STATISTICAL EVIDENCE AND THE COURTS—RECENT DEVELOPMENTS

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Where an item of evidence in a case is presented in statistical terms it may cause particular problems for the courts. The use of DNA profiling evidence, a highly discriminatory technique, has increased awareness of the potential for fallacious reasoning with regard to statistical evidence and the difficulty the jury may have in combining such evidence with the other evidence in the case. These issues mean that it is essential that the parties concerned present the evidence in a clear and logical manner. However, dispute may arise in relation to precisely how this should be accomplished and to what extent mathematical theory may be presented to the jury without leading to undue confusion and usurping their function.

Two cases which recently came before the Court of Appeal, *R v Adams (Dennis John)*[1] and *R v Doheny (Alan James); R v Adams (Gary Andrew),*[2] can be used to elucidate these problems.

Presenting the statistical value of an item of evidence to the court: *R v Doheny*

In both the case of Doheny, an appeal against conviction for rape and buggery, and that of Gary Andrew Adams, an appeal against conviction for buggery, DNA evidence formed a significant part of the prosecution case and one common ground of appeal concerned the manner in which the DNA evidence was presented to the jury.

In order to understand the judgment and its implications, it is necessary to consider the way in which DNA evidence has been presented to the courts and the relevant terminology. Since the first introduction of DNA evidence its evidential value has been presented statistically. Initially these statistics were reported as an estimate of the relative frequency of the profile in the appropriate population. If, for example, the expected frequency of the profile was 1 per 10,000 members of the population, ie a frequency of 0.0001, then that could be presented in terms such as '... the chance of obaining this profile from an individual chosen at random is 1 in 10,000'. This is known as the match probability. However, increasingly an alternative method of presentation has been used. This method is

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[1] [1996] 2 Cr App R 467; 61 JCL 170.

[2] [1997] 1 Cr App R 369.

considered by many to be more appropriate to a courtroom[3] and involves presenting the evidence as a likelihood ratio. The likelihood ratio is the ratio of the probability of the evidence, given that the suspect left the sample to the probability of the evidence, given that someone other than the suspect left the sample. (In a simple scenario we may presume the perpetrator left the sample.)

The likelihood ratio can be written as:

$$\frac{p(E|G)}{p(E|\bar{G})}$$

This in effect denotes the probability of the evidence, a matching DNA profile, given the suspect left the sample over the probability of the evidence given that the suspect did not leave the sample.[4]

In a simple example, the numerator, the probability of the evidence given the suspect is guilty, may be taken to be 1 as it is certain that there will be a match if the suspect left the sample. The denominator, the probability of the evidence given the suspect did not leave the sample, equals the match probability, ie the relative frequency of the profile in the population.

Therefore the likelihood ratio equates to:

$$\frac{1}{\text{match probability}}$$

In the above example this would result in:

$$\text{Likelihood ratio} = \frac{1}{0.0001} = 10{,}000$$

This may be reported in terms such as '... the evidence is 10,000 times more likely given the hypothesis that the suspect left the sample than the hypothesis that someone other than the suspect left the sample'. The likelihood ratio can thus discriminate between the two hypotheses and indicate the probative value of the DNA evidence. The strength of the evidence is measured by how much the likelihood ratio differs from one.

In *Doheny* the Court of Appeal laid down the following guidelines concerning the procedure for introducing DNA evidence in trials:

(1) The scientist should adduce the evidence of the DNA comparisons together with his calculations of the random occurrence ratio.

(2) Whenever such evidence is to be adduced, the Crown should serve upon the defence details as to how the calculations have been carried out, which are sufficient for the defence to scrutinise the basis of the calculations.

[3] A Collins and NE Morton, 'Likelihood Ratios for DNA Identification', Proceedings of the National Academy of Science (1994) vol 91, pp 6007–6011.

[4] In this form 'p' represents 'probability',
'|' means 'given',
'E', 'G' and '$\bar{G}$' stand for 'evidence', 'guilty' and 'not guilty' respectively.
Hence p(E|G) represents the probability of the evidence given the suspect is guilty and p(E|$\bar{G}$) represents the probability of the evidence given the suspect is not guilty.

(3) The Forensic Science Service should make available to a defence expert, if requested, the databases upon which the calculations have been based.

The second and third points are uncontentious. The defence have the right to obtain an independent assessment of the DNA evidence and should be provided with all relevant information to enable them to do so.

The first point, however, is of greater significance. The court appears to have introduced a new term 'random occurrence ratio' which is defined as the frequency with which the matching DNA characteristics are likely to be found in the population at large. It would seem that this new term is intended to be synonymous with the term 'match probability'. There is little benefit in introducing a new term and indeed the phrase adopted by the court could be said to be inappropriate; it is not truly a ratio and could lead to confusion with the term likelihood ratio.

The court then stated that it may be appropriate for the scientist to say how many people with the matching characteristics are likely to be found in the UK or a more limited relevant population.[5] The danger with this approach is that it may lead to the jury committing the 'defense attorney's fallacy', so called as it will normally favour the defence.[6] This form of fallacious reasoning results in the evidence being given less weight than it deserves. Such a situation may arise when the evidence concerned is deemed to be of little value as, taken in isolation, it does no more than indicate that the suspect is one of a group of individuals, any one of whom could have been the perpetrator. The DNA evidence must of course be viewed in the context of the whole of the evidence in the case and not in isolation. The court appeared to recognise this problem, but it is important to note that a clear direction to the jury will be required in relation to this issue.

Having stated how DNA may be presented, the court, concerned that the scientist should not in any way usurp the function of the jury, further stated that '... the scientist should not be asked his opinion on the likelihood that it was the defendant who left the crime stain, nor when giving evidence should he use the terminology which might lead the jury to believe that he was expressing such an opinion'. The ambiguity here concerns whether or not the court are in fact inferring that the evidence should be presented in terms of the random occurrence ratio only and may not be presented in terms of a likelihood ratio. This is not the only interpretation and indeed it is worth noting that likelihood ratios were not presented at trial in either of the cases before the court. However, the court was clearly concerned with the way in which the DNA evidence had been presented to the jury and that in both cases before them there was evidence that the expert had committed the 'prosecutor's fallacy'. This

[5] Determining the relevant population may be a difficult matter: see IW Evett and BS Weir, 'Flawed Reasoning in Court', *Chance* (1991) vol 4, no 4, pp 19–21.

[6] This phrase was first adopted in WC Thompson and EL Schumann, 'Interpretation of Statistical Evidence in Criminal Trials: The Prosecutor's Fallacy and the Defense Attorney's Fallacy', *Law and Human Behaviour* (1987) vol 11, pp 167–187.

form of fallacious reasoning normally favours the prosecution and came before the Court of Appeal in *R v Deen.*[7]

There are a number of ways in which the prosecutor's fallacy may be committed,[8] but in simple terms it may involve reasoning such as, 'There is a 1 in 10,000 probability that a person chosen at random could have this profile, the defendant matches the profile therefore there is only a 1 in 10,000 probability that he did not leave the sample and is not guilty'. This problem arises as the jury are concerned with the likelihood of guilt given the evidence whereas the scientist is concerned with the likelihood of the evidence given a particular hypothesis. Provided the scientist confines himself to the latter he will not usurp the function of the jury. When the scientist gives evidence in terms of the likelihood ratio he is not stating his opinion on the likelihood that it was the defendant who left the crime stain. Rather he is indicating to the jury how the DNA evidence might assist them in comparing the two hypotheses before them, ie the probability of obtaining the DNA evidence given that the defendant left the sample and the probability of obtaining that evidence given that he did not leave the sample. The statistics presented, whether as a match probability or a likelihood ratio, will indicate the potential probative value of the evidence in respect of the relevant hypotheses. It is then for the jury to combine this evidence with the rest of the evidence in the case to determine the likelihood of guilt given the whole of the evidence before them. The likelihood ratio is therefore an appropriate way to present the evidence to the jury, it will assist in avoiding improper reasoning and indeed in complex situations involving mixed stains or relatives,[9] it will be essential to present the DNA evidence in this manner.

Combining the DNA evidence with the other evidence in the case: *R v Adams*

DNA evidence will normally only form a part of the evidence in the case and the jury will need to consider all the items of evidence in order to determine whether or not the case against the defendant has been proved. Due to the highly discriminatory nature of DNA evidence the defence may be concerned that the jury will be overawed by the statistics and may not give appropriate weight to other relevant evidence offered by the defence such as alibi.

In the case of Dennis John Adams the defence took what might be considered a rather unusual step in order to counter this problem. At trial the prosecution case rested entirely on the DNA evidence which, viewed conservatively, indicated that the chance that a randomly chosen unrelated

[7] (1994) *The Times,* 10 January described in detail in Balding and Donnelly, 'The Prosecutor's Fallacy and DNA Evidence' [1994] Crim LR 711–721.

[8] IW Evett, 'Avoiding the Transposed Conditional', *Science and Justice* (1995) vol 35(2), pp 127–131.

[9] IW Evett, 'Evaluating DNA Profiles in a Case Where the Defence Is "It was my brother" ', *Journal of Forensic Science Society* (1992) vol 32(1), pp 5–14.

man would match the profile from the semen on the vaginal swab was 1 in 200 million. The defendant, however, denied being present at the scene and claimed that he had spent the night in question with his girlfriend who testified to this effect. In addition at an identification parade, two and a half years after the offence, the victim did not identify Adams and at committal proceedings she said that Adams did not look like the man who had attacked her. The defence called an expert, by agreement, before the prosecution case was closed, who testified as to the possibility of the jury using a mathematical theorem, Bayes Theorem, in order to enable them to deal with the whole of the evidence in statistical terms. The aim of this approach was to facilitate the combining of the DNA evidence with the other evidence in the case.

Bayes Theorem

Bayes Theorem is a recognised mathematical theorem which enables an individual to adjust their belief in the likelihood of a given hypothesis in the light of new evidence.

This theorem can be expressed in its odds form as:

$$\frac{p(G|E)}{p(\bar{G}|E)} = \frac{p(G)}{p(\bar{G})} \times \frac{p(E|G)}{p(E|\bar{G})}$$

Posterior odds	Prior odds	Likelihood ratio

In relation to a criminal trial the prior odds may be taken to be the jury's assessment of the guilt of the defendant prior to taking into account a particular item of evidence, eg DNA evidence. If the probative value of that further item of evidence is then presented as a likelihood ratio, when that is combined with the prior odds it will provide the jury with the posterior odds, ie the likelihood of guilt given all of the evidence.

The validity of the above as mathematical theorem is not in doubt and indeed it is widely accepted that this approach provides a logical method of reasoning and is of significant importance in the interpretation of evidence.[10] However, the use of this theorem as a method of updating our belief in the light of new evidence is not uncontroversial and it must be accepted that to attempt to use Bayes Theorem in a practical courtroom setting is a very complex matter.[11]

Despite the potential difficulties in presenting this theorem to the jury, the defence in *Adams* may have felt that without this assistance the jury may accept the DNA evidence as equating to the posterior odds and so fail to consider the other evidence in the case. It should also be noted that the defence in this case sought not simply to instruct the jury in a logical method of reasoning but how to assess the whole of the evidence in probability terms.

[10] RD Friedman, 'Assessing Evidence', *Michigan Law Review* (1996) vol 94, pp 1810–1839.
[11] M Redmayne, 'Science, Evidence and Logic' [1996] 59 MLR 747–760.

In *Adams* four items of evidence were identified which the jury would need to combine with the DNA evidence:

(1) The probability that it was a local man who committed the offence.
(2) The non-identification evidence of the victim.
(3) The evidence of the defendant himself.
(4) The alibi evidence called on behalf of the defendant.

The jury were given guidance as to how they might assess each of these items in statistical terms.

The probability that the perpetrator was a local man was dealt with first. The jury were informed that as a working figure there were approximately 150,000 men between the ages of 18 and 60 in an area within 15 km. Hence, if they estimated that there was a 75 per cent chance that it was a local man, then the chance of it being a particular local man, eg the defendant would be approximately 1 in 200,000 (100/75 × 150,000).

It was made clear to the jury that the 75 per cent chance was just an example and that they should decide for themselves what they thought was the probability of the perpetrator being a local man.

The non-identification evidence was then dealt with. The jury were informed that they needed to consider the question of the probability that if the defendant was innocent he would not match the victim's description. The example given to them was in percentage terms and was 90 per cent. It was again made clear to the jury that this figure was merely an example. Now that they had a probability for this item of evidence they needed to consider a second question which was the chance of the evidence if the defendant was guilty, ie that if he were guilty he would not match the description. The example given to the jury was 10 per cent. The jury were then instructed as to how to deal with these two figures and that what mattered was the ratio between them, ie the probability of the evidence given guilt over the probability of the evidence given that the defendant was not guilty.

This can be written:

$$\frac{p(E|G)}{p(E|\bar{G})}$$

and from the above it can be seen that the jury had been instructed in how to compose a likelihood ratio for the non-identification evidence.

From the example given to the jury where:

$$p(E|\bar{G}) = 90 \text{ per cent}$$
$$p(E|G) = 10 \text{ per cent}$$

$$\text{Likelihood ratio} = \frac{10}{90} = \frac{1}{9}$$

The jury were then in effect instructed in the use of Bayes Theorem.

Their estimate of the probability of it being a local man was their prior odds on guilt, ie 1 in 200,000 so multiplied by the likelihood ratio of the non-identification evidence, ie 1/9, this would give them the posterior odds, ie the likelihood of guilt given the evidence so far.

$$\frac{1}{200{,}000} \times \frac{1}{9} = \frac{1}{1{,}800{,}000}$$

Prior odds × Likelihood ratio = Posterior odds

Hence, the posterior odds would be a 1 in 1.8 million chance that the defendant was guilty.

The jury were then taken through the other items of evidence, ie the evidence of the defendant himself and the alibi evidence. In each case hypothetical figures were used to show the jury how, for each item of evidence, they should create a likelihood ratio and each time multiply that by their previous estimate of guilt. When this was completed for all four items of evidence they would be left with a statistical representation of their estimate of guilt given the non-statistical evidence. The hypothetical figures used in court gave this estimate to be 1 in 3.6 million.

The jury were then informed how to combine the DNA evidence, which was presented in statistical terms, with their numerical evaluation of the non-statistical evidence. The prosecution evidence was that the chance of a randomly chosen man matching the DNA profile was one in 200 million and, although the defence disputed the accuracy of this figure, the jury were in effect told that if this figure was accepted the likelihood ratio for the DNA evidence would be 200 million.[12] Therefore to determine the posterior odds given all the evidence of this case, ie both the DNA evidence and the non-statistical evidence, the jury needed to multiply the likelihood ratio for the DNA evidence by their numerical estimate of the non-statistical evidence. For the example given by the court this would be:

$$\frac{p\,(G|E)}{p\,(\bar{G}|E)} = \frac{1}{3.6 \text{ million}} \times 200 \text{ million} = 55$$

Posterior odds — Prior odds— non-statistical evidence — Likelihood ratio of DNA evidence

The posterior odds equal 55 which indicates that given the evidence it is 55 times more likely that the defendant is guilty than not guilty, ie odds of 55 to 1 on guilt.

The defence then went on to demonstrate that if the statistical value assigned to the DNA evidence is disputed this may significantly affect the posterior odds, eg reducing the value of DNA evidence by a factor of 10 to 20 million would reduce the posterior odds to 5 to 1.

As stated earlier it may be appropriate to present the value of certain types of evidence as a likelihood ratio. In such a case the expert will need to explain clearly what this ratio represents in order that the jury recognise that this does not equate to the likelihood of guilt given the evidence. It may also be appropriate to instruct the jury in the logic behind Bayes Theorem in order that they are able to comprehend the importance of the other evidence in the case and the fact that the posterior odds are affected

[12] Likelihood ratio $= \frac{p(E|G)}{p(E|\bar{G})} = \frac{1}{1/200{,}000{,}000} = 200{,}000{,}000.$

by both the prior odds and the likelihood ratio. Where there is little or no other evidence supporting the DNA evidence the prior odds may be very low and this will significantly affect the likelihood of guilt.

However, in this case the defence went far beyond this and suggested that the jury may wish to put in their own statistical evaluation of the strength of each item of evidence and determine the likelihood of guilt numerically. It could certainly be argued that the jury may have had difficulty in understanding the approach put to them and that, even if they were able to follow the method put forward by the defence expert, they may not have felt competent to insert their own figures and carry out the calculations. In addition had they wished to follow the procedure they may well have been influenced by the figures presented to them.

Given the difficulty the jury may have experienced in understanding this theorem and the mathematics presented to them, a clear direction from the judge as to how this information might be used was essential. It is perhaps unsurprising that, following Adams' conviction, one ground of appeal was that '... the judge misdirected the jury in relation to Bayes Theorem and left the jury unguided as to how the theorem could be used in properly assessing the statistical and non-statistical evidence in the case'.[13] Appeal on this ground was successful, the court felt that the jury had not been properly directed with regard to Bayes Theorem and that in addition they had not been directed in the more common sense and basic ways of determining the weight of the DNA evidence. The appeal was allowed and a re-trial ordered. The court expressed, obiter, significant doubts as to the appropriateness of presenting Bayes Theorem to the jury. It was felt that the use of such a method in a criminal trial would '... plunge the jury into inappropriate and unnecessary realms of theory and complexity deflecting them from their proper task'.[14] Considering the above description of the case it is clear that there is significant merit in this point and that these concerns are justified.

The court also felt that the relationship between one piece of evidence and another was a matter that was exclusively within the province of the jury and hence not a matter to which the defence expert should have testified. This is an arguable point, certainly it would seem appropriate, particularly in cases involving cogent DNA evidence, to inform the jury of the logical reasoning inherent in Bayes Theorem, to do so would not usurp their function and may prevent improper reasoning. Going into greater depth and proposing the assignment of a numerical value to each item of evidence is atomistic, complex and controversial. When making decisions in our day-to-day lives we instinctively take a more holistic approach and assimilate a number of items of information at one time. The advantage of this approach is that it allows us to take account of interdependencies between various items of information. Such an approach is precluded if each item of evidence is considered in turn. Bayes Theorem may be of value in instructing the jury in logical reasoning but this does not necessitate the input of a numerical value for each item of evidence.

[13] [1996] 2 Cr App R 467, at p 470.

[14] Ibid, at p 482. This comment was endorsed by the Court of Appeal in *R v Doheny*.

In *Adams*, the defence were too ambitious in their assessment of what the jury could reasonably be expected to understand. The most important message that they were trying to portray concerned the link between the prior odds, the likelihood ratio and the posterior odds; on reflection if this could be achieved verbally rather than numerically it may be more accceptable to the courts.[15]

[15] Despite the concerns of the Court of Appeal the defence again presented Bayes Theorem at the re-trial in September 1996. Adams was convicted. An appeal against conviction was heard on 16 October 1997, reported as *R v Adams (No. 2)* (1997) The Times, 3 November. The Court of Appeal held, dismissing the appeal, that reliance on Bayes Theorem in relation to non-scientific evidence was a recipe for confusion, misunderstanding and misjudgment, and accordingly, in the absence of special features, Bayesian evidence should not be admitted.