

## **First Impressions Count: Serious detections arising from Criminal Justice Samples**

MICHAEL TOWNSLEY, CHLOE SMITH & KEN PEASE

### **Abstract**

DNA samples on the England and Wales national database matching those found at scenes of serious violent or sexual crimes were identified. The earlier offence leading the sample to appear on the database was noted. The bulk (60-84% according to inclusion criteria) involved theft, drug or other offending. The result, indicating offender versatility, is consistent with most research on criminal careers. Its importance for operational police lies in identifying the contribution made by DNA samples taken after less serious offences in clearing subsequent serious crime, and the importance of taking such samples from as wide a list of apparently 'trivial' crime types as possible. Examining specific relationships between early and later offences revealed a significant link between providing a DNA sample following a drug offence and subsequently committing murder.

### **Background**

In little under two decades, the use of DNA in the investigation of crime has become widespread. Since Sir Alec Jeffreys and colleagues pioneered what was first known as genetic fingerprinting<sup>1</sup>, advances in technology have allowed DNA profiling to be carried out at high speed and volume, at lower cost and with smaller crime scene samples, making its wider use in crime detection increasingly viable and appealing.

The England and Wales National DNA Database (NDNAD) has been impressive in scale, speed of development, and the protections it affords against false matches.<sup>2</sup> The technique's potential was anticipated from an early stage and received significant Government support. Large investments were made in populating the NDNAD<sup>3</sup> and legislation was introduced to facilitate sampling as many of the offending population as possible<sup>4</sup>. By increasing the number of putative offenders from whom samples are taken (hereinafter Criminal Justice samples), the probability of samples taken from scenes of crime being matched will increase. This will come to be limited primarily by the turnover of the active offending population, ie the rate of which people begin and end their active offending career.

The Home Office DNA Expansion Programme was launched in 1999, funded with £182 million between April 2000 and March 2004<sup>5</sup>. The 1994 Criminal Justice and Public Order Act had previously enabled the police to take non-intimate samples without consent from all those charged with (not necessarily arrested for) any recordable offence. The Act also reclassified a mouth swab as non-intimate, thereby removing the need to involve medical professionals for sample collection. Additionally the growth of the NDNAD was facilitated by powers introduced in the Criminal Justice and Police Act 2001 (CJPA) allowing retention of samples from persons who were not prosecuted or who were acquitted, providing such samples had been obtained lawfully in the first instance.

Since the first record was entered in 1995, the NDNAD has grown to over 3 million entries by November 2005<sup>6</sup>. With the ‘active criminal population’ in England and Wales estimated at 2.6 million people<sup>7</sup>, the magnitude of the achievement is undeniable, although the notion that this means that all of (or more than?) the active criminal population features on the database would be a substantial overestimate, because of the churn rate referred to above.

### **Criminal Careers and Crime Switching**

The term ‘criminal career’ refers to the offending trajectory of criminal behaviour, and its consistency and variation between and within offenders. The pertinent research literature deals with questions such as: Why do some people desist from crime and others continue? Are there people who do not stop offending at any stage of their lives? How does age and length of offending affect what crimes are committed? Such questions are relevant to operational policing because they allow a detailed picture of the active offending population to be developed. Individual criminal careers are described in terms of a number of dimensions, notably length, offending rate, and offending patterns (primarily versatility and escalation). Combinations (long or short careers, high or low offending rates, specialisation or versatility) produce diverse patterns at the individual level. This information has the potential to inform strategy. For example, the estimated size of the offender population and the offending patterns within it should favour certain crime control strategies over others. If the offending population were relatively small but those active remained so over substantial periods of time and offended at a high rate, then the targeting of individuals by police would be an appropriate tactic. If the offending population were large and comprised people committing only a couple of offences each, preventive approaches would be more attractive. Of course the real world will contain a mixture of ‘types’, but their relative size will favour some reduction strategies over others.

Understanding of criminal careers has traditionally been acquired through analysis of convictions and other official processing of offenders. DNA affords another window on criminal careers, with some disadvantages relative to the conventional approach, but with advantages, for example the possibility of including ‘prolific unknowns’ i.e. those whose DNA is found at many crime scenes but not in the NDNAD, and looking at residual career lengths of those never arrested<sup>8</sup>. In this brief paper, an attempt is made to use DNA sampling to address the issue of offender specialisation and its policing implications.

The simplest way of addressing offender specialisation/versatility using NDNAD is to compare the offence which resulted in an offender having DNA taken (the Criminal Justice sample) with the offence at which matching DNA was subsequently found. If the two offences were always the same, specialisation would be total (within the limits of the data). If the two offences were no more alike than a pair taken randomly, one from Criminal Justice samples, and one from crime scene samples, then versatility would be total, again within the limits of the data.

Recent analysis of DNA matches in England and Wales seems to suggest that offenders are, to a substantial degree, versatile in their offending behaviour. In 2002–2003, eighty percent of matches for Criminal Justice samples related to offences that

were different from the initial arrest offence for which the Criminal Justice sample was taken<sup>9</sup>. This may overestimate offending versatility. For example if the offence leading to a Criminal Justice sample being taken is Burglary in a Dwelling, and matching DNA later found at the scene of an offence categorised as Burglary Other, the two offences, because falling in different Home Office recording categories, would count towards versatility and away from specialisation, although most people would regard such an offender as a somewhat specialised burglar. It would be very instructive if the data could be presented as a full matrix of pairs. This would then allow both a view of versatility less obscured by categorisation, and calculation of a baseline of total versatility.

Having noted the potential of NDNAD in looking at offender careers, and that it has so far been scarcely realised, it must be asserted that previous research of the more conventional kind establishes a high degree of versatility in most criminal careers<sup>10</sup> <sup>11</sup> <sup>12</sup> <sup>13</sup>. Although debate exists about the precise level of specialisation exhibited by offenders, the degree of their versatility in both offence and method is substantial<sup>14</sup>. It is difficult to overstate the implications of this for the targeting of prolific offenders, by forensic and by other means. Insofar as offenders are versatile, detection in one offence offers an opportunity for detection in subsequent offences of other types. The evidence for this comes from the detection of notorious offenders – for example the highwayman and murderer Dick Turpin was brought to justice for poultry theft!<sup>15</sup> It also comes from research showing the high proportion of those committing trivial offences who are also involved in more serious offending<sup>16</sup> <sup>17</sup>. Schneider<sup>18</sup> identifies the high rate of self-reported shop theft amongst active burglars. Wellsmith and Guille<sup>19</sup> (2005) show the levels of active criminality in a sample of those repeatedly subject to fixed penalty notices. Rose<sup>20</sup> found little evidence of specialisation amongst serious traffic offenders, compared to mainstream offenders. Further, Sugg observed a wide range of ancillary offending (pre- and post-conviction) for attendees of probation motoring programmes<sup>21</sup>. In work highly relevant to the context of this paper, Frederick et al. <sup>22</sup> examined the impact of expanding the Offender Index (equivalent to UK's Criminal Justice samples) of New York State. They found, regardless of the severity of an individual's first adult offence, a high degree of versatility for all but a minority of offenders

There is an urgent need to begin looking at exactly what types of crime are linked with serious offending. Are there indicator or precursor minor offences? If so then how can this knowledge be used to greater effect? The questions we propose to address are the following:

What other types of crime do offenders committing a serious offence also commit? What implications does the resolution of that question have for the practice of taking DNA samples from those coming into contact with the criminal justice system as putative minor offenders?

It is probably worth emphasising that the purpose of this modest research is not to demonstrate any kind of Markov-type property in crime switching patterns<sup>23</sup>, as useful as that assuredly is. Rather, we wish to explore in a very simple way the potential power of consistent and vigorous use of Criminal Justice sampling powers by police officers with a view to best enabling detections of serious offences. This

paper sits alongside the findings of Soothill et al.<sup>24</sup> which quantify the relative risks of convictions of very serious offences based on prior convictions of a range of offences.

## Data

We obtained data on all solved serious offences within the Metropolitan Police Service (MPS) jurisdiction for the calendar year 2003. The offence types were all cases of murder, manslaughter, attempted murder, sexual offences, rapes and various types of robbery. This amounted to 9424 criminal matters. These events will be termed *index offences* in what follows.

Of these 9424 index offences, some 11 percent yielded a crime scene sample which could be matched with an offender on the National Database, i.e. where a Criminal Justice sample had been taken at an earlier time, some 1003 index offences in all. The earlier event which led to the taking of a Criminal Justice sample will henceforth be referred to as the *precursor event*. Matching Criminal Justice samples from precursor events after April 2000 to index offences could be performed very quickly. Those precursor events collected before April 2000 were stored on a separate database, and their extraction would have been extremely time-consuming, particularly for an unfunded study such as the one reported here. It was thus decided to use only those observations with a precursor event Criminal Justice sample collected after April 2000. The resulting sample size came to 492 index offences.

The data fields obtained from the MPS included information about each index offence: the *crime reference number*, *specific offence*, *crime type*, *occurrence date* and *police beat*. For every record the precursor event that was the origin of the corresponding Criminal Justice sample was recorded. Entries in the *specific offence* field relate to the actual charge as legally defined in legislation. The *crime type* field groups charges into broad categories consistent with Home Office counting rules. Even though *crime type* is primarily an administrative field it was used for this analysis in order that research findings could be interpreted by police officers and analysts consistent with their systems. Had another typology of aggregated offence types been developed, the practitioner audience may have difficulty generating the same relationships observed here.

A few points about these data are worth making. First, there was no information about location and dates for the precursor offences. It would have been desirable to determine spatial patterns between precursor and index offences, but the data precluded this avenue of analysis.

Second, links between index offences and precursor offences could only be supplied for precursor offences recorded after April 2000. As Criminal Justice sampling, in principle, is meant to follow an individual's first detected recordable offence, the conclusions reached are limited to those with short criminal careers to date. The longest career represented in these data will be around three years. The study thus focuses on detections achievable by Criminal Justice sampling *in the short term*. This is important in its own right. Detections achieved in the longer term should also be researched.

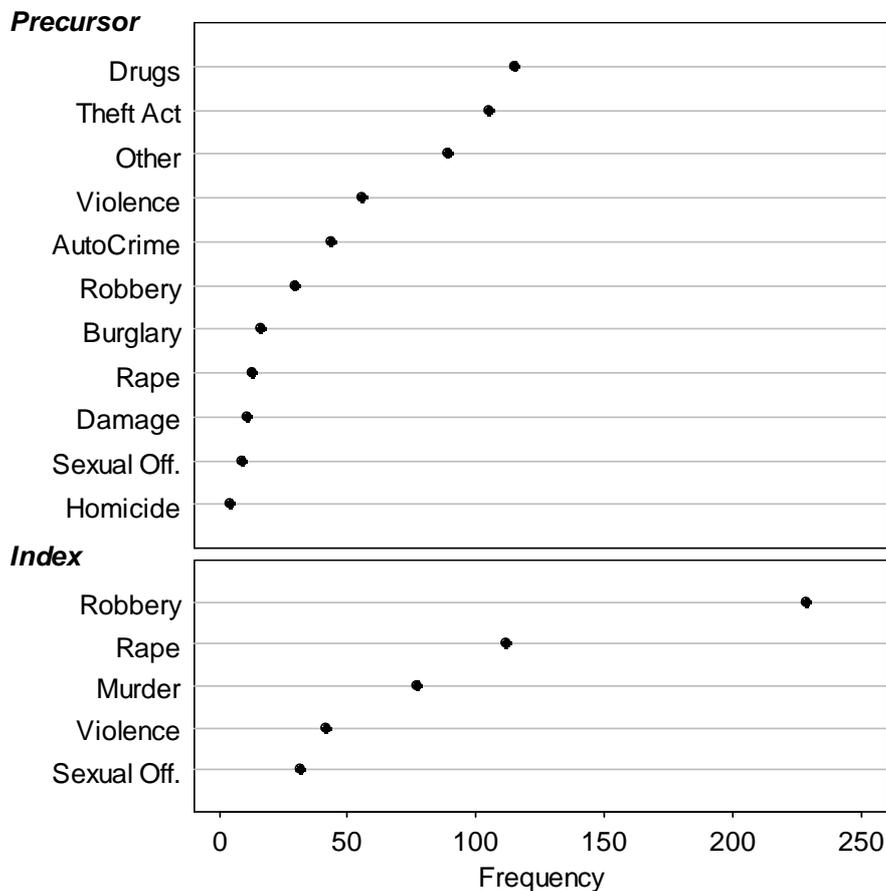
Third, it would be desirable to comment on and control for the Criminal Justice sampling rates of different offence types. This may influence patterns observed for precursor offences with low Criminal Justice sampling rates (due to most arrestees having been sampled for a previous offence, say). While feasible, scrutinising the Criminal Justice sampling rate was beyond the scope of this study.

The last qualifier about these data is that we have no information about the details of individual offences, apart from their type. Thus, we cannot make any inferences about variation in the level of seriousness of index offences according to precursor offence type. Given that all the index offences are serious, this is not of immediately crucial importance, but should be explored in future work.

### Analysis

The first step was to calculate the frequency distribution for the index and precursor offence types separately. The resulting distributions (see Figure 1) showed an uneven distribution for both, reflecting that some offences are more common than others<sup>25</sup>. Of the eleven possible offence types for precursor events, four categories were responsible for approximately seventy-five percent of the respective distribution. Precursor offences represent a wider range of criminal behaviour than index offences as the latter are, by definition, restricted to a subset of all potential criminal activity, whereas precursor crimes are not constrained in a similar way.

**Figure 1 – Precursor and Index Offence Frequencies**



It is apparent that the distribution of incidents for the index offences is skewed towards a couple of categories. It is worth pointing out that the observed distribution relates to detected crime, not recorded crime, hence the reason that there were so few violent crimes observed in the data. Due to the small observed frequency for ‘Other Sexual Offences’, it was decided for the remainder of this analysis to collapse this category with ‘Rape’ and label these observations ‘Sexual Offences’.

The next step involved cross tabulating precursor by index offences. The results showed a number of low row and column totals and a large number of empty cells. Given that a fifth of the cells had no observations it was decided to only include the four most prevalent precursor events (drugs, theft act, other<sup>26</sup> and violence). This diminished the sample size to 365 index offences, a loss of twenty-seven percent of the sample. The contingency table is displayed in Table 1.

**Table 1 – Joint frequency distribution of Precursor and Index offences**

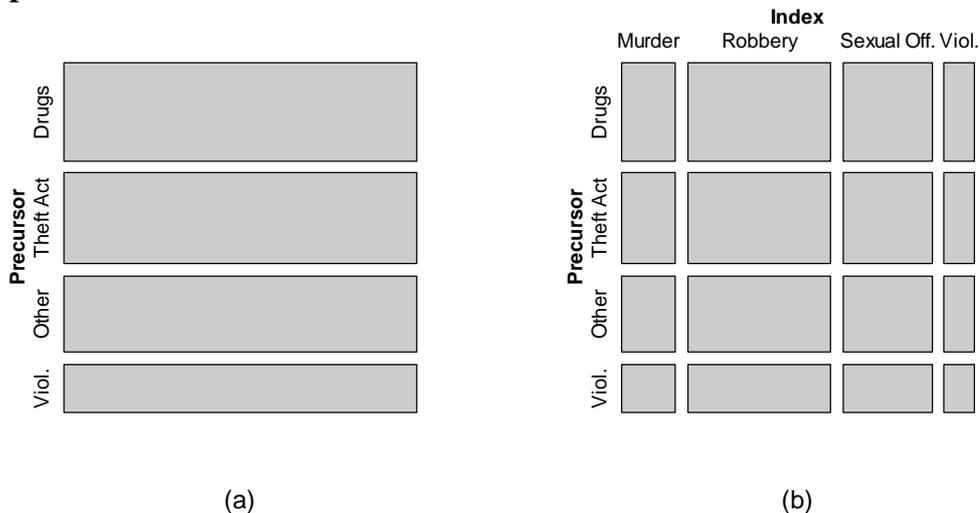
	Index				Total
	Murder	Robbery	Sexual Offences	Violence	
Precursor					
Drugs	29	49	26	11	115
Theft Act	10	59	27	9	105
Other	16	32	31	10	89
Violence	7	25	19	5	56
Total	62	165	103	35	365

The distribution presented in Table 1 allows a conventional chi-square test of independence to be performed, that is whether the distribution of index offences is dependent on the distribution of precursor offences. However, even if the null hypothesis of no dependence is rejected, it is far from clear how the relationship between the two variables influences the magnitudes of the cell frequencies. Typically we would be interested in which cell combinations deviate from expectation by a substantial amount and in which direction. Cells ‘of interest’ can only be identified in a post hoc manner as the p value produced by a chi-square test only takes us so far.

To aid interpretation we visualise the bivariate distribution using a *mosaic* plot in Figure 3. Mosaic plots are merely a graphical representation of a contingency table that are easier to interpret and more informative than a contingency table coupled with a p value from a chi-square test. In effect mosaic plots are an extension of grouped bar charts<sup>27, 28</sup>. Mosaic plots consist of tiles, representing individual cells, having areas proportional to the cell counts in the original table. The plot is constructed in the following way: begin by splitting a unit square into horizontal bars with heights relative to the marginal frequencies of one factor. Figure 2(a) depicts this stage (verified by observing from Table 1 the relative differences between the marginal totals of the precursor offences). The next stage involves splitting each horizontal bar vertically according to the frequencies of the second factor. In other words, the vertical splits are based on frequencies of the second factor *conditioned on the first*. Due to this conditional splitting property, the tiles will only be aligned vertically if the two factors are independent. Figure 2(b) shows the second phase of splitting, in this case using the marginal frequencies of the second factor (index offences). This depicts a joint distribution identical to the expected distribution, which is logical as

we have not yet conditioned by either factor. If the vertical splits were calculated using conditional proportions and they were identical or thereabouts to the marginal proportions then: (i) conceptually this would be weak evidence against the null hypothesis of no dependence and (ii) visually the tiles would be aligned with each other.

**Figure 2 – Mosaic plots showing marginal splits of (a) precursor events only and (b) precursor and index events**

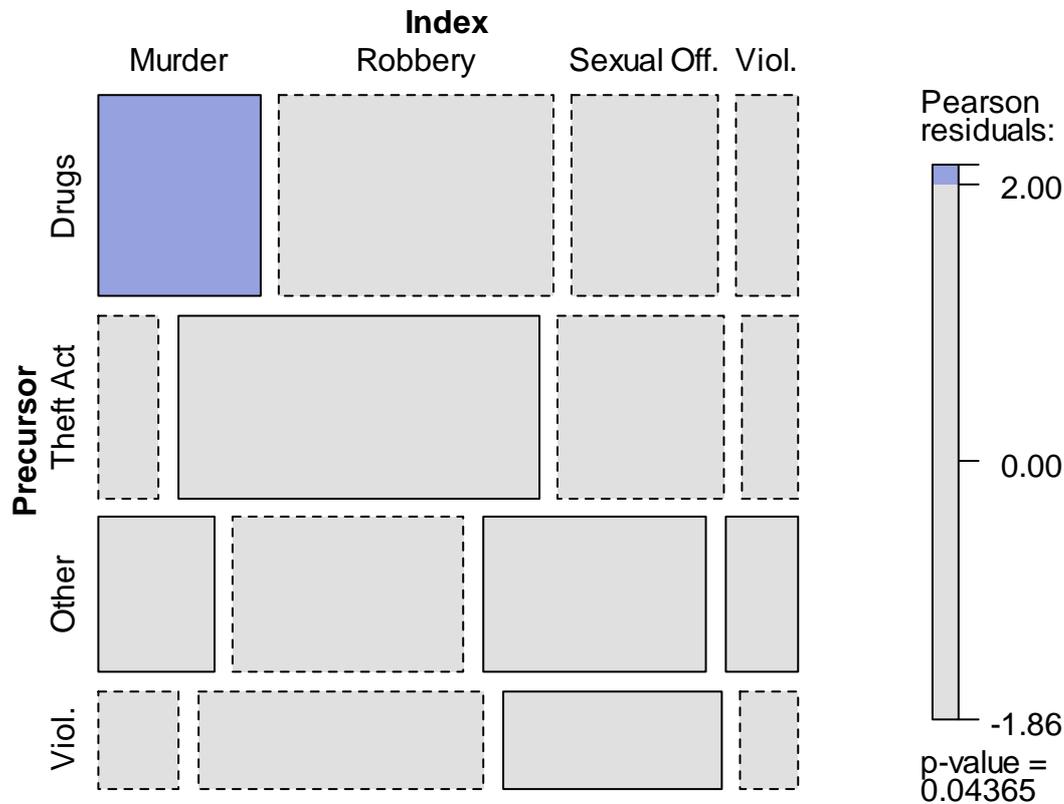


Friendly<sup>29</sup> extended the application of mosaic plots by shading and bordering tiles according to the magnitude and sign of residuals at the cellular level.

Figure 3 displays the mosaic plot of index offences by precursor events. The area of the tiles indicates the cell frequency relative to the sample size. The tiles' border (solid or dashed) indicates the sign (positive or negative respectively) of the residual for each cell and the shading indicates its magnitude. Here, the standardised Pearson residual<sup>30</sup> has been used to compute individual cell deviations from expectation. They are normally distributed so that values greater than absolute two are statistically significantly different at  $p < 0.05$ .

Taking the top row of tiles, corresponding to the precursor offence of Drugs, we can see it is relatively thick compared to the other categories (from Figure 1 we can verify it is in fact the most common precursor offence). Four tiles make up the Drugs row. The largest of which corresponds to Robbery offences (located second in from the left) and accounts for a sizable proportion of Drug offenders. The border of the tile is dashed, indicating the observed frequency for the cell, although large, was less than the expected frequency. Finally, the shading the cell (grey) combined with the legend indicates the standardised residual for this cell lies somewhere within two standard deviations of zero.

**Figure 3 – Mosaic of Index Offence and Precursor Event combinations.**



The index-precursor mosaic has a number of remarkable features. Overall there was moderate evidence of a relationship between precursor and index offences ( $\chi^2=17.3$  (d.f.=9),  $p = 0.044$ ). This is reflected in Figure 3 by the observation that the tiles do not align vertically. The second point is that the bulk of precursor events (60%) were for drug and theft offences, evidenced by the proportion of the plot taken up by the tiles within the top two rows. The same figure using all precursor events (i.e. those shown in Figure 1) is nearly forty-five percent. This dramatically illustrates the point about offender versatility. It means that the bulk of DNA evidence used to detect serious violent and sexual offenders will come from matches taken following theft or drugs offences. Including the ‘Other’ category boosts the figure to eighty-four percent for the data used in Figure 3 and sixty-three percent including all cases. More dramatically, the proportion of cases where the precursor event was the same as index offence (ie offender specialisation) was only about ten percent.

This does not mean that no specialisation is evident in the data. To know this one would need to know the sampling fraction for taking DNA samples for each precursor event type. However it does mean that the absolute majority of DNA evidence in serious cases as defined here results from taking swabs from the perpetrators of other

offence types. In our view it strongly supports the case for taking Criminal Justice samples as widely as possible.

While Figure 3 shows the general picture linking precursor and index offences, it also allows us to go further and look at particular individual associations evident in individual cells. Only one cell (murder-drugs) had a standardised residual greater than absolute two, although there were two other cells (murder-theft and robbery-theft) with substantial residuals significant at the 10% level. The remainder of cells (13) had residuals of trivial magnitude.

Arrestees for precursor drug offences go onto murder at significantly higher numbers than expected, accounting for *nearly half* of all detected murders. One plausible reason for this may be that the murders are drug related; if the precursor offence indicates participation in the supply of controlled drugs then the consequential commission of murder, while not normal, is not unexpected. Unfortunately, the data available for this analysis do not allow the testing or even the exploration of this explanation. What type of drugs offences (possession, supply or production) or murders (drug-related, gang-related, intimates) these represent is unknown<sup>31</sup>. Further research on the topic would be valuable, but as a preliminary indicator the vast majority of drug offences detected by MPS are for possession (approximately eighty percent for 2004/05). If this relationship holds for the Criminal Justice samples used in this analysis, then it would suggest against an explanation of murders directly related to drug dealing.

Regarding the murders, all homicides in the MPS are the remit of the Serious Crime Group, the investigative unit housing, among other things, Operation Trident<sup>32</sup>. There is no way of telling from these data what types of murders these represent. One way to explore this further would be to compare the composition of murder categories<sup>33</sup> by the different Criminal Justice sampling offences as well as all murders. If there were a greater number of Category B murders linked to precursor drug offences compared to other Criminal Justice sampling offences, then the high number of murders linked to earlier drug offences could be explained by occupational (drug dealing) risks. Unfortunately this information was not able to be provided by the MPS.

### ***Sensitivity analysis***

In order to determine if the standardised residuals for the murder-drug, murder-theft and robbery-theft cells (the only cells displaying substantial residuals) are linked in some way, a sensitivity analysis was performed (for details see the Technical Note at the end of the paper). The objective is to observe whether changes in frequencies of certain cells generate high residuals in other cells.

The first cell selected was the murder-drug combination. By controlling for the high murder-drug frequency, the residuals for murder-theft and robbery-theft were diminished such that they were no longer statistically significant. The next residual to be scrutinised was that associated with the murder-theft cell. The impact of adjusting the observed murder-theft frequency was that the robbery-theft residual was no longer significant at the ten percent level, but the murder-drugs cell was (just). Finally, manipulating the robbery-theft frequency impacted the residual of murder-theft so that it was no longer significant at any level, but murder-drugs retained a high positive

residual, significant at just over five percent. Table 2 displays the results of the sensitivity analysis. Pearson residuals have been converted to p values, to aid in interpreting to significance level of high magnitude residuals.

**Table 2 – p values of cells due to sensitivity analysis**

	P values of Pearson residuals		
	Murder-Drugs	Murder-Theft	Robbery-Theft
Observed	0.03	0.06	0.09
Controlling for influence of:			
(i) Murder-Drugs	0.36	0.17	0.14
(ii) Murder-Theft	0.10	0.93	0.19
(iii) Robbery-Theft	0.05	0.12	0.29

To summarise the results of the sensitivity analysis, the frequency of murder-drugs combinations appeared to ‘produce’ the low murder-theft frequency, which in turn served to inflate the significance of the robbery-theft combination. It appears that the excessive murder-drugs frequency is a stable feature of the relationship between precursor and index offences, over and above manipulations of other offence combinations. Other apparent links between precursor and index offences depend on the drugs-murder combination.

## Discussion

The analysis presented shows first and foremost that the offender versatility found in other criminal career research is reflected here. The central and in our view important finding is that taking Criminal Justice samples from theft and drug offence arrestees has a higher payoff in absolute terms in providing evidence in later cases of serious violent and sexual offences than does taking them from earlier offences of violence. This does not mean that the per case benefit is greater, simply that at the levels at which samples are currently taken by offence type, more later evidentiary benefit is gained from prior theft, drug and other offences than from prior violent or sexual offences. The implication of the study is believed to be that opportunities to take Criminal Justice samples in less serious cases should never be foregone, since they provide the bulk of DNA evidence in later serious offences. The deterrent effect of the buccal (mouth) swab should also not be understated, and its extent should be quantitatively researched.

A secondary finding of the study speaks to the more specific links between detected crime types. These observations are not of profound relevance in their own right. What makes them notable is that they offer an insight as to how unsolved crimes may be tackled through efforts in detecting other crime types. Criminal Justice sampling facilitates crime detection in a proactive sense by providing the immediate ability to test crime scene samples against a database of known individuals. There was a relationship between individuals arrested for drug offences and murderers and this was greater than we would expect by chance. This offence combination appeared to explain virtually all of the dependence observed between precursor and index offences. Once the murder-drug effect was accounted for the other relationships diminished. The interesting aspect of the murder-drug observation is that drug

offences are the only precursor crime category not associated with a detection rate (in that the total number of drug offences are not known or reported in a similar fashion as burglaries or assaults are), but we argue that it probably reflects police attention. A number of explanations present themselves. First, it could simply be that the murders are drug related in the sense that involvement in the drugs industry is dangerous. Another possibility is that drug offenders who go onto murder are the extreme result of a labelling phenomenon<sup>34</sup> although why that should be especially so for drug offenders is difficult to state. A third possibility is that attributes associated with drug offending above the threshold at which it comes to be officially processed may be associated with murder via the linkage of both with impulsivity. Qualitative study of, and interviews with, the substantial numbers who present with the precursor-index link of drug offence and murder seems worthwhile.

The major qualifier for these results is that the data used for this work only considers relatively short career lengths (three years at most). This is a considerable weakness in the sample. It is highly likely that the individuals with serious offence detections are those who have long careers. The most versatile, prolific and serious offenders are most likely to have been excluded from our sample. This could easily be circumvented by expanding the search criteria in a more ambitious study. If this comment is well-founded, it may suggest that the central finding, of the relevance of less serious precursors to more serious later offences and the consequence of maximising DNA capture in the solution of serious crime, is conservatively stated here.

Despite the uncertainties surround the data, the results indicate some promising directions for operational policing. They encourage police to take Criminal Justice sampling seriously and point to the wider benefits of increasing detection rates for volume crime. More certainty of the impacts of volume crime detections could be gained by taking a more longitudinal approach and considering a more representative sample. A research programme to develop the approach mooted here could offer substantial benefits in understanding and practice.

### **Acknowledgements**

The authors are grateful to the Metropolitan Police Service (in particular Gary Pugh, Delia Moss and Alan Chalkley) for the provision and use of data.

### **Technical Note: Sensitivity Analysis on a Contingency Table**

The procedure used here involves determining which cells, or factor combinations, display frequencies excessively high or low compared to the expectation level. The rationale comes from three observations as to the nature of contingency tables:

Extreme values within a cross tabulation have the ability to skew expected cell frequencies of the entire table. This is because the row and column totals, derived from the observed distribution, form the basis of determining the expected distribution. The row and column totals of an extreme value cell will become elevated (or diminished), thus raising (or lowering) the expected frequencies for *all* cells that share a row or column with the extreme value cell. The expected

frequencies for cells not sharing a row or column with an extreme value are skewed in the opposite direction.

In order to discern other patterns in the observed distribution, the influence of extreme value cells needs to be neutralised. A relative measure of the influence of any cell to the rest of the table is the standardised Pearson residual (which is just the square of the cell's  $\chi^2$  component). The significance of a cell's observed frequency can be assessed by the magnitude of its residual (anything greater than absolute two indicates deviation from expectation at the five percent level).

Artificially altering the observed distribution so that the influence of extreme values is negligible would reduce the skewness inherent in the expected distribution and therefore allow residuals for the remainder of the table to be scrutinised while “controlling” for extreme values.

In order to discern the structure of dependence in the contingency table, cells with large absolute standardised Pearson residuals are selected and artificially altered so that their residual is less than absolute two. The resulting observed distribution is scrutinised, through calculating residuals, for remaining patterns of dependence. Cells with a standardised residual greater than absolute two are of interest here. If none exist, one could infer that any patterns present in the original observed distribution were generated by the extreme value. Cells with high residuals after extreme values are controlled for represent factor combinations which are significant over and above the influence of the extreme value.

It is possible that pairs of cells may display a reciprocal relationship, so it is important to repeat the exercise by altering other cells. We would expect that cells displaying large absolute residuals post adjustment to be evidence of real relationships.

This type of analysis can be easily implemented in a spreadsheet application. The observed, expected, residuals and  $\chi^2$  scores can be displayed using embedded formulae from the observed table. Thus, the impact of manipulating the distribution can be scrutinised directly. Different cells can be selected until the user has a good understanding of how or if the bivariate distribution deviates from expectation.

---

1 A.J. Jeffreys et al. Hypervariable ‘minisatellite’ regions in human DNA, *Nature*, 1985; 314: 67-73.

2 See [http://www.forensic.gov.uk/forensic\\_t/inside/about/annual.htm](http://www.forensic.gov.uk/forensic_t/inside/about/annual.htm) for a complete set of annual reports. Accessed 19th Dec 2005.

3 R. Williams and P. Johnson, *Circuits of Surveillance, Surveillance and Society*, 2003; 2(1): 1-14.

4 P. Johnson, et al. *Genetics and Forensics: Making the National DNA Database*, *Science Studies*, 2003; 16: 22-37.

5 Forensic Science Service 2003. *The National DNA Database: Annual Report 2002-03*. Forensic Science Service Communications Department.

6 [http://www.forensic.gov.uk/forensic\\_t/inside/news/docs/NDNAD.doc](http://www.forensic.gov.uk/forensic_t/inside/news/docs/NDNAD.doc) Accessed 19 Dec 2005

7 Forensic Science Service 2004. *The National DNA Database: Annual Report 2003-04*. Forensic Science Service Communications Department.

8 For a comprehensive discussion of residual career lengths and residual number of offences see L. Kazemian 2005. *Criminal Careers and Deterrence*. Unpublished doctoral thesis, Cambridge Institute of Criminology.

9 Forensic Science Service op. cit. 5

10 A. Blumstein et al. *Criminal Careers and “Career Criminals”*, Vol. 1, 1986. National Academic

Press, Washington, DC.

11 A. Blumstein, et al. Specialization and seriousness during adult criminal careers. *Journal of Quantitative Criminology* 1988; 4: 303-345.

12 R. Paternoster et al. The Forward Specialization Coefficient: Distributional Properties and Subgroup Differences. *Journal of Quantitative Criminology* 1998; 14: 133-154.

13 M. Wolfgang et al. (eds.) 1987 *From Boy to Man: From Delinquency to Crime*, Chicago: University Chicago Press.

14 N Bouhana, 2003 *Profiling Arson*. Unpublished doctoral thesis, Cambridge Institute of Criminology.

15 <http://www.york-united-kingdom.co.uk/dickturpin/> Accessed 19 Dec 2005

16 G.L. Kelling and C.M Coles. 1996. *Fixing Broken Windows: Restoring Order and Reducing Crime in Our Communities*. New York: Free Press

17 S. Chenery. *Illegal Parking in Disabled Bays: A Means of Offender Targeting*. 1999; Briefing Note 1/99. London: Home Office Policing and Reducing Crime Unit

18 J. Schneider. Research Note: The Link Between Shoplifting And Burglary: The Booster Burglar. *British Journal of Criminology*, 2005: 45(3): 395-401.

19 M. Wellsmith and H. Guille. Fixed penalty notices as a means of offender selection. *International Journal of Police Science and Management* 2005; 7(1): 36-43

20 G. Rose. 2000. *The criminal histories of serious traffic offenders*. Home Office Research Study 206. London: Home Office

21 D. Sugg. 1998. *Motor Projects in England and Wales: An Evaluation*. Home Office Research and Development Statistics Directorate, Research Findings 81. London: Home Office

22 B. Frederick. et al. 2002. *Expanding the Offender Index of the New York State DNA Data Bank*. Policy Research Report. Albany (NY): Division of Criminal Justice Services

23 For examples see J. Stander, et al *Markov Chain Analysis and Specialization in Criminal Careers*. *British Journal of Criminology* 1989; 29: 317-335 and R. Tarling, 1993 *Analysing Offending: Data, Models and Interpretations*, London: HMSO

24 K. Soothill. Et al. 2002. *Murder and Serious Sexual Assault: What criminal histories can reveal about future serious offending*. Police Research Series Paper 144. London: Home Office

25 Goodness of fit tests were performed and the observed distributions were significantly different from the expected uniform distribution ( $\chi^2 = 375.2$  (precursor), 257.0 (index);  $p < 0.001$  for both).

26 These offences include all other notifiable offences not listed in Figure 1. They will typically be volume offences of a varied nature such as public order offences or dangerous driving.

27 J.A. Hartigan. and B. Kleiner. 1981. *Mosaics for contingency tables*. In *Computer Science and Statistics: Proceedings of the 13th Symposium on the Interface*. W. F. Eddy ed. New York: Springer-Verlag: 268-273

28 D. Meyer et al. *Visualizing Independence Using Extended Association and Mosaic Plots*, *Distributed Statistical Computing 2003: A Meeting on the Future of Statistical Computing*, March 20-22, 2003, Vienna

29 M. Friendly *Mosaic Display for Multi-Way Contingency Tables*. *Journal of the American Statistical Association* 1994; 89: 190-200. Readers interested in greater detail of the history of mosaic plots and their employment in analysing categorical data are referred to M. Friendly 2001. *A Brief History of the Mosaic Display*, [www.math.yorku.ca/SCS/Papers/moshist.pdf](http://www.math.yorku.ca/SCS/Papers/moshist.pdf). Site accessed December 20, 2005

$$\frac{Obs - Exp}{\sqrt{Exp}}$$

30 It is possible to determine this information, but it is not easy. In the latter's case some typology could be developed, but in the former's case only crude offence types have been recorded in the Criminal Justice sampling database.

32 The MPS' operation targeting gun crime in black communities ( see <http://www.met.police.uk/trident/>).

33 The MPS class murders into three categories: A (murders with a high level of public interest), B (where the offender is unknown) and C (where the offender is known). Obviously, high profile or challenging cases are assigned commensurate with level of detective experience.

34 H. Becker. 1963. *Outsiders: Studies in the Sociology of Deviance*, New York: Free Press