) *The potential for error in forensic DNA testing (and how that complicates the use of DNA databases for criminal identification)* [Online]. New York: Council for Responsible Genetics. Available from: http://www.councilforresponsiblegenetics.org/pagedocuments/h4t5eoyuzi.pdf

Thomson, C.W. (Jan/ Feb 2006) Tarnish on the "gold standard": Understanding recent problems in forensic DNA testing. *The Champion*. p. 10

United Kingdom. Home Office. (2014) *National DNA Database: Annual Report 2013–2014* [Online]. United Kingdom: The Williams Lea Group. Available from: https://www.gov.uk/government/publications/national-dna-database-annual-report-2013-to-2014

United Kingdom. Office of the National Statistics. (2012*) Ethnicity and national identity in England and Wales 2011* [Online]. Available from: www.ons.gov.uk

United Kingdom. Wales Gene Park and Techniquest. (2007) *The National DNA Database: The Public's views*. UK: Wales Gene Park and Techniquest.

United Nations. (2013) *UNODC Global study on homicide*. United Nations publication, Sales No. 14.IV.1.

United States of America. National Sexual Violence Resource Centre. (2015) *Statistics about sexual violence* [Online]. Available from: http://www.nsvrc.org/

Valji, N., Harris, B., Simpson, G. (2004) Crime, security and fear of the other. *SA Reconciliation Barometer*. 2(1) van Camp, N., Diedrikx, K., Leuven, K.U. (2007) The expansion of forensic DNA databases and police sampling powers in the post-9/11 era: Ethical considerations on genetic privacy. *Ethical Perspectives.* 14 (3): 237–268

van Oorschot, R. A.H., Ballantyne, K.N., Mitchell, R.J. (2010) Forensic trace DNA: a review. *Investigative Genetics*. 1 (14)

Van Oorschot, R.A., Jones, M.K. (1997) DNA fingerprints from fingerprints. *Nature*. 387 (6635): 767

van Oorschot, R.A.H., Phelan, D.G., Furlong, S., Scarfo, G.M., Holding, N.L., Cummins, M.J. (2003) Are you collecting all the available DNA from touched objects?. *International Congress Series*. 1239: 803─807

van Oorschot, R.A.H., Treadwell, S., Beaurepaire, J., Holding, N.L., Mitchell, R.J. (2005) Beware of the possibility of fingerprinting techniques transferring DNA. *J Forensic Sci*. 50(6)

Vandewoestyne, M., van Hoofstat, D., de Groote, S., van Thuyne, N., Haerinck, S., van Nieuwerburgh, F. *et al*. (2011) Sources of DNA contamination and decontamination procedures in the forensic laboratory. *J Forensic Res*. 82

Wallace, H.M., Jackson, A.R., Gruber, J., Thibedeau, A.D. (2014) Forensic DNA databases: Ethical and legal standards: A global review. *Egyptian Journal of Forensic Science* [Online]. Available from: http://dx.doi.org/10.1016/j.ejfs.2014.04.002

Williamson, A.L. (2012) Touch DNA: Forensic collection and application to investigations. *J Assoc Crime Scene Reconstr*. 18 (1): 1─5