The nature of expert opinion and the structure of reports

Graham Jackson
Advance Forensic Science
and University of Abertay Dundee

graham@advanceforensicscience.com

AFSP. Standard for the formulation of evaluative forensic science expert opinion
Science and Justice 2009; 49: 161-164

The AFSP standard helps meet the UK Forensic Science Regulator’s requirement:
• robust, transparent, balanced and logical interpretation model...
  ... and it embraces the two key C.A.I. concepts of:
• classification of expert opinion
• hierarchy of issues

Underpinning, logical framework:
Bayes Theorem

Formal means of dealing with uncertainty and forming opinion:

Bayes Theorem

Biedermann A, Taroni F, Delemont O, Semadeni C, Davison, AC.
The evaluation of evidence in the forensic investigation of fire incidents

Biedermann A, Taroni F, Delemont O, Semadeni C, Davison, AC.
The evaluation of evidence in the forensic investigation of fire incidents
Part II: practical examples of the use of Bayesian networks.

Bayes Theorem

How do we form opinions?

Opinion about an uncertain event
Opinion about an uncertain event
Opinion about an uncertain event

Factual evidence 1
Factual evidence 2
Factual evidence

We adjust our opinion one way or the other
given new items of evidence

There’s two things to consider

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Bayes Theorem

Tells us how to combine logically new pieces of information (or evidence) to update our opinions about an uncertain event

\[
\text{Prior probability} \times \text{Prob. of the evidence} \propto \text{Posterior probability}
\]

\[
\text{Posterior odds} \propto \frac{\text{Posterior probability}}{\text{Prior probability}}
\]

\[
\text{Pr}[H \mid E, I] \propto \text{Pr}[E \mid H, I] \times \text{Pr}[H \mid I]
\]

Where does the expert sit in this process? What is her/his role and contribution?
An example – comparison of hand images

Images courtesy of Prof. Sue Black, Centre for Anatomy and Human Identification, University of Dundee

Image of the hand of the offender

• The hand that can be seen in the video is the left hand of the defendant

• The image of the hand is very likely to be that of the left hand of the defendant

• The hand seen in the video could be the left hand of the defendant

• The image of the hand is consistent with that of the defendant’s

The hand in the video is Mr A’s left hand.

Shirley McKie

Sir Anthony Campbell

Fingerprint Enquiry

• Takes away all uncertainty
• Authoritative and convincing
• Appears to be a good manifestation of true expertise

Benefits

• Can the categoric answer be justified:
  • Is it truly a deductive answer?
  • Is it a personal ‘conviction’?
  • May be implicit use of other information or evidence
  • BIAS! (e.g. confirmation bias)

Limitations

The scientist should not be asked his opinion on the likelihood that it was the defendant who left the crime stain …...

The scientist cannot give a reliable view on the likelihood that the semen came from a particular suspect because that likelihood depends not only on the scientific evidence but also on the other, non-scientific evidence …... of which the scientist may be unaware.

This guidance is correct for logical reasons
... and the logic applies to all forms of expert evidence!

The scientist should not be asked his opinion on the likelihood that it was the defendant who left the crime stain

"The scientist should not be asked his opinion on the likelihood that the glass fragments came from the window"

The accused kicked the victim

The defendant’s shoe left the mark

The recovered hair came from the victim

The image is that of Mr A’s left hand

The shoes had probably been in contact with petrol

The findings are consistent with the image being that of Mr A’s left hand.


R v Puca [2005] EWCA 3001

The State of Western Australia v Dair [2006] WADC 157

"Strengthening Forensic Science in the United States: A Path Forward’ NAS 2009

The degree of correspondence observed between the image of the hand in the video and the known image of Mr A’s left hand is far more probable (e.g., approx 100 times more probable) if the video image were truly that of Mr A’s left hand rather than of the hand of some other, unknown, person

The degree of correspondence ... provides (qualifier) support for a view that the video image is that of Mr A’s left hand rather than of the hand of some other, unknown, person

"The findings are approximately 100 times more probable (if..."

"The findings provide moderate support for the view that..."

Benefits

- Logical, balanced and robust, if based on appropriate propositions and on sound knowledge and understanding
- Allows combination of different pieces of evidence
- Helps in assessing whether sensible use of resources

Limitations

- Is it comprehensible to lay people, lawyers and police?
- Not liked by some - insufficient certainty; too ‘wishy-washy’
- Are there sufficient data/knowledge to help assess probabilities?
These formulations have implications for report-writing.

Ensure readers are aware of:
- the initial hypotheses and the prior probabilities
- the background information and expert knowledge (all part of 'I') that we have used to help generate hypotheses and inform their prior probabilities
- the background information and expert knowledge (all part of 'I') that we have used to assign values for probabilities of the evidence (E)

Ensure readers are aware of:
- the propositions given to you by the prosecution and defence
- the relevant background information (I) that we have used to inform probabilities of the evidence (E) given the two propositions
- the magnitude of the ratio of those two probabilities
- where that magnitude sits on verbal scale, if used
- the vital importance of the background information (I) and its influence on probabilities of the evidence
- on what basis (expert knowledge) we have assigned values for the conditional probabilities of E
‘Hierarchy of issues’

Specifying the questions we can address as forensic scientists may be one of the most important activities we do.

... and perhaps one of the most difficult aspects of forensic science.

The ‘Hierarchy’ provides a guiding structure.

What type of question is being asked?

**Evaluative**

... in a judicial context

Did he commit the **offence**?

Did he do the **activity**?

Is he/his item the source of the trace material?

What type of question is being asked?

**Investigative**

... in a judicial context

Did the defendant pour petrol from the can?

Did he commit arson?

Is the petrol at the scene the source of the ‘trace’ on the shoes?

What type of question is being asked?

**Investigative**

Was it arson?

Was flammable liquid poured through letter-box?

What is the source of the ‘trace’ at the scene?

Hierarchy of issues

Requires dialogue between scientist and client on which are the most important, the most useful, issues for the scientist to address to help resolve uncertainties for the police, lawyers, defendant, court.

After agreement on the issues to be addressed, propositions and their alternatives can be developed from those issues.

Hierarchy of issues

Hierarchy of propositions
This hierarchical approach to the issues in a case, together with the investigative/evaluative model, provides clarity on the issues being addressed... ...and therefore helps clarify and communicate the purpose of the scientific examination

For example, if evaluative:

The purpose of my examination has been to help address the issue of whether Mr A was the person who poured petrol through the letter-box.

For example, if investigative:

The purpose of my examination has been to answer the question of whether flammable liquid was poured through the letter-box. The purpose of my examination has been to provide suggestions for the type of flammable liquid used at the scene.

Structure of reports and statements maps over from the basic principles, reflecting the flow of a logical process

- What have I been told?
- What items have I been given?
- What am I trying to achieve?
- What techniques am I going to use; what results will I expect?
- What have I done; what have I found?
- What do the results mean?
- What’s the bottom line?


Circumstances

Include those, and only those, pieces of background information that:

1. help specify the issues (investigative and/or evaluative) and the propositions
2. influence our probability assignments for Pr(E|H_p) and Pr(E|H_n, I) and, if investigative, our priors

State clearly that our assessment and interpretation rely critically on these pieces of information (I)

E.g. This is the information I used to determine the examination strategy for this case and on which I relied when interpreting the results of the examinations. If any part of that information is wrong, or if any new information comes to light, I will need to reappraise my interpretation and conclusions.
The purpose of my examination has been to help address the issue of whether Mr A was the person who poured petrol through the letter-box.

The purpose of my examination has been to answer the question of whether flammable liquid was poured through the letter-box.

The purpose of my examination has been to provide suggestions for the type of flammable liquid used at the scene.

The findings provide very strong support for the view that it was Mr A, rather than some other person, who poured petrol through the letter-box.

Types of flammable liquid that could have been used at the scene include...

In my opinion, it is very likely that flammable liquid was poured through the letter-box.

Simple summary of result of interpretation

Relate to ‘Purpose’

If evaluative, express the magnitude of the likelihood ratio

If investigative, express as ‘explanations’ or as ‘best conjectures’, i.e. highest posterior probabilities

Report extracts kindly provided by Dennis McAuley

Conclusion

Interpretation

If evaluative, set out the propositions addressed and discuss probabilities for the observations: Pr[E|H1,I] and Pr[E|H2,I]

If investigative, present all feasible ‘explanations’ [H1|E,I], [H2|E,I] ...

WHERE APPROPRIATE, discuss Pr[E|H1,I], Pr[E|H2,I] ...

Pr[E|Hn,I] together with priors Pr[H1,I], Pr[H2,I] ... Pr[Hn,I] and posteriors Pr[H1|E,I], Pr[H2|E,I] ...

Opportunity for the expert to lead the readers/users through their thinking, share their knowledge in order to help them form their own views and reach their own conclusion.

Examples of ‘Purpose’

Evaluative

Investigative

Conclusion

Evaluation

Investigation

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In my opinion, the fire was caused by an external factor (most probably from a leaking tank) to the lower regions of the fire-damaged container. The resultant "hot-spot" on the inner surface of the side-wall (coincident with the lower area of external fire damage) ignited the container box closest to this high temperature source.

\[
\text{Pr}(H | E, I) = 1
\]

\[
\text{Pr}(H | E, I) = 0
\]

Does 'no support' mean:

- \( \text{Pr}(E | H_{\text{self}} | I) = \text{very low} \)

Or is it meant to imply:

- \( \text{Pr}(H | E, I) = \text{very low} \)

Fallacy of the transposed conditional

The opinion that a carelessly discarded cigarette caused the fire is highly unlikely, given that the double thickness cardboard boxes would not be susceptible to ignition by a cigarette. There was also no evidence of any cigarette butts within the container.

\[
\text{Pr}(H | E, I) = \text{very low}
\]

As stated, this opinion is a post. prob.

But, logically, posterior probability can only come from combining the prob. for the evidence \( \{ \text{Pr}(E | H_{\text{self}} | I) = \text{very low} \} \) and the prior probability for the event \( \{ \text{Pr}(H | E, I) = \text{very low} \} \).
Fire Investigators Association of Ireland, Dublin, 30 April 2014

Case Study – Suspicious death and fire

Case circumstances

• Fire Brigade called to a fire in a small, fenced-off yard late in the late evening
• Because of difficult access to the yard from the roadway, officers removed one concrete fence panel and directed jet of water to the fire among a small ‘pile of rubbish’
• Officers then became aware that the pile was a body

• Body was that of a 12-year old, local female, last seen about 18.45 that evening with a girlfriend
• Had been with her 17-year old boyfriend about 16.00 that day
• He says that was last time he saw her

Samples available

• Debris from under body
• Debris from second seat of fire
• Hair from near second seat of fire
• Remains of clothing from deceased

What are the questions/issues?

• What was the sequence of events?
• Was a flammable liquid used; if so, what type?
• Who did what?

Was a flammable liquid used; if so, what type?

Investigative

\[ \text{Pr}(H \mid E, I) \times \text{Pr}(E \mid H, I) \times \text{Pr}(H \mid I) \]

• Specify the question
• List all realistically possible hypotheses
• Estimate prior probabilities
• Consider prob. of observing the various outcomes of tests
• Do tests
• Multiply priors by the (previously estimated) probability of the test result
• Normalise to arrive at posterior probability

| Priors | Pr(E H | J) | Prior x Pr(E H | J) | Posteriors |
|--------|---------|----------------|------------|
| H1 Petrol | | | |
| H2 White spirit | | | |
| H3 Paraffin | | | |
| H4 Lighter fuel | | | |
| H5 Diesel | | | |
| H6 Something else | | | |
| H7 No accelerant | | | |
| 1 | 1 | 1 |

| Priors | Pr(E H | J) | Prior x Pr(E H | J) | Posteriors |
|--------|---------|----------------|------------|
| H1 Petrol | 0.4 | | |
| H2 White spirit | 0.2 | | |
| H3 Paraffin | 0.1 | | |
| H4 Lighter fuel | 0.08 | | |
| H5 Diesel | 0.001 | | |
| H6 Something else | 0.001 | | |
| H7 No accelerant | 0.218 | | |
| 1 | 1 | 1 |

• Values for prior probabilities are for illustrative purposes only and would not necessarily reflect the assignments of an expert

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### Was a flammable liquid used; if so, what type?

| H1 Petrol  | 0.4 | 0.03 | 0.102 |
| H2 White spirit | 0.2 | 0.04 | 0.048 |
| H3 Paraffin | 0.1 | 0.05 | 0.005 |
| H4 Lighter fuel | 0.08 | 0.01 | 0.007 |
| H5 Diesel | 0.001 | 0.01 | <0.001 |
| H6 Something else | 0.001 | 0.01 | <0.001 |
| H7 No accelerant | 0.218 | 0.01 | 0.018 |

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### Was a flammable liquid used; if so, what type?

| H1 Petrol  | 0.4 | 0.03 | 0.012 |
| H2 White spirit | 0.2 | 0.04 | 0.008 |
| H3 Paraffin | 0.1 | 0.05 | 0.001 |
| H4 Lighter fuel | 0.08 | 0.01 | 0.001 |
| H5 Diesel | 0.001 | 0.01 | <0.001 |
| H6 Something else | 0.001 | 0.01 | <0.001 |
| H7 No accelerant | 0.218 | 0.01 | 0.018 |

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### Who did what?

- Police believe that someone squirted BBQ lighter fuel over girl and ignited it by flicking lit matches at her; they suspect the boyfriend
- Boyfriend denies this and states he spilt turps on his shoes the day before
- Shoes taken 5 hours after incident

Judicial/Evaluative

- Identify the issue
- Set out the proposition and alternative
- Consider probability of observing all the various outcomes of the tests used (pre-assessment)
- Do the work
- Evaluate the likelihood ratio for the test outcome
- Convey the magnitude of the LR
Identify the issue: Did he squirt the fuel over her?

Judicial/Evaluative

\[ \frac{\Pr(E|H_2, I)}{\Pr(E|H_0, I)} \]

Develop the proposition and alternative:

- \( H_2 \): He squirted the fuel over her
- \( H_0 \): He did not squirt fuel; he split turps...

Set out probabilities for all outcomes of headspace analysis on shoes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>( \Pr(H_0) )</th>
<th>( \Pr(H_2) )</th>
<th>LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>No trace</td>
<td>0.005</td>
<td>0.005</td>
<td>1</td>
</tr>
<tr>
<td>'Weak' trace, paraffinic</td>
<td>0.25</td>
<td>0.01</td>
<td>25</td>
</tr>
<tr>
<td>'Strong' trace, paraffinic</td>
<td>0.7</td>
<td>0.005</td>
<td>140</td>
</tr>
<tr>
<td>Any other trace</td>
<td>0.045</td>
<td>0.98</td>
<td>1/22</td>
</tr>
</tbody>
</table>

- Values for probabilities for the evidence are for illustrative purposes only and would not necessarily reflect the assignments of an expert

Set out probabilities for all outcomes of the test

<table>
<thead>
<tr>
<th>Outcome</th>
<th>( \Pr(H_0) )</th>
<th>( \Pr(H_2) )</th>
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<tr>
<td>Any other trace</td>
<td>0.045</td>
<td>0.98</td>
<td>1/22</td>
</tr>
</tbody>
</table>

The findings provide moderately strong support for the view that he squirted the fuel over her rather than he did not (and...)

In summary

The principles of interpretation, including the use of the ‘hierarchy of issues’ and a scheme to classify expert opinion, help provide...

- clarity to the role and contribution of an expert
- ... that can be explained to, and developed with, users
- clear guidance on the data and knowledge required for each type of opinion
- the means with which to test and challenge opinions!
- pointers to the structure and content of reports
Thanks for your attention
Hope you found it interesting and useful