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Evaluating DNA Profile Evidence When the Suspect Is Identified Through a Database Search

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ABSTRACT: The paper is concerned with the strength of DNA evidence when a suspect is identified via a search through a database of the DNA profiles of known individuals. Consideration of the appropriate likelihood ratio shows that in this setting the DNA evidence is (slightly) stronger than when a suspect is identified by other means, subsequently profiled, and found to match. The recommendation of the 1992 report of the US National Research Council that DNA evidence that is used to identify the suspect should not be presented at trial thus seems unnecessarily conservative. The widely held view that DNA evidence is weaker when it results from a database search seems to be based on a rationale that leads to absurd conclusions in some examples. Moreover, this view is inconsistent with the principle, which enjoys substantial support, that evidential weight should be measured by likelihood ratios. The strength of DNA evidence is shown also to be slightly increased for other forms of search procedure. While the DNA evidence is stronger after a database search, the overall case against the suspect may not be, and the problems of incorporating the DNA with the non-DNA evidence can be particularly important in such cases.

KEYWORDS: forensic science, DNA typing, DNA profiles, databases, statistical inference

Currently, the most common use of DNA profiling in forensic identification is either to exonerate, or to strengthen the case against, an individual identified as a suspect on other grounds. However, cases have arisen in which the suspect was identified *because* his DNA profile was observed to match a crime scene profile. Such cases are likely to become more prevalent in view of the current rapid expansion in the use of databases consisting of the DNA profiles of named individuals to try to identify suspects in current and future crimes. The recent UK Criminal Justice Act, for example, authorizes a national database of individuals currently arrested for, or previously convicted of, a wide range of offences. DNA databases of named individuals are also maintained in the USA and other countries.

In a case in which a suspect has been identified via a database search, the issue arises as to how the DNA evidence should be presented and assessed at trial. The 1992 report of the US National Research Council (NRC) (1), recommends that, when a suspect has been identified through a database search, additional loci should be tested (in both crime and suspect profiles) and that "only the statistical frequency associated with the additional loci should be presented at trial (to prevent the selection bias that is inherent in searching a database)" (page 124). It has been suggested (2,3) that, because the finding of a match is more likely in a database search than when only one individual is examined, the resulting evidence is substantially weaker. (This rationale may also have figured in the NRC's deliberations.)

In this paper, we argue that in a situation in which exactly one matching individual is found from a database search, the strength of the DNA evidence against that individual is *not* reduced relative to the setting in which the suspect has been identified on other grounds and subsequently subjected to DNA profiling. (For convenience, though possibly inaccurately, we will refer to this latter scenario as the "probable cause" setting.) In fact, in the database search case, under reasonable assumptions, the DNA evidence will be slightly stronger than in the probable cause setting.

After a suspect has been identified through a database search, the crime investigation agency will usually attempt to gather additional relevant information concerning the suspect. It may be that no further incriminating evidence is obtained, or that some of the information (for example, a plausible alibi) tends to exonerate the suspect. Although we argue that the strength of the DNA evidence against the suspect is not reduced in the database search case, it may well be that, due to a lack of supporting evidence, the strength of the overall case against the suspect is much weaker than in the probable cause setting. We have argued elsewhere (6,7) that there is a danger that DNA evidence will be misinterpreted, and that these concerns may be of practical importance in cases with limited incriminating, or additional exonerating, non-DNA evidence. While these issues may be particularly apposite in the database search context, our concern in this paper is solely with the strength of the DNA evidence in such cases.

There has been considerable controversy over the correct statistical evaluation of DNA evidence (1,4,6). We do not address the general arguments here. Instead, we make a qualitative comparison between the database search and the probable cause settings. This problem was also considered briefly in (5,6). Serious ethical and social questions arise in connection with the maintenance of a DNA database of named individuals (for a discussion of relevant issues see (1, [Chap. 5]). These issues are also not addressed in this paper.

To simplify the discussion we will consistently use the term "suspect," whereas "defendant" may be more appropriate in some instances. For the purposes of this paper we ignore the possibility of handling or laboratory error leading to a "false positive" match, although this possibility must be addressed in practice.

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Analysis

We suppose the availability of a database which contains the DNA profiles of N named individuals. A DNA profile is available from body tissue obtained at the scene of a crime and believed to be left by the culprit. As part of the investigative procedure a search is made through the database with the result that exactly one of the profiles in the database is found to match the crime scene profile. The individual whose profile matches becomes the suspect in the case. (Note that we assume exactly one match from the database. To simplify the discussion we also assume that no other individuals are known to match the crime profile.) The problem is then to assess the strength of this evidence against the suspect. In particular we compare it with the setting in which the suspect is the only individual profiled.

There is a broad consensus that the appropriate method for quantifying the strength of DNA evidence is through likelihood ratios (3,4,8–11). The DNA evidence relates directly to the question of whether the suspect is the source of the crime stain. In this context the likelihood ratio can be written

$$LR = \frac{\text{P(DNA evidence | suspect is source)}}{\text{P(DNA evidence | suspect is not source)}}. \quad (1)$$

In the database search scenario that we are considering, the DNA evidence consists of the measured DNA profiles of the suspect and the crime stain (including the observation that they match) and the fact that particular other individuals do not match the crime stain profile. (The actual measured profiles of non-matching individuals are also available in principle, but they have little effect on the analysis and would usually not be presented at trial.)

One immediate observation is that the likelihood ratio, and hence the strength of the DNA evidence against the suspect, *does not* depend on the chance that a search through the database would find a matching profile: the DNA evidence is not simply that at least one (or that exactly one) of the individuals in the database matches the crime stain profile. Further, the strength of the DNA evidence does not depend on the reasons for examining the profiles of the individuals considered. If there are good reasons for suspecting the individuals tested (and the information is admissible as evidence) then these will be heard at trial. The point here is that such other information does not form part of the DNA evidence, nor does it affect the strength of the DNA evidence.

An important consequence of the simple form of (1) is that situations which differ from the straightforward search described above are readily accommodated. One such setting arises if, following the identification of a suspect through a database search, further loci are subsequently tested and suspect and crime stain profiles match at the additional loci. (This procedure is currently implemented by some crime investigation agencies.) Equation (1), and the analysis below, apply without modification to this scenario.

We now consider the likelihood ratio in more detail. Write E_S and E_C for the measured genotypes of respectively, the suspect and source of the crime stain, O for the event that none of the other individuals in the database match E_C, and G for the hypothesis that the suspect is the source of the crime stain. Then,

$$LR = \frac{P(E_S, E_C, O \mid G)}{P(E_S, E_C, O \mid G^c)} = \frac{P(O \mid G)}{P(O \mid G^c)} \frac{P(E_S, E_C \mid G, O)}{P(E_S, E_C \mid G^c, O)}, \quad (2)$$

in which we introduce the notation G^c for "not G." In considering the first factor in (2), it may be easier to compare $P(O^c|G)$ and $P(O^c|G^c)$. Under hypothesis G^c, there are two ways in which O^c might occur. It may be that one of these other individuals is the source of the crime stain. Alternatively, none of them may be the source but at least one happens by chance to match E_C. Under hypothesis G, only the second of these explanations is possible. It follows that $P(O^c|G) < P(O^c|G^c)$, so that $P(O|G) > P(O|G^c)$, and the first factor in (2) is larger than unity. A simplification of this factor is derived in the appendix; here, we need only the result that it is larger than one.

In the probable cause setting, the likelihood ratio for DNA evidence is

$$\frac{P(E_S, E_C \mid G)}{P(E_S, E_C \mid G^c)}. \quad (3)$$

In the match-binning framework, this likelihood ratio is often taken to be the reciprocal of the relative frequency of the profile in some population. In ignoring positive correlations of the genotypes of distinct individuals, such an argument rests on independence assumptions that may not be appropriate (6,12,13). Nonetheless, we note that if these correlations are ignored, the second factor in (2) will be equal to the likelihood ratio (3) in the probable cause setting. More generally, in the light of (positive) genetic correlations, knowledge that certain individuals do not share the profile in question may warrant a revision downwards of estimates of its frequency, and thus the second factor in (2) will be larger than (3).

In summary, the strength of the DNA evidence, as measured by the likelihood ratio, is greater when the evidence results from a database search than in the probable cause setting. One source of intuition for this conclusion is that the database search has served to eliminate some individuals as possible sources of the crime stain. Although the difference in strength is difficult to quantify in general, it seems likely that (2) will be only slightly larger than (3), and hence it may be convenient, and not unfavorable to the defendant, to calculate and report (3).

Other Approaches to the DNA Evidence

The NRC report (1) recommends in the database search context that any DNA evidence that leads to the identification of a suspect should not be presented at trial. In view of the analysis of the previous section, this recommendation seems excessively conservative. Indeed, there will be cases, with limited or degraded crime samples, in which it may not be possible to obtain any, or much, additional DNA evidence. The effect of the NRC's recommendation in some such cases is that a prosecution would not proceed, in spite of strong DNA evidence linking the suspect with the crime.

The approach advocated by the NRC to evidence obtained from databases is not usually employed, for example, when a suspect is identified via a search through a database of fingerprints or photographs. When applied more generally, the suggestion that evidence which leads to the identification of a suspect should not be presented at trial seems difficult to sustain, and contrary to most current judicial practice.

The example given in (5) is illuminating here. Consider two cases. In one, the suspect is identified through weak and unreliable eye-witness evidence. Subsequent DNA testing reveals that he matches the crime stain profile. In the second case, a DNA database search identifies a match between an individual (who then becomes the suspect) and the crime stain, and subsequent investigation unearths the weak and possibly unreliable eye-witness identification evidence. Assuming that the DNA evidence is identical in each case, and similarly for the identification evidence, and that the different types of evidence are independent in each case, the jury at trial will be presented with identical information from the eyewitness and from the forensic scientist in describing the DNA match. It seems difficult to argue that they should, or will, react differently to this information in the two cases (except in so far as distinct juries will react differently to the same evidence). In the second case, they may consider relevant the fact that certain other individuals have been eliminated as possible sources of the crime stain, but, if anything, this should increase their perception of the strength of the case against the suspect.

It is, of course, true that (in the absence of other information about the individuals concerned) the searching of a database is more likely to result in the finding of a match than if a single individual were tested. The probability of finding a "chance" match in a database of size N is bounded above by N times the match probability and, for the values typically quoted in connection with DNA profile evidence, the bound will usually be tight. This probability is, however, not relevant to the strength of the DNA evidence against the (unique) individual found to match. In particular, we do not accept the claim (for example (2,3)), which we refer to as the *reduction argument,* that in the database search case the strength of the DNA evidence is reduced, approximately by a factor of N.

The analysis of the previous section shows that the reduction argument is inconsistent with the principle that the strength of the evidence against the suspect should be measured by the likelihood ratio. On a more intuitive level, a particular individual is on trial. The DNA evidence against him is that his DNA profile matches the crime stain profile while the profiles of certain other individuals do not. The individuals in the database are not collectively on trial and the chance that at least one (or exactly one) of them would match if all were innocent is therefore not relevant.

Consider a hypothetical example in which laboratory errors can be ignored and the available database consists of the profiles of every individual on earth. If this database is searched and exactly one individual is found who matches the crime profile, then it is clear that this individual is the source of the crime stain. This is exactly the conclusion of the analysis of the previous section, based on the likelihood ratio, since both factors in the likelihood ratio (2) will be infinite. In contrast, since the finding of a match in such a database is certain, the reduction argument would imply that the DNA evidence has no probative value.

By analogy with the example described, it seems difficult to distinguish between database search scenarios in which a particular individual is identified but in which different search orders are used. More generally, it seems intuitively reasonable that the information that the suspect matches and that certain other individuals do not match should be equally probative regardless of the order in which the individuals were tested, or their profiles examined. (It can be shown that under mild conditions, which obtain in the current context, the likelihood ratio is the same in each case (6, 14).) Now consider a suspect, identified for other reasons, who is profiled and found to match the crime stain profile. The crime investigators may think it prudent to check the available databases for other individuals who match the profile in question. Were they to do so, and not find such individuals, the rationale behind the reduction argument could then be used to argue that the original DNA evidence against the suspect had been considerably weakened. In the absence of a database search on the part of the investigators, this rationale could also lead to the rather absurd situation in which a cunning defence lawyer could insist on one and subsequently claim that the failure to find additional matches had substantially weakened the case against their client. (Of course the finding of other matches in the database could also be extremely helpful to their case.)

One rationale behind the reduction argument draws on an analogy with the issues that arise in assessing the overall significance level in multiple hypothesis tests, on the basis that comparisons of multiple profiles with the crime profile have been made. We have argued elsewhere (13) that a hypothesis testing perspective is inappropriate in connection with the evaluation of evidence at trial. Notwithstanding this, and the problems with the reduction argument outlined above (its inconsistency with the use of likelihood ratios to quantify the evidence against the suspect, and its clearly undesirable consequences in particular settings), it is not clear that the multiple comparison methodology itself is appropriate in the legal setting. Loosely speaking, the rationale in the multiple testing case is that a fixed probability of (type 1) error should be "spread" across all of the hypotheses to be tested. (In the implied analogy with DNA, each comparison between a profile in the database and the crime profile corresponds to a hypothesis test.) At trial, the court is concerned with the suspect, and not with other individuals whose DNA profiles might have matched but did not. Even within the hypothesis testing framework it does not seem clear that the court should feel compelled to adjust upwards its significance level because of the existence of other hypothesis tests (relating to individuals who were eliminated from earlier investigations in the case) with which it is not then directly concerned.

Likelihood ratios quantify the weight of evidence for a pair of competing hypotheses. Our analysis relates to the hypotheses that the suspect was/was not the source of the crime stain. A different pair of hypotheses is that the source of the crime stain is/is not in the database. Not surprisingly, the evidence of exactly one match in the database has a different weight for the latter hypotheses than for the former. In fact, if it were assumed that each of the individuals in the database would, without the DNA evidence, be equally likely to be the source, then it can be shown that the likelihood ratio is smaller by a factor of N for the latter pair of hypotheses than for the former pair, which is close to the value obtained by the reduction argument. However, at trial a court is concerned only with the suspect, and not with the collective guilt or innocence of the database. Further, it will usually be the case that evidence presented at trial will not bear symmetrically on all the individuals in the database, and in such cases it will not be plausible to assume that, without the DNA evidence, all members of the database would be equally likely to be the source of the crime stain.

Other Types of Search

Sequential Search

Issues similar to those in the database search case arise when it is decided to continue the DNA profiling of suspects until a match with the crime stain profile is found. The suspects may or may not be identified for other reasons connected with the crime. It is arguable that most actual investigations follow this paradigm, with the investigation continuing until a suspect is found whose DNA profile matches the crime stain profile.

Calculation of the appropriate likelihood ratios in this setting is more complicated than in the database search case. For details see (6,14). The result is that (under mild assumptions which will be satisfied in many cases) the DNA evidence amounts to the facts that the suspect matches and that certain other tested individuals do not. It follows, as above, that such evidence will be somewhat stronger than had the suspect been the first individual profiled.

In a case not involving a database search, the analogue of the reduction argument might seem to suggest that the match probability should be increased by a factor equal to the number of comparisons made between the crime profile and the profiles of other individuals. We reject this approach on the grounds of logic, aside from its obvious practical difficulties. In fact, in this context such an approach would appear even more misguided. Given enough resources and the cooperation of the individuals involved, the search was certain eventually to find a match, so that, by analogy with the reduction argument, the DNA evidence would have no probative value. Our point is that a rationale very similar to that used to justify the reduction argument for database search would result in the DNA evidence being substantially weakened, or rendered valueless, in almost every current case.

Search of DNA Profiles from Unsolved Crimes

A distinct situation involving searches of DNA profiles arises when an individual's DNA profile is compared with profiles from a number of unsolved crimes and found to match one or more of them. Suppose that exactly one match is found; the extension to the case that the suspect matches more than one crime scene profile, and hence is suspected of more than one crime, poses no difficulty in principle. The analogue of the reduction argument here is that, since the occurrence of at least one match from among several crime profiles is more likely than the occurrence of a match with a specific crime profile, the DNA evidence is substantially weaker after such a search. If the match probabilities associated with each crime profile are approximately the same, then under the logic of the reduction argument the evidence is weakened approximately by a factor equal to the number of crime profiles searched.

Rigorously adhered to, such an argument poses serious problems for the presentation of DNA profile evidence. A court may not be aware that a search of unsolved crimes has occurred and, if so, how many crime profiles were searched. As in the sequential search scenario, a defense lawyer could insist on further searches and subsequently argue that the lack of any resulting matches weakens the case against their client (although here the discovery of subsequent matches may be unwelcome to the defence).

Inspection of the appropriate likelihood ratio reveals that the logic of the reduction argument is also flawed in this setting. The data is that the suspect's profile matches the profile from the crime, C, with which the suspect is now accused, and that these two profiles do not match any of the profiles from certain other crimes. The likelihood ratio can then be written

$$LR = \frac{P(E_S, E_C, U \mid G)}{P(E_S, E_C, U \mid G^c)}$$

$$= \frac{P(E_S, E_C \mid G)}{P(E_S, E_C \mid G^c)} \frac{P(U \mid E_S, E_C, G)}{P(U \mid E_S, E_C, G^c)}, \qquad (4)$$

in which U is the event that E_S and E_C do not match the other crime profiles.

The first factor in (4) is the probable cause likelihood ratio (3) and hence the effect of the search is incorporated in the second factor. Ignoring false exclusions, the event U requires that the perpetrator of C did not commit any of the other crimes. The probability of U, given E_C and E_S, is thus effectively unchanged by whether or not G obtains. In fact, $P(U|E_S, E_C, G)$ will be slightly greater than $P(U|E_S, E_C, G^c)$ for two reasons. The first relates to correlations in profile possession between individuals and the second is that, under G^c, there is an additional individual who is excluded as a possible perpetrator of the other crimes. The likelihood ratio (4) will thus be slightly greater than that in the probable cause setting, so that it would be conservative to ignore the effect of the search. In practice, however, these effects will be extremely weak and the two likelihood ratios effectively identical.

Conclusions

We have considered settings in which a suspect is identified as the result of a search through a DNA profile database. We have argued that in such cases the DNA evidence against the individual found to match is no weaker (and in general will be stronger) than had the suspect been identified for other reasons, and, on subsequent DNA profiling, found to match the crime stain profile. The suggestion of the NRC report (1) that any DNA evidence used to identify the suspect should not be presented at trial seems unnecessarily cautious. In addition, when applied to other types of evidence, the reasoning seems inappropriate, and contrary to current judicial practice.

It has been argued by other authors that when a suspect is identified from a database search the strength of the evidence is weakened (approximately by a factor of N, the size of the database) because the finding of a match in searching a database is more likely than when testing a single individual. This contention, which we have called the "reduction argument," is shown to be inconsistent with the widely accepted principle, for which there exists strong justification, that the strength of the evidence against the suspect should be measured by the likelihood ratio. (Note that this principle, and hence the arguments of the paper, does not require the concept of a "prior" probability, based on the non-DNA evidence, that the suspect is the source of the crime stain.) Further, the reduction argument is shown to lead to absurd conclusions in certain situations. In addition, an argument very close to this one leads to the (incorrect) conclusion that DNA evidence is worthless in most current cases.

In some legal jurisdictions, at least some matters relating to the database may not be admissible as evidence at trial. For example, information as to previous convictions of the suspect may be inadmissible. If the suspect is on the database because of a previous conviction, *any* mention of the database at trial may then be inappropriate. Our analysis shows that in the database search context, the DNA evidence against the suspect amounts to the fact that his DNA profile matches the crime stain profile and that the profiles of certain other individuals do not. The forensic scientist can present information as to the match of suspect and crime profiles, and if required to the non-match of the profiles of certain other individuals, without recourse to inadmissible evidence. Our fundamental objection to the reduction argument is one of logic. However, it suffers from the additional practical problem that its implementation and explanation may be impossible when no mention of the existence of a database, let alone of its size N, is allowable.

The paper has focussed on the strength of the DNA evidence in the database search setting. The intuition that in such settings the suspect may be less likely to be guilty is nonetheless reasonable. Some such cases may go to trial with little or no other evidence against the suspect, or with other evidence which tends to exonerate the suspect. The consequence is that while the DNA evidence in these cases is no less strong, the *overall* case against the suspect may be weaker, possibly substantially so. We have argued elsewhere (6,13) that in such cases it is vital that the DNA evidence is properly interpreted and appropriately combined with the non-DNA evidence.

Appendix: Simplification of Equation (2)

Although not required for the argument of Section 2, it is of interest to explore further the database search likelihood ratio (2). As argued above, the second factor of this likelihood ratio is typically similar in value to the probable cause likelihood ratio (3) and hence the important distinction between the two likelihood ratios lies in the first factor of (2).

Let A denote the event that the individuals in the database, other than the suspect, are not the source of the crime stain. Recall that O is the event that none of these individuals has a profile which matches that from the crime stain. Assuming no false exclusions, $P(O|A^c) = 0$. Consequently, $P(O|A^c, G^c) = 0$. The first factor in (2) can then be written

$$\frac{P(O\,|\,G)}{P(O\,|\,G^c)} = \frac{P(O\,|\,G)}{P(O\,|\,A, G^c)P(A\,|\,G^c) + P(O\,|\,A^c, G^c)P(A^c\,|\,G^c)}$$

$$= \frac{P(O\,|\,G)}{P(O\,|\,A, G^c)P(A\,|\,G^c)}. \quad (5)$$

Further, it seems reasonable to assume that the event O is just as likely to occur if the suspect were the source of the crime stain as if an individual not in the database were the source. That is, we assume that $P(O|G) = P(O|A, G^c)$ and hence (5) simplifies to

$$\frac{P(O\,|\,G)}{P(O\,|\,G^c)} = \frac{1}{P(A\,|\,G^c)}. \quad (6)$$

In words, under the two assumptions introduced above, the first factor in the database search likelihood ratio (2) is one over the conditional probability that the source of the crime stain is not included in the database given that the suspect is not the source.

In general, information other than that connected with DNA profiles is presented as evidence at trial. The actual order in which evidence is presented at trial should be immaterial to the strength of the case. For convenience, we assume that the DNA evidence is presented last so that there is an implicit conditioning in (1), and subsequent equations including (6), on the non-DNA evidence. If it were certain, based on the non-DNA evidence, that one of the individuals in the database was the source of the crime stain, then the DNA evidence (assuming no false exclusions) implies that the suspect is the source. This conclusion is reflected in the analysis described here since (6), and hence (2), is infinite under these assumptions. (Such a scenario might be appropriate when the other evidence establishes that the offense was committed by one of a group of individuals, without specifying which one. In this case, the "database" would consist of the profiles of the group.) Suppose, on the other hand, that the non-DNA evidence established that none of the individuals in the database, other than the suspect, could be the source of the crime stain. (The information leading to this conclusion may have arisen after the database search, so that the search was not necessarily redundant.) In this case the additional knowledge that the other profiles in the database do not match is (almost) uninformative, which is reflected by (6) taking the value unity. (As discussed above in Section 2, observing that other individuals do not match the crime stain profile may lead to a (slight) revision downwards of estimates of the frequency of the profile and hence (slightly) strengthen the evidence against the suspect. This effect is incorporated in the second factor of (2).)

Of the two assumptions which underpin (6), the assumption of no false exclusions seems the more doubtful. Extending the analysis to allow for false exclusions is straightforward in principle, although the assessment of false exclusion probabilities may be problematic. For any assessment of false exclusion probabilities, the effect is to reduce the value of (6). Provided only that O is less likely if the source of the crime stain is one of the individuals in the database, other than the suspect, that is $P(O|A^c, G^c) < P(O|A, G^c)$, the modified value will remain greater than unity (we continue to assume that $P(O|G) = P(O|A, G^c)$).

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