Technology Transition Workshop| *Paul Chamberlain*

Probability and Forensic Science

Overview

- **In this presentation we are going to introduce some basic probability concepts**
- **We will focus only on those ideas you will need to appreciate the fingerprint probability software**

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What is Probability?

- **In any forensic science investigation we need to deal with uncertainty**
- **How likely is it that the recovered trace came from the suggested source?**
  - **Fibres from a coat**
  - **Paint on a jacket**
  - **Hair from an individual**

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What is Probability?

- **We need a way of assessing the likelihood of a specific event**
- **Given the use to which our assessment is being put, it is desirable that our assessment is not wholly based on intuition**
- **Is there a way in which we can do this?**

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What is Probability?

- **Science of statistics refers to two distinct but linked areas of knowledge**
  - **Counts, analysis of events, etc.**
  - **Examination of uncertainty**
- **We are interested in the second of these**

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What is Probability?

- We can define two types of probability
  - Aleatory: deduce from observation of a system
    - Ideal
  - Epistemic: induce from observation of a system
    - Real

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What is Probability?

- **Deduction**
  - **Conclusion from stated premises: from the general to the specific**
- **Induction**
  - **Deriving general principles from facts or instances: specific to the general**

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What is Probability?

- **Probability is a branch of mathematics and therefore mathematical language is used**
- **Here we are going to simplify the ideas**
  - **We will keep the use of mathematical nomenclature and formulae to the minimum**

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What is Probability?

- "First Law of Probability"
  - Probability *(Pr)* can take any value between 0 and 1
    - Where 1 = certainty
    - Where 0 = impossible

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What is Probability?

- We can think of probabilities as odds
  - 1/10
  - 1/1000
  - 2/3
- Which is the same as
  - 0.1
  - 0.001
  - 0.67

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What is Probability?

- "Second law of probability"
  - The sum of the probabilities of mutually exclusive events equals 1

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What is Probability?

- Real probabilities are induced by observation
- Realist interpretation is concerned with frequencies and numbers of outcomes

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What is Probability?

- Let's think about the rolling of a die
- What is the probability of rolling a 6 with one die?
  - 1/6
- How did we calculate this?

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What is Probability?

$$\frac{\textbf{Number of events being considered}}{\textbf{Number of possible events}}$$

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What is Probability?

- **To calculate this probability we have made an assumption**
- **We have accepted the die to be fair**
- **This is unlikely to be the case in the real world**
- **We have created a simple model**

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What is Probability?

- **Of course any assumptions we make will affect our assessment of the probability**
- **If our assumptions are wrong then our outcome will be wrong**

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What is Probability?

- **What about rolling a 6 on each on two fair dice?**
  - **1/36**
- **How did we arrive at this?**
- **Did we make any assumptions?**

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What is Probability?

- **Multiplied the odds for each event**
- **Assumed that one die does not influence the other; the events are independent**

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What is Probability?

- How about tossing a coin?
- How likely is it to toss a head with one coin?
  - ½
- Again we assume the coin is fair
- We have created a model

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What is Probability?

- How accurate are models?
- If the coin model is accurate, we would expect to see the distribution of outcomes predicted in the long run
- Comte de Buffon, Karl Pearson and John Kerrich
  - Close to ½ with approximately 4000, 24,000 and 10,000 throws, respectively

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What is Probability?

- **In forensic science we are generally concerned with the likelihood of one specific event**
- **Is it possible to speak of the probability of a single event?**

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What is Probability?

- Consider our answer to rolling a 6 with a single die
- There is no physical state of affairs which corresponds to a probability of 1/6 for a single event
  - It either happens or it doesn't!

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What is Probability?

- **To quantify a probability for a single event it needs to be conceived of as a product of the mind**
- **This has been called subjective probability[1]**

[1] O'Hagan 2004

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What is Probability?

- **Subjective Probability is informed by**
  - **Empirical observations**
  - **Beliefs**
- **We need to be careful of the word subjective because we are not implying that the probability is unfounded**

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What is Probability?

- **What is the probability it will rain tomorrow?**
- **How might we arrive at that decision?**
  - **Weather today, yesterday, this week, etc.**
  - **Month**
  - **Season**
  - **Last year**
  - **Etc.**

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What is Probability?

- **For each of these factors we can make a statement:**
  - **If rained yesterday, it always rains in April**
  - **Etc.**

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What is Probability?

- **Given the use of forensic science, this has some limitations**
  - **How do we get consistency?**
  - **How do we get reproducibility?**
- **What if we assign numerical probability to each of these pieces of information?**

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What is Probability?

- A way of doing this is to consider two competing propositions for a particular event and then assess the probability of the observations in each case
- We can then calculate a Likelihood Ratio (LR)

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What is Probability?

- **In forensic science we can frame propositions like these to consider trace evidence:**
  - **What is the probability of the observations we have made (E) if the prosecution hypothesis (H_p) is correct and the suspect did leave the trace?**
  - **What is the probability of the observations we have made (E) if the defense hypothesis (H_d) is correct and the trace was left by a random other person?**

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What is Probability?

- **In mathematical language the Likelihood Ratio (LR) is:**

$$LR = \frac{P_r(E \mid H_p)}{P_r(E \mid H_d)}$$

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What is Probability?

- **Let's assume that the probability of making one particular observation if the prosecution hypothesis (H_p) is correct is 0.9**
- **Therefore, the probability of making the same observation if H_d is true is 0.1**
- **What is the LR?**

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What is Probability?

- **LR = 9**
- **A LR which is greater than 1 indicates that the observations are more likely if H_p is true than H_d**

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What is Probability?

- **Now let's assume that the probability of making one particular observation if the prosecution hypothesis H_p is correct is 0.5**
- **Therefore, the probability of making the same observation if H_d is true is 0.5**
- **What is the LR?**

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What is Probability?

- **LR = 1**
  - **This means the evidence is of no assistance**
  - **It is equally likely to make the observations in each case**

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What is Probability?

- **Finally, if the probability of the observations in the case of H_p is 0.2**
- **And H_d is 0.8**
- **What is the LR?**

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What is Probability?

- **LR = 0.25**
- **A LR which is less than 1 indicates that the observations are more likely if H_d is true than H_p**

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What is Probability?

- **The greater the LR, the greater the support for the prosecution proposition**
- **If the LR is 1 then the examination is of no assistance**
- **If the LR is less than 1 then it supports the defense proposition**

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What is Probability?

- We can articulate LR as numbers, through graphs or diagrams, or by relating to a verbal scale
- Each of these approaches has benefits and issues
- In this workshop we will use a verbal scale such as this:

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What is Probability?

LR	
$>10^6$	Extremely strong
10^5 - 10^6	Very Strong
10^3 - 10^5	Strong
10^2 - 10^3	Moderate
>1 - 10^2	Limited

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What is Probability?

- **Let's consider a very simple example to explain these numbers**

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What is Probability?

- **Let's evaluate the probability of observing a correspondence if H_p is true as 0.99999999**
- **Therefore, the probability for H_d is 0.00000001**

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What is Probability?

$$\text{LR for this scenario} = \frac{0.99999999}{0.00000001} = 9.9 \times 10^7$$

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What is Probability?

- **Referring to our verbal scale, we would call this extremely strong evidence**

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What is Probability?

- **Why use a LR?**
  - **It provides a versatile and simple measure**
  - **It allows evidence to be combined and evaluated**
- **Bayes Theorem**

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What is Probability?

- Posterior odds of C = likelihood ratio of the evidence (E) x prior odds of C
- What you want to know = what you calculate x what you already know

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What is Probability?

- In the next sessions we will take these ideas and see how we can apply them to fingerprint examination

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Questions?

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