Case Report

Interpretation of Evidence: The Key to Conveying Information to Court

تفسير الأدلة : مفتاح نقل المعلومات إلى المحكمة

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Abstract

The advent of new technologies such as DNA typing, the weight of scientific evidence in criminal trials of widespread publicity, and the proliferation of fictional and non-fictional works in popular media have contributed to making forensic science well known, although perhaps not as well understood, by the general public. One of the consequences of this popularisation of forensic science was a sharp change in the attitude of investigators, who increasingly tend to delegate to scientists the collection of information necessary to identify the perpetrator of the crime. However, the prominent focus on the search of biological traces or fingerprints, due to their high potential for the personal identification of the individuals present at the crime scene, somewhat fade the interest towards other kinds of evidence, such as trace evidence. This kind of evidence is in fact perceived by judges and lawyers as less informative, because they think that "all plastic items are the same", i.e. that it is impossible to discriminate among mass produced items. The purpose of this paper is to stress that, with sound methods for interpreting evidence, it is possible to improve the communication between the scientist and the Court, and to show the real significance of the analytical results, in the context of the case.

The analysis of the traces found on a knife used in a murder case were performed by optical microscopy, IR spectroscopy, and UV-visible spectroscopy. The interpretation of evidence was carried out according to a Bayesian approach.

A description of the interpretation of evidence in a case in which fibres were the key evidence. It is shown that the key aspects for having a high value of the evidence are the circumstances of the case and the reconstruction of the events given by the prosecutor and by the defence, in addition of course to a sound analytical procedure. In other words, it is shown that in some cases the evidential value of fibres or other trace evidence can be very high, sometimes comparable to that of fingerprints or DNA: when properly interpreted, trace evidence can give key information for solving cases.

Keywords: *Forensic Science, Fibres, Polymers, Trace Evidence, Interpretation, Bayes Theorem, Court.*

المستخلص

ساهم ظهور التكنولوجيا الجديدة مثل فحص بصمة الحمض النووي، ووزن الأدلة العلمية في الأعمال الجنائية الموجهة للإعلان والدعاية على نطاق واسع، وانتشار الأعمال الخيالية وغير الخيالية في وسائل الإعلام العامة في جعل العلم الجنائي معروفا جيدًا، على الرغم من أنه ربما ليس مفهوما بشكل جيد من قبل عامة الناس. وكانت إحدى نتائج هذا التعميم لعلم الأدلة الجنائية التغيير الحاد في موقف المحققين الذين يميلون بشكل متزايد إلى تفويض العلماء بجمع المعلومات اللازمة لتحديد مرتكب الجريمة. ومع ذلك فإن التركيز البارز على البحث عن آثار أو بصمات بيولوجية بسبب مزاياها العالية في التعرف على الأفراد الموجودين في مسرح الجريمة جعل الاهتمام بالأنواع الأخرى من الأدلة، مثل الأدلة الآثار الزهيدة، يتلاشى إلى حد ما. وفي الواقع ، ينظر القضاة والمحامون إلى هذا النوع من الأدلة على أنها أقل فائدة، لأنهم يعتقدون أن «جميع المواد البلاستيكية هي نفسها» ، أي أنه من المستحيل التمييز بين الأصناف المنتجة ذات العدد الهائل.

والغرض من هذه الورقة هو التأكيد على أنه مع وجود طرق سليمة لتفسير الأدلة فإنه من الممكن تحسين الاتصال بين خبير الأدلة الجنائية والمحكمة، وإظهار الأهمية الحقيقية للنتائج التحليلية، في سياق الحالة.

أجريت الدراسة من خلال تحليل الآثار التي وجدت على السكين المستخدمة في قضية القتل عن طريق الفحص المجهري، والتحليل الطيفي للأشعة تحت الحمراء، والتحليل الطيفي للأشعة المرئية فوق البنفسجية، وقد تم تفسير الأدلة وفقا لنظرية بايزي.

وتم تقديم وصف لتفسير الأدلة المتبع في الحالات التي يتم فيها تقديم الألياف كدليل الرئيسي. وقد تبين أن الجوانب الأساسية لوجود قيمة عالية من الأدلة هي ظروف الحالة وإعادة بناء الأحداث التي قدمها المدعي العام والدفاع، بالإضافة إلى إجراء تحليلي سليم. وبعبارة أخرى يتبين أنه يمكن أن يكون للألياف وغيرها من آثار التلامس قيمة عالية جدا في بعض الحالات الجنائية، ويمكن مقارنتها في بعض الأحيان ببصمة الأصابع أو بصمة الحمض النووي عندما يتم تفسيرها بشكل صحيح، كما يمكن أن تقدم هذه الأدلة الزهيدة معلومات أساسية ومحورية لحل القضايا.

الكلمات المفتاحية: علوم الأدلة الجنائية، الألياف، البوليمرات. أدلة الآثار الزهيدة، التفسير، نظرية بايز.

1. Introduction

Science can be defined as the study of the nature and behaviour of natural things and the knowledge that we obtain about them. As such, investigation of crimes and scientific research share the same quintessence, as both activities aim at obtaining, by observation of the consequences, information about the causes of a phenomenon. Despite this similarity, criminal investigation and science only formally met in the nineteenth century. Since then, though, the progress has been rapid and dramatic. The advent of new technologies such as DNA typing, the weight of scientific evidence in criminal trials of widespread publicity, and the proliferation of fictional and non-fictional works in popular media have contributed to making forensic science well known by law professionals and also by the general public.

However, one of the consequences of this popularisation of forensic science was a sharp change in the attitude of investigators, who increasingly tend to delegate to scientists the collection of information necessary to identify the perpetrator of a crime.

However, the prominent focus on the search for biological traces or fingerprints, due to their high potential for the personal identification of the individuals involved in a crime made the interest towards other kinds of evidence such as trace evidence somewhat faded.

This kind of evidence is in fact perceived by judges and lawyers as less informative, because they think that "all plastic items are the same", i.e. that it is impossible to discriminate between mass produced items.

The purpose of this paper is to stress that, with sound methods for interpreting evidence, it is quite possible to increase the value and usefulness of the analytical data acquired from items found at the crime scene.

The case presented in this paper regards a stabbing case, in which DNA or fingerprints were not available, since such traces were carefully removed. The alleged weapon was a knife. On its blade, two groups of fibres and a plastic smear gave positive results when compared with those of the polyester wadding of the victim's jacket. An interpretation of such evidence is described, with the aim of analysing the most critical variables affecting the likelihood ratio, and thus the value of the overall evidence.

2. Methodology

Exhibits from the alleged crime scene were submitted to the forensic laboratory by the police investigating the case. Samples of the victim's jacket were available for analysis and were kept in a room separate from the knife. The outer textile and the inner padding were characterized in different days than the fibres found on the knife.

For characterization, the fibres of the jacket were mounted in XAM-neutral medium on glass slides. Traditional methods of bright field transmission observation were adopted. The microscope used was a Leica DM4000M equipped with 10x, 20x and 50x objectives. The photomicrographs were taken with a Leica DFC280 digital camera. In order to gather UV/VIS absorption spectra, a MPM 800 (Zeiss) instrument was used. The apparatus was set with an Ultrafluar 32x/0.8 Glyc objective and a Ultrakondensor 0.8/0.3 condenser for measurements extended in the UV region (230-450 nm). When acquiring absorption spectra in the visible range (380-780 nm), a Plan Neofluar 40x/0.75 was chosen with a disc condenser. In both cases, an XBO 75W/2 lamp was used. The samples were mounted in UV-free glycerin (Zeiss) on quartz slides. Transmission measurements were performed with a resolution of the data of 2.5 nm. IR absorption spectra were acquired on a Nexus FTIR spectrometer (Thermo Nicolet) hyphenated with a Continuμm microscope (Thermo Nicolet). A MIR Globar source was used and the detector was of the MCT/A type. The spectral region spanned from 4000 to 650 cm-1, with a resolution of 4 cm^{-1}. 128 acquisitions were gathered. Samples were suspended across slits in order to make measurements in the transmission mode.

3. Results and Discussion

The case used as an example in the present paper involved a fight between two individuals, which ended in one of them stabbing and killing the other. During a search in the suspect's premises, a knife with a burnt blade was found (Figure-1).

This item was examined with the aim of extracting biological traces or fingerprints, but such attempts were negative. The only potentially useful traces were two types of fibres, which adhered to the blade close to the handle and a plastic smear, which was found on the burnt portion of the blade.

Figure 1- *Knife allegedly used in the stabbing case. Major divisions on the scale bar correspond to 1 cm.*

These items were analysed according to a standard analytical procedure, starting with a morphological characterisation by optical microscopy, followed by UV-visible microspectrophotometric measurements and IR microspectroscopy. Given the white or dark brown colour of the recovered fibres, UV-visible spectra were featureless and useless for comparison. IR spectroscopy showed that the fibres recovered from the area close to the handle were made of poly(ethylene therephthalate) (data not shown). However, there was a full morphological compatibility between the fibres on the knife and those composing the padding of

the victim's jacket. In both cases, the nature of the polymer was nylon.

When confronted with these data, the suspect admitted that he had attacked the victim with that knife.

As evident from the above, this is a quite typical fibre case. The purpose of this paper is to show how this evidence can be translated into a quantitative interpretation of evidence, and especially how the different variables involved in the assignment of a likelihood ratio affect the final assessment.

The evidential value of all traces is critically dependent

Figure 2- *Micrograph (50 x objective) showing the comparison between one of the fibres retrieved from the knife (left) and one of the fibres composing the padding of the jacket of the victim.*

the victim's jacket, as exemplified by Figure-2.

Two groups of fibres, both polyester in nature, but with different morphological features, such as diameter and delustrant content, were found on the knife, which corresponded to those used in the padding of the victim's jacket.

The plastic smear on the blade had completely lost its original shape, because the polymer had melted when the blade was burnt. Therefore, microscopical observation was not useful for comparison purposes. In this case, IR spectroscopy was valuable in comparing the smear on the blade with the textiles from which the victim's jacket was composed. As can be seen in Figure-3, the spectrum of the smear was superimposable to that of the external textile of

on the context. The Bayesian approach is a very efficient way to manage the issue of interpretation and contextualisation of evidence. Excellent references exist dealing with the different probabilistic methods for interpretation of evidence in forensic science, and the interested reader is encouraged to consult them [1-3].

Given two competing propositions (H_1 and H_2, which for the sake of simplicity can be summarised as the "proposition of the prosecution" and the "proposition of the defence"), formally, Bayes' theorem can be stated as:

$$\frac{P(H_1|E)}{P(H_2|E)} = \underbrace{\frac{P(H_1)}{P(H_2)}}_{\text{prior odds}} \cdot \underbrace{\frac{P(E|H_1)}{P(E|H_2)}}_{\text{LR}} \quad (1)$$
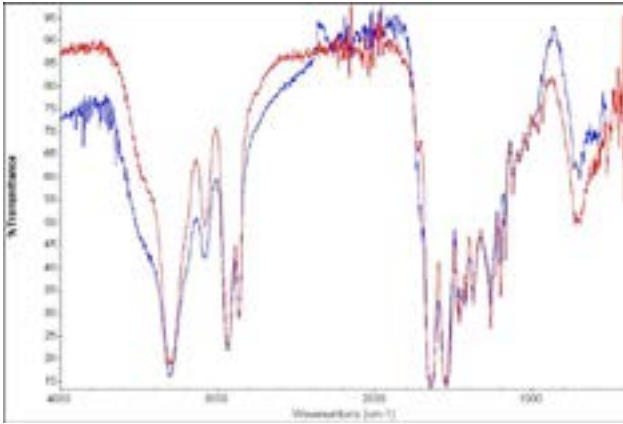
Figure 3- *IR spectra of the plastic smears recovered on the knife (blue line) and of the external fabric of the jacket of the victim (red line).*

where E represents the new information coming from forensic analyses. $P(Hi)$ indicates the probability of the proposition Hi and $P(y|x)$ is the probability of the event y, given x is true. This formula means that the ratio of the final probabilities is equal to the product of two ratios: prior odds and Likelihood Ratio (LR). Prior odds are updated by the LR to give posterior odds which are conditioned on E. The role of the forensic scientist in this process consists of assessing the LR. Evaluation of prior and posterior odds is, on the contrary, the prerogative of the Court [4].

As may be seen in the equation above, the LR is composed of a numerator and a denominator. The numerator represents the probability of the evidence E, given the proposition H1, usually the proposition favourable to the prosecution.

The denominator is the probability of the same evidence E, but under the proposition H_2 developed on the basis of the account of events proposed by the defence [Unclear]. In other words, the LR says how much more probable it is to observe evidence E if proposition H1 is true, rather than if proposition H_2 is true.

The LR depends on many variables, some of which can be assigned on the basis of literature data, some others being more subjective. In the following paragraphs, a formal expression for the LR will be developed. Its examination will show how the LR varies as a function of the different variables.

The two simplest competing propositions which can be formulated in this case are:

H_1: the pool of traces recovered on the knife came from

the stabbing of the victim;

H_2: the pool of traces recovered on the knife came from some other activity.

In other words, no alternative explanation is given by the defence for the presence of the fibres on the knife and random chance is invoked.

Under the hierarchy of propositions of Cook and Evett [5], the case has been addressed at an activity level. There was, in fact, enough information on the spatial distribution and on the nature of the traces to address the case in a deeper perspective than simply at a source level.

To evaluate the LR, it is necessary to give an analytical form to its numerator and denominator.

A first simplification was done, in order to ease the evaluation of these two probabilities. The recovered traces have been classified according to their nature and appearance, obtaining 3 groups: white polyester whole fibres with low delusterant level (2 fibres); brown polyester whole fibre with high delusterant level (1 fibre); and plastic nylon smear on the blade. The whole fibres were considered separately from the smear.

The LR related to the fibres was constructed according to a well-established procedure [1-3,6]. For the numerator, at least 3 possible explanations for the evidence E must be considered [2, 3]:

1. the two groups of whole fibres were transferred, persisted and were recovered as a result of the stabbing;
2. one group was transferred during the stabbing, the remaining one was originated from other sources;
3. the two groups are not associated with the stabbing but have different origins.

As a consequence of the above mentioned simplification, each of these terms should be rigorously formalised considering a different frequency value for each of the two different polyester fibres. Even though literature data on the frequency of fibres in different environments and contexts exist [7-22], they are usually organised either according to the chemical nature or to the colour. In other words, it is not possible to retrieve literature data on the different frequencies of white and brown polyester fibres. A further simplification was then applied, combining the frequencies of the two groups of fibres into a single one. In the following parts of this paper, the consequences of the choice of such "average" value will be discussed.

The numerator is then the sum of 3 terms:

$$P(E|H_1) = b_0 t^2 + \binom{2}{1} t(1-t)b_1 f + b_2 f^2 (1-t)^2$$

(2)

where:

"t" is the probability that a group of fibres comparable to the victim's jacket has been transferred from the jacket of the victim, has persisted and has been recovered. The proposition under which this probability must be assigned is H_1.

"f" is the frequency of the fibres recovered on the knife. As a consequence of the grouping of the fibres into a single class, this value corresponds to the frequency of polyester fibres.

"b_n" is the probability of the presence by chance of n groups composed of extraneous fibres in numbers compatible with those of the case. The term "extraneous fibres" denotes those distinguishable from textiles owned by the habitual users of the knife.

Each term in (2) represents one of the 3 possible explanations presented above. A general form of (2) can be found elsewhere [6].

The binomial coefficient is needed to consider all the possible combinations of crime-related and non-crime related groups. In the second addend of (2), $\binom{2}{1} = 2.$ This means that there are two ways in which this situation can occur: white fibres are crime related and brown fibres are not, or brown fibres are associated with the offence, while the presence of white fibres is due to chance.

Terms "t^k" in (2) are associated with the probability that k groups of fibres compatible with those selected as targets may have been transferred, persisted and have been recovered simultaneously. Combination $b_n f^n (1-t)^n$ takes into account the presence, by chance, of n groups. (1-t) is the probability of the complementary event with respect to t, i.e. that the group has not been transferred, has not persisted or has not been recovered as a result of the stabbing, while $b_n f^n$ represents the probability that the n recovered compatible groups were there by chance alone.

The expression for the denominator is formalised on similar grounds to eq (2). Also in this case, the frequency of the two groups of fibres should have been considered

separately, the same approximation done in eq (2), i.e. the combination of the fibres into a single variable f, was applied in this case also. Since the defence does not connect the presence of the fibres to a particular action, but just to random chance, it follows that all terms containing the probability of transfer are equal to zero, and the denominator of the LR reduces to:

$$P(E|H_2) = b_2 f^2$$

(3)

The LR for a case like that exposed can be calculated by:

$$LR = \frac{P(E|H_1)}{P(E|H_2)} = \frac{b_0 t^2 + \binom{2}{1} t(1-t)b_1 f + b_2 f^2 (1-t)^2}{b_2 f^2}$$

(4)

This formal assessment of the LR, albeit familiar to scientists conversant with issues of interpretation of the evidence, may be extremely difficult to convey to a Judge or a Jury. The most critical aspect is the dependence of the expressions on several variables which cannot precisely and unambiguously be defined. An efficient approach to convey the meaning of each parameter is to show their influence on the value of LR.

"b_i" values can be assigned assuming a Poisson distribution [2]:

$$b_i = \frac{e^{-\lambda} \cdot \lambda^i}{i!}$$

(5)

where $\lambda = -\ln b_0$ and b_2 was determined as $1 - (b_0 + b_1)$ and represents the probability of finding by chance 2 or more foreign fibres' groups. In other words, starting from an initial assessment of the value of b_0, i.e. the probability of finding no extraneous group of traces on the knife, the other b_i values can be calculated according to (5).

Three scenarios were devised. In the first, a high probability ($b_0 = 0.90$) was associated to finding no extraneous fibres on the blade of a knife. This is the case of a very clean and uncontaminated knife.

The opposite situation was simulated attributing a low probability ($b_0 = 0.01$) to finding no fibres on a knife. This is the case of a very dirty knife, where many extraneous

substances are expected. An average scenario was also considered. Table-1 reports the obtained bi values.

The frequency f of the groups can be assigned from literature data. For the sake of simplicity, it was assumed that the probability of transfer t was the same for both groups and that all the fibres had the same frequency f among the population. Target fibre and population studies [7-22] showed that the probability of finding a particular kind of fibre is rarely larger than 1%.

Figure-4 shows how LR changes with f in the three scenarios described above. Figure-4 was created assigning a fixed value of 0.5 to t.

As may be seen, with increasing f there is a sharp decrease of the value of the LR. However, in the clean knife scenario the LR remains well above 104, up to f values close to 0.1. As noted above, the literature shows that the frequency of fibres is normally less than 0.01, so an f value of about 0.02 seems to suit literature data with a conservative pro reo perspective. For such a value, the LR takes the value of 225475, 4225 and of 15 for the clean knife, average and the dirty knife scenario, respectively.

Figure-5 shows the LR as a function of probability t,

Table-1: *estimates of bi parameters in three different scenarios.*

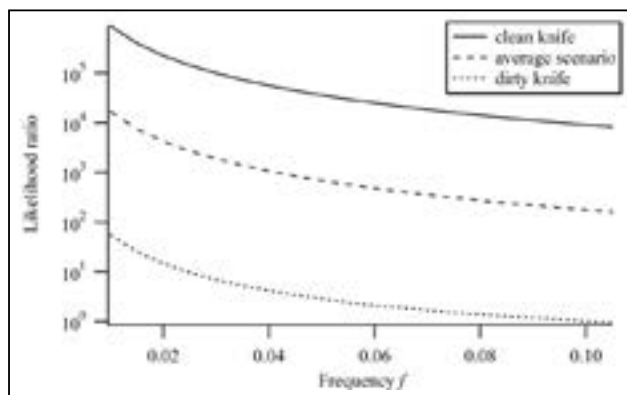| Situation	b_0	b_1	b_2
Clean knife	0.90	0.095	0.005
Medium scenario	0.50	0.35	0.15
Dirty knife	0.01	0.05	0.94

Figure 4- *Likelihood ratio of the whole fibre evidence vs. frequency f, under three background scenarios.*

for the three aforementioned hypotheses and for f = 0.02.

The trend of the LR reflects that already reported in a previous case [6]. The LR, after a steep increase, rapidly levels up to a plateau for t larger than 0.2. t is indeed the most difficult variable to precisely assess, because it strictly depends on the dynamics of the events. However, Figure 5 shows that it does not have a very critical influence on the final value of the LR. t is the probability that n fibres are transferred from the jacket of the victim, persisted on
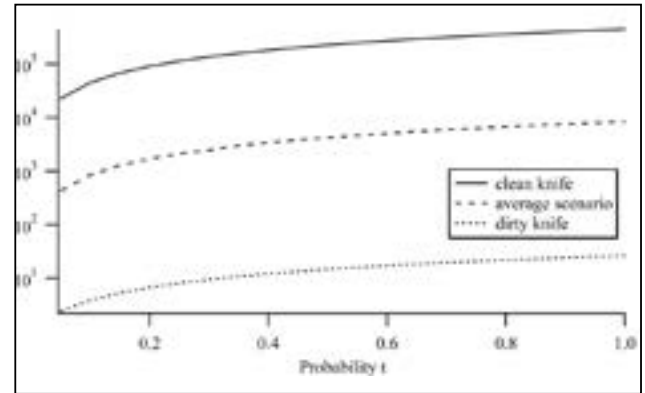

Figure 5- *Likelihood ratio of the whole fibre evidence vs. the probability of transfer t, under three background scenarios.*

the knife and were recovered. The probability of transferring fibres on a knife when this is used to stab someone is high, because stabbing is a violent mode of contact which is expected to transfer a large number of traces. However, in this case the blade of the knife was burnt to delete blood or other biological traces. As may be seen from Fig. 1, such treatment was concentrated on the central part of the blade, not close to the handle, where the whole fibres were found. Combining these two factors contributing to t, it seems reasonable to assess as moderate-low (0.2-0.4) the probability that 3 fibres among those transferred in the stabbing persisted on the knife after the cleaning treatment and were ultimately recovered.

Eventually, the most important factors to assign are those related to the background, i.e. the bn parameters. A survey of 30 knives, similar to that of the case and used in a domestic environment, was carried out within employees of the authors' institutions and showed that fibres are indeed very rarely present on such implements. Just in one case, one fibre was found lightly adhering to the surface of the blade. There was no case in which fibres were detected stuck between the handle and the blade, as seen in this case.

The clean knife scenario is therefore the one which most closely represents the amount of traces expected on an average knife, yielding a LR of about 104.

The above calculations were made on the simplest case, in which no alternative transfer activities were given for the presence of the fibres on the knife, invoking just random chance. The effect of alternative transfer activities on the LR was discussed elsewhere [23]. In that instance, the LR was calculated according to different defence versions (propositions H_2). In particular, it was found that an explanation such as "the knife was not used for stabbing the victim and the fibres were transferred onto it when the owner accidentally cut his own jacket" decreased the LR to a range between 60 and 1000, still in quite strong support of the prosecution perspective. If the defence proposed an explanation such as "the knife was not used for stabbing the victim and the fibres were transferred onto it when the owner stabbed a burglar that entered his house a week before", the LR would be further decreased to values of about 1, which mean that the analysis was uninformative. This outcome is very logical, because fibre analysis can only inform investigators about the probability of the observations if the weapon was used to pierce someone's garments, but it is not a means of personal identification.

The LR related to the presence of the plastic smear on the blade of the knife has a much simpler analytical form. The numerator and denominator were formulated according to the procedure used for obtaining equation (2). Since just one group of traces is present, LR is the following:

$$LR = \frac{P(E|H_1)}{P(E|H_2)} = \frac{b_0 t + b_1 f(1-t)}{b_1 f}$$

(6)

b_0 values reported in Table 1 can still be employed, and b_1 will be $1 - b_0$. Figure-6 shows how the LR changes as a function of t for different f values.

In this case, t should be intended as the probability of transferring polymeric material in a stabbing, followed by its persistence while melting when the blade is burnt and recovery afterwards. During the examination of the knife, in fact, the plastic smear was adhering very firmly to the metal, consistent with the melting of a polymer to the blade, rather than to a transfer of molten and deformed
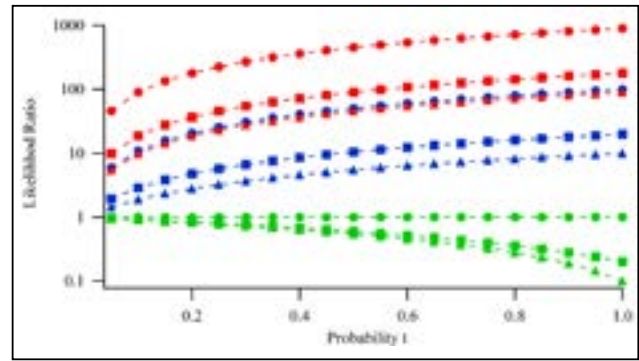

Figure 6- *Likelihood ratio of the plastic smear evidence vs. the probability of transfer t, under three background scenarios. Red symbols are relative to the clean knife scenario, blue symbols to the average scenario and green symbols to the dirty knife scenario. Circles are the LR calculated for f = 0.01, squares are the LR calculated for f = 0.05, and triangles are the LR calculated for f = 0.10.*

fragments of polymers from elsewhere to the knife. As in Figures-4 and 5, the LR as a function of t levels off very rapidly, making the assignment of t not so critical for assessing the order of magnitude of the LR.

f should be interpreted as the frequency of nylon material within the population of trace material dispersed in the environment. No such data exist in the literature to the knowledge of the authors, but it seems reasonable to assess this value on the basis of information on fibre population. Like in the previous case regarding whole fibres, a value comprised between 0.01 and 0.05 can be considered reasonable. Again, the key factor which has the largest influence on the LR is the definition of the background conditions, i.e. the choice of b0 and b1. These parameters indicate how likely it may be to find molten polymeric smears on the burnt blade of a knife. Since it was established that finding groups of fibres on the blade of a knife is very rare, it will be equally not probable that groups of molten fibres will appear on such implements. Therefore, realistic choices for b_0 and b_1 should be those of a clean knife or at most of the average scenario [Unclear]. This corresponds to the blue and red lines in Figure-6, and so to LRs comprised between 2 and 900.

Since the presence of the two fibre groups and of the plastic smear are conditionally independent, their LR values, 104 and between 2 and 900, respectively, can be combined in a total LR by multiplying them. This allows to identify the range within which the LR can vary as a consequence of the choice of the various factors from

which it depends: from a minimum of 104 to almost 106. In other words, it is between 10,000 and one million times more probable to observe the fibres found on the knife if the knife had been used for the stabbing, rather than if the fibres were there by chance. The more information on the case, the easier it will be to precisely identify such factors and thus to reduce the width of the LR interval. It is worth noting that polyester fibres are considered very common. Nylon fibres are not rare either. Nevertheless, the obtained LRs are very large, showing that the traces involved in the case, due also to their location and spatial distribution, have a very probative evidential value. Such LRs, according to Evett's verbal scale for reporting forensic LRs, mean that the evidence very strongly supports the proposition that the pool of traces recovered on the knife came from the stabbing of the victim.

4. Conclusion

The multifarious branches of forensic science allow us to obtain a very large amount of information about criminal cases and the dynamics of a crime. Being able to assess the usefulness and the evidential value of such data is a key ability of a forensic scientist. The analytical form of the LR shown in this paper may be difficult to understand for laypersons or law professionals. A major effort must be done for an effective communication of the results of the calculations and assessments performed for a Bayesian interpretation of evidence. If this can be done, it will be possible to show the court that not just fingerprint or DNA cases are valuable traces: when properly interpreted, other type of trace evidence can also give highly probative information for solving cases.

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