Statistics in Practice
Forensic Science

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No particular needs for this lecture.

Forensic Science

Criminal evidence becoming increasingly “scientific”.

- Greater use of trace evidence (paint/glass/fibres).
- DNA revolution.

The rise of DNA was coincident with a greater awareness on the part of courts that observations are subject to uncertainty.

Forensic Science

Over the last 20 years or so there has been something of a small revolution in the way in which scientific evidence has been presented to the courts. This revolution is very slow and low-key, and likely to continue into the indefinate future.

In criminal cases courts have been more and more willing to use evidence of a “scientific” type to establish various propositions of interest to them.

This has been partly due to the increasing availability of this sort of evidence, and partly due to increasing scepticism of the courts about eye-witness types of evidence.

However, what has given real impetus to the scientic revolution is the rise of DNA evidence.

Forensic Science

Greater realisation that uncertainty is important has lead to:

- Trace evidence (glass/paint/fibres) being treated statistically.
- More evidence types:
  - common observations - shoe types - facial features - all being treated with some form of statistical method.
  - observation of co-incidence of treatment in cases where carers are suspected of harming their charges.

Forensic Science

In a vaguely circular fashion the rise in the use of scientific evidence had led to the realisation that statistical approaches can be used in other areas of forensic science.

Most notably most trace evidence is now begining to be considered in a statistical manner. This includes paint traces, glass fragments and fibres.

More recently statistical methods have been applied to common types of observations such as type of shoe, and type of projectile from firearm. Here it has been realised that even if the object under investigation has insufficient individualising marks for an expert examiner to say that, for example a shoemark was from a particuilar shoe, the observation that a shoe type is common between a crime-scene and suspect is itself of evidental value, and it is a matter for statistical considferation to evaluate that value.

Forensic Science

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Most disapointing for statisticians is where statistical methods have been employed to comment on the co-incidence between the presence of carers and adverse outcomes for their charges.

Examples are where nurses in hospitals have been accused of harming patients, or parents have been accused of harming their children.

This is an area where the public attention has been directed mainly due to the misuse of statistical methods.

Forensic Science

DO NOT CHANGE SLIDE

Most notably in the United Kingdom the cases of Sally Clark and Trupti Patel who were women who lost several children. A pediatritian, Professor Sir Roy Medows testified that the probability of loosing so many children was very small, and that it indicated that a criminal offense had occured. Unfortunately Professor Sir Roy Meadow assumed independence between losses of children, and this grossly exaggerated the rareity of multiple events. Sally Clark and Trupti Patel were subsequently found not to have harmed their children.

This sort of use of statistics to support criminal justice is ongoing. In the Netherlands there is a case involving a nurse, Lucia de Burk, who has been convicted of harming patients in her care. The case is causing much controversy, and involved statiticians from several different countries.

Forensic Consultancies

Typically:

- Police.
- Customs and Excise.
- Criminal Defense lawyers.

Start with an approach by one of the above.

- Usually concludes with the subission of a statistical report.
- Rarely concludes with a court appearance.

Forensic Consultancies

It is against this background that we come to the actual process of being consulted.

Usually it will be the Police who wish to have some item of evidence evaluated, however, I have been consulted by Customs & Excise, and by Criminal defense lawyers, and even by Trading Standards authorities.

It is usual for a meeting to be set up, and the case explained to the statistician. The statistician will then write a report on the evidence, and submit it as part of either a prosecution, or defense, case.

This will usually be the end of it. It is rare for you to ever find out anything more such as how the case went, or even the names of those involved. However, very occasionally, the case goes to court in which case one has the trauma of making a personal appearence in one of the higher courts.

Case work - Tinley

The facts were:

- Evening of 9th April 2004 Andrew Tinley was assaulted by his partner Sally Rose.
- He picked up a champagne bottle and struck her on the head.
- Rose died at the scene of the incident.

Case work - Tinley

On the evening of the 9th April 2004 Andrew Tinely was dozing off in his, and his partners Sally Roses' Paignton home when Rose poured a saucepan of boiling caustic soda into his lap.

Tinley responded by picking up a bottle of champagne and striking Rose on the head. Rose died shortly thereafter at the scene of the incident.

Case work - Tinley

Under interrogation:

- Tinley said he had struck Rose twice with the bottle.
- The pathologist could find no evidence for two strikes.

A double blow is more incriminating than a single - obviously of interest to the court

The question was: what is the probability of administering two blows with a champagne bottle and leaving only a single wound?

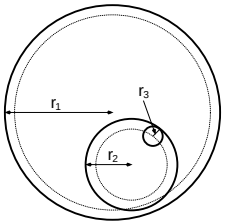
Case work - Tinley

Under police interrogation Tinley said that he had hit Rose twice.

There was evidence for only a single blow to the head, however, a double blow might indicate that more force than was reasonable was employed, so whether a double blow was used was of interest to the court.

So the question of interest was what is the probability of administering two blows with a champagne bottle and leaving only a single wound?

Case work - Tinley



If:

1. r_1 is the radius head.
2. r_2 is the radius of the area of the wound.
3. r_3 is the radius of the area of the implement.

Case work - Tinley

Tinley's description was critical in that it suggested that the any blows to Roses head happenned as an essentially random process.

To approximate the probability some unwarrented assumptions were made which mainly involved things being circular. Unwarrented assumptions were also made about the nature of randomness across the putative target area, such as uniform probability of striking any point upon the head.

Case work - Tinley

$$\Pr = \frac{2\pi(r_2 - r_3)^2}{2\pi(r_1 - r_3)^2}$$

Given the values for $\mathbf{r}$ in the pathologists report gives a probability of about 8%.

- Only a guide for the court.
- Could spend a lot of time working out a more exact value.
- Limits of knowledge given by Tinley's account.

Case work - Tinley

$$\Pr_2 = \frac{2\pi(r_2 - r_3)^2}{2\pi(r_1 - r_3)^2}$$

Gives us a probability of about 8% given all the unwarrented assumptions.

One might wonder whether, given its imprecision, this 8% figure is in any way useful. Well it is in that all the assumptions er have made fall into insignificance when we are so reliant upon Tinleys report of his own activities.

We could spend a long time doing 3D modelling to get a more precise figure, and the case might very well have been over by that stage, or Tinley, mindful of wanting the wound to look as though it were from a single blow, might have held Rose down and repeatedly struck her on the same spot, thus negating all the assumptions of random process.

As it was the figure, and reasoning above was adequate for the courts purposes, and combined with all the other evidence, Tinley was convicted of manslaughter rather than murder.

Firearm rifling patterns

Two firearms offenses committed in "a town"

- The first incident was the shooting of a man in "the Town" in June 2000.
- The second was a shooting of a man in "the Town" in March 2003.

Both incidents featured a 0.32 calibre revolver with a 5-right rifling pattern.

What is the evidential value of the "match"?

Firearm rifling patterns

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What is the evidential value of the "match"?

5-right 0.32 calibre

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Here is a 5-right, 0.32 calibre projectile. This is not one of the ones used, but is of a similar type.

Notice the lands of the rifling. From this it is reletively easy to get calibre and rifling marks. In this instance the firearms examiner was unable to make any statements about the individual weapon. That is the striations could not be used to “individualise” the weapon.

“individualisation” is the process whereby a forensic examiner makes statements like “I am convinced that this projectile has been fired by this firearm”.

In this case the examiner was unable to do that, so the investigators were left with just the calibre and rifling pattern.

Firearm rifling patterns

A suspect had been located.

- That suspect was been found to possess a firearn with a five-right rifling pattern.

Start with two propositions

1. H_p is that two firearms offences employed the same weapon, and that weapon is that found in the posession of the suspect.
2. H_d is that the firearms used in the two offences were different weapons to that of the suspect.

Firearm rifling patterns

A suspect has been located.

- That suspect has been found to possess a firearn with a five-right rifling pattern.

Start with two propositions:

1. H_p: that two firearms offences employed the same weapon, and that weapon is that found in the posession of the suspect.
2. H_d: that the firearm(s) used in the two offences were/was a different weapon(s) to that possessed by the suspect.

Likelihood ratios

A standard measure of evidential value is a likelihood ratio
Let:

- $E \equiv$ the firearm used was of calibre 0.32 and rifling pattern 5 right.

Then:

$$\mathrm{LR} = \frac{\Pr(E|H_p, I)}{\Pr(E|H_p, I)}$$

where $I \equiv$ a firearm has been used in the commission of the offences.

Likelihood ratios

A likelihood ratio is a standard measure of evidential worth used in forensic science these days - of at least that part of forensic science dealing with uncertainty.

Essentially it is the probability of observing the evidence, in this case 5-right, 0.32, calibre, given the prosecution and defence propositions respectively.

All this is conditioned on there having been a firearm used in the offenses.

Numerator

The numerator is: $\Pr(E|H_p, I)$.

- What is the probability of observing 5-right, 0.32 calibre, were the firearm used that of the suspect.
- The suspect has only one firearm.
- Some other individual may have used the suspect's firearm - should be from defence case if so.

The probability is quite high ≈ 1

Numerator

The denomonator is the probability of observing 5-right, 0.32 calibre, were the firearm used that belonging to the suspect.

The suspect has only been observed to posess one firearm.

However, it could be someone else borrowed the firearm concerned - but we would expect that to be brought up in the defense case earlier.

The numerator is probably pretty close to one as were the suspect's only weapon used, then one would fully expect the projectile to be 5-right, 0.32 callibre.

Denominator

The denomonator is: $\Pr(E|H_d, I)$.

- What is the probability of observing 5-right, 0.32 calibre, were the firearm used some other firearm other than that of the suspect.
- This is proportional to the frequency of 5-right, 0.32 calibre, firearms from the population of illegally held firearms.

Need for data - supplied by investigators.

Denominator

The denomonator is the probability of observing 5-right, 0.32 calibre, were the firearm used some other firearm selected from the population of illegally held firearms.

Denominator

- From data supplied of observations from a suitable sample of weapons recovered
- There are 716 illegal firearms known to the firearms intelligence branch
- 4 were revolvers with right handed rifling of 5 grooves, and were of 0.32 calibre.

The likelihood ratio is 716/4 = 179

Denominator

- From data supplied of observations from a suitable sample of weapons recovered
- There are 716 illegal firearms known to the firearms intelligence branch
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Likelihood ratio

The likelihood ratio is 716/4 = 179 can be interpreted:

The observation of 0.32 calibre, and 5-right rifling, is 179 more likely were the weapon used in these offences that of the suspect rather than any other weapon from the population of illicit firearms.

This does not take into account the fact that there were two scenes - should it be 179^2.

Should I have done so? - some disquiet about using the higher figure.

Likelihood ratio

The likelihood ratio is 716/4 = 179 can be interpreted as: The observation of 0.32 calibre, and 5-right rifling, is 179 more likely were the weapon used in these offences that of the suspect rather than any other weapon from the population of illicit firearms.

This ignores the fact that there were two incidents which under the defense proposition would be regarded as independent, so should the likelihood ratio be 179^2?

I felt a little uneasy about this, so went with the more conservative figure. But it is a matter of judgement which one opts for.

How incriminating

Evett *et al.* (2000) give the following table:

likelihood ratio	verbal equivalent
$1 < \text{LR} \leq 10$	limited support for H_p
$10 < \text{LR} \leq 100$	moderate support for H_p
$100 < \text{LR} \leq 1000$	moderately strong support for H_p
$1000 < \text{LR} \leq 10000$	strong support for H_p
$10000 < \text{LR}$	very strong support for H_p

179 is in the middle of this range - thus implying moderately strong support for H_p.

How incriminating

For the propositions as framed the higher the likelihood ratio the more incriminating.

Evett *et al.* give the following table as a guide to some sort of verbal equivalence.

Notice here how all the likelihood ratios are framed in terms of support for H_p. For values of likelihood ratio less than one you could take the reciprocal and substitute H_d for H_p.

Notice here that a likelihood ration of 1.464 is very much at the lower end of things. The observation of blood of type O at a crimescene and from a suspect is, in this case, not very incriminating.

Case work

The Tinley case was unusual but:

- Most have distinct features.
- Many revolve around “comparison” problems.

Academia one of the best ocupations for those involved in this sort of work:

- Quite often your conclusions favour the side who has not employed you.
- You can become quite unpopular with both sides.

Case work

The Tinley case was unusual but:

- Most have distinct features.
- Many revolve around “matching” problems where an item of interest needs “matching” in some sense to another item to see whether the two items share a common source. This happens for glass, shoe marks from a crimescene, recorded voice patterns, and lately, measurements from faces.

Academia one of the best ocupations for those involved in this sort of work. This is because you have been consulted because nobody knows intuitvely whether the evidence favors the prosecution or defence, and the court needs some idea of where the evidence is pointing. You need some sort of buffering from the usual concerns of commercial activity because:

- Quite often your conclusions favour the side who has not employed you.
- You can become quite unpopular with both sides.

Conclusions

A career in forensic statistics:

- has variety of challenging problems.
- Is in a growing field (FSS just recruited).

But:

- Is difficult to operate in, particularly independently.
- Really need institutional support.

Conclusions

Forensic statistics and the statistical evaluation of evidence is a growing field, offering a wide variety of challenging problems to the statistician.

In fact the Forensic Science Service is just recruiting more statisticians at the moment.

However, it does really require a Ph.D. for you to maintain any credibility within the forensic community, and it is a difficult area to operate in. For instance it would be very difficult to maintain a position as an independent forensic statistics consultant. One really needs some sort of institutional support in ones career.