Forensic Science for Biometricians

Geoffrey Stewart Morrison

Aston University

- This presentation provides a brief introduction to evaluation of strength of forensic evidence and validation of forensic analysis systems.
- The presentation assumes and is tailored for an audience familiar with signal-processing biometrics such as finger, face, and speaker recognition.

Biometrics

- Modes:
  - automatic fingerprint identification
  - automatic face recognition
  - automatic speaker recognition

- Applications:

– security	yes / no?
– intelligence	threshold exceeded?
– investigative	top *n* from database searched
– forensic evaluation	strength of evidence

Biometrics

- Other applications:
  - score
  - threshold
  - binary decision

- Forensic evaluation:
  - score
  - forensic scientist does not apply a threshold or make a decision
  - likelihood ratio answering a specific question of interest to the court

Forensic evaluation

- Likelihood ratio framework:

  – Association of Forensic Science Provider in the United Kingdom and Republic of Ireland 2009 Standards for the formulation of evaluative forensic science expert opinion

  – European Network of Forensic Science Institutes 2015 Guideline for evaluative reporting in forensic science

  – 2016 report by President Obama's Council of Advisors on Science & Technology

Forensic evaluation

posterior odds

$$\frac{\mathrm{p}(\text{ same speaker} \mid \text{acoustic properties } x_1, x_2 \text{ })}{\mathrm{p}(\text{ different speaker} \mid \text{acoustic properties } x_1, x_2 \text{ })}$$

$$=$$

$$\frac{\mathrm{p}(\text{ acoustic properties } x_1, x_2 \mid \text{same speaker })}{\mathrm{p}(\text{ acoustic properties } x_1, x_2 \mid \text{different speaker })} \times \frac{\mathrm{p}(\text{ same speaker })}{\mathrm{p}(\text{ different speaker })}$$

likelihood ratio ***prior odds***

Forensic evaluation

responsibility of trier of fact

posterior odds

$$\frac{p(\text{ same speaker } \mid \text{ acoustic properties } x_1, x_2\ )}{p(\text{ different speaker } \mid \text{ acoustic properties } x_1, x_2\ )}$$

$$=$$

$$\frac{p(\text{ acoustic properties } x_1, x_2 \mid \text{ same speaker }\ )}{p(\text{ acoustic properties } x_1, x_2 \mid \text{ different speaker }\ )} \times \frac{p(\text{ same speaker }\ )}{p(\text{ different speaker }\ )}$$

likelihood ratio ***prior odds***

responsibility of forensic scientist

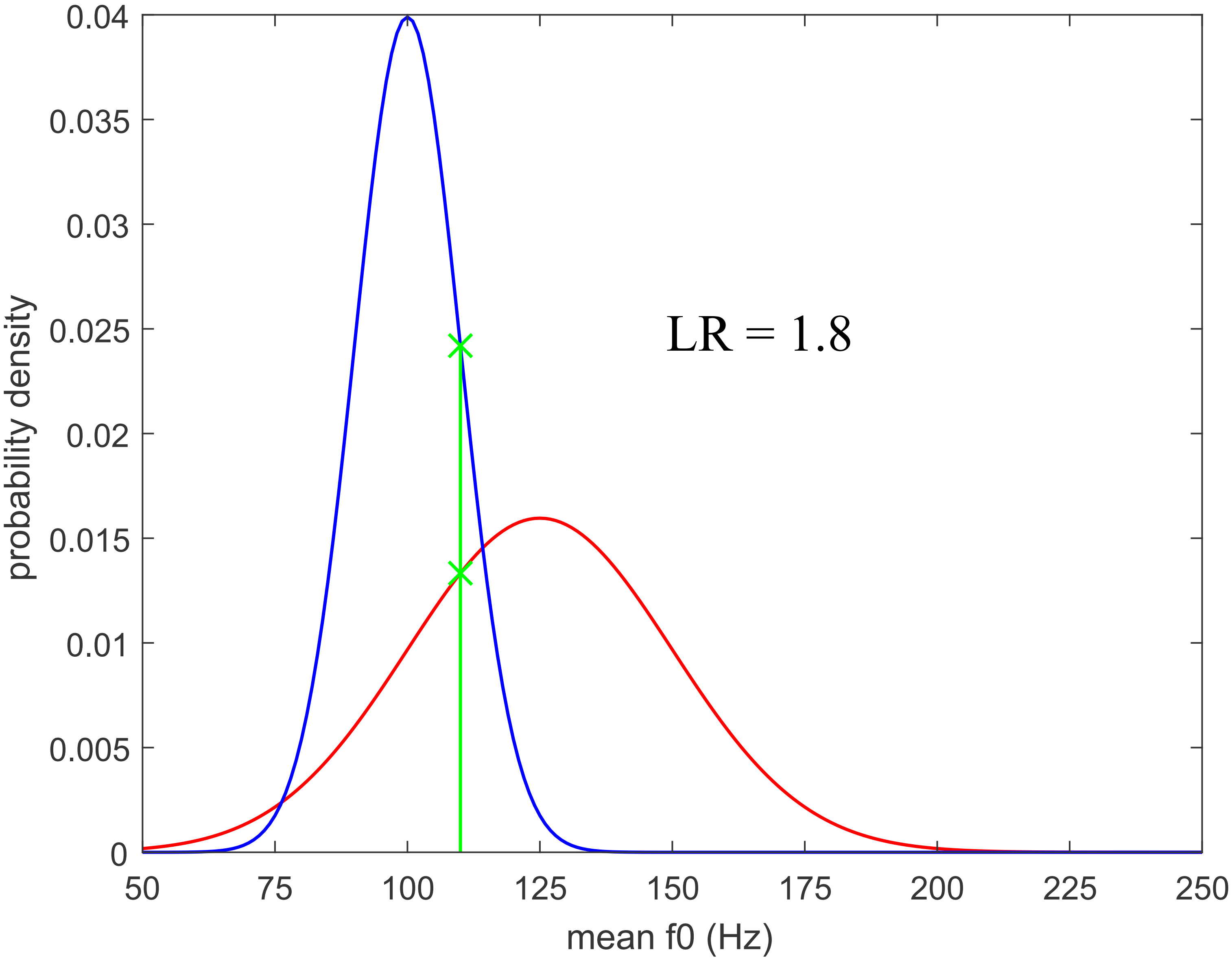
Forensic evaluation

- Likelihood ratio value will only be meaningful if the trier of fact understands the question that it answers, and that question is a question of interest for the court.

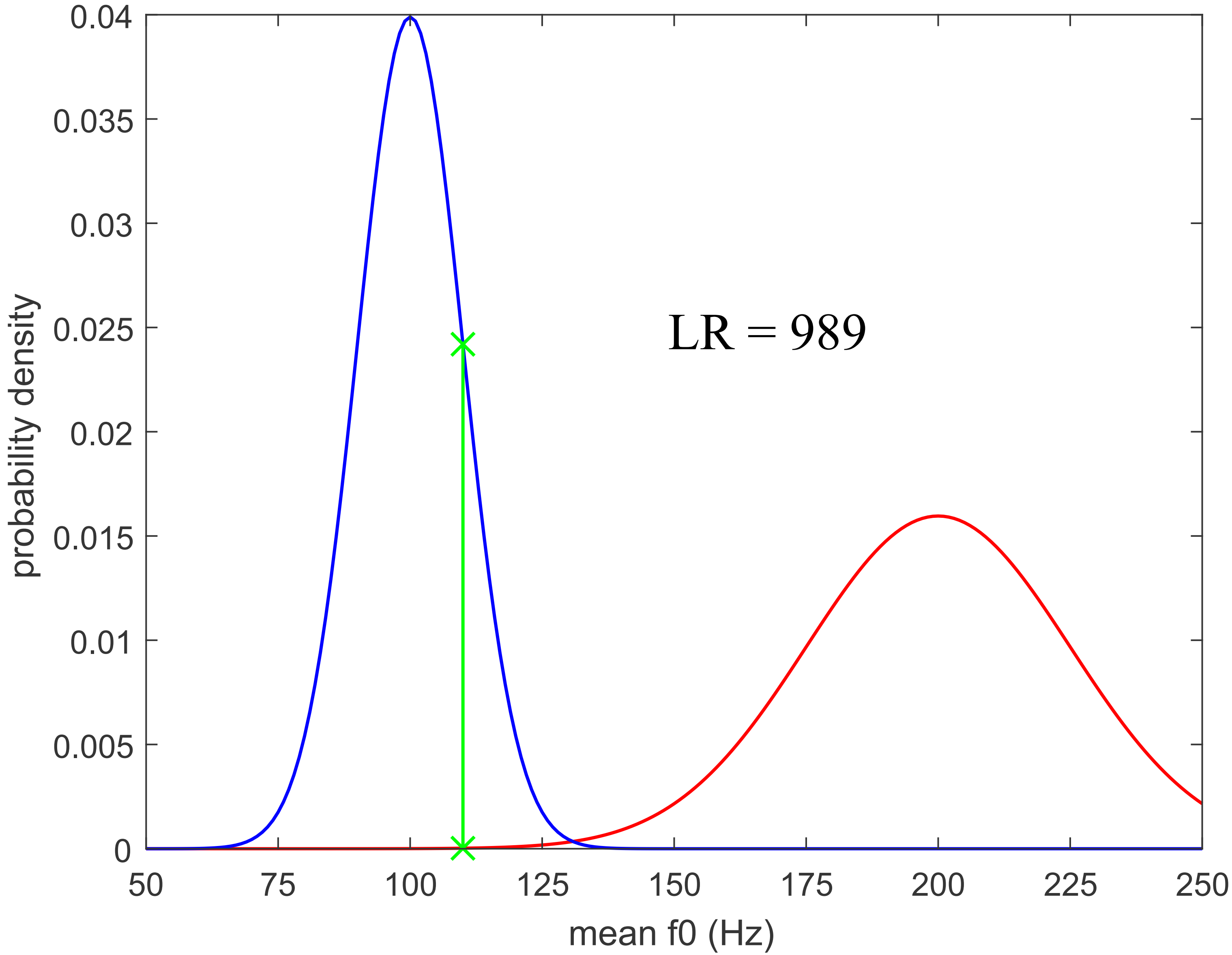
$$\frac{p(\ E \mid H_{\text{same-origin}}\ )}{p(\ E \mid H_{\text{different-origin}}\ )}$$

Probability of acoustic properties of questioned-speaker recording if it were spoken by the known speaker versus if it were spoken by some other speaker selected at random from the relevant population.

Relevant population



Relevant population



Forensic evaluation

- The forensic scientist must carefully explain to the court what question the forensic scientist has set out to answer
  - the court can decide if it is a relevant question
  - the trier of fact can understand the answer

Forensic evaluation

- The forensic scientist must carefully explain to the court what data the forensic scientist has used to calculate the denominator of the likelihood ratio

  – the court can decide whether the data are sufficiently representative of the relevant population

Aside

- The statistical models use for calculating the likelihood ratio should be generative models that actually calculate the ratio of two likelihoods or discriminative models that are analogous with such generative models

  – Gaussian mixture models

  – logistic regression (analogous with linear discriminant analysis)

Validation

- A rigorous application of US Federal Rules of Evidence 702 and the criteria established by the Supreme Court in *Daubert*, *Joiner*, and *Kumho Tire*

- A rigorous application of England & Wales Criminal Practice Directions 19A

  – would require empirical validation under conditions reflecting those of the case under investigation

Validation

- See also:

  – 2016 report by President Obama’s Council of Advisors on Science & Technology

  – Forensic Science Regulator of England & Wales 2014 Guidance on validation

  – European Network of Forensic Science Institutes 2015 Methodological guidelines for best practice in forensic semiautomatic and automatic speaker recognition

Validation

- The forensic scientist must carefully explain to the court what data the forensic scientist has used to test the performance of the forensic analysis system

  – the court can decide whether the data are sufficiently reflective of the conditions of the case that the test results will be meaningful indicators of the performance of the system under the conditions of the case

  – the court can decide whether the performance of the system under those conditions is good enough

Aside

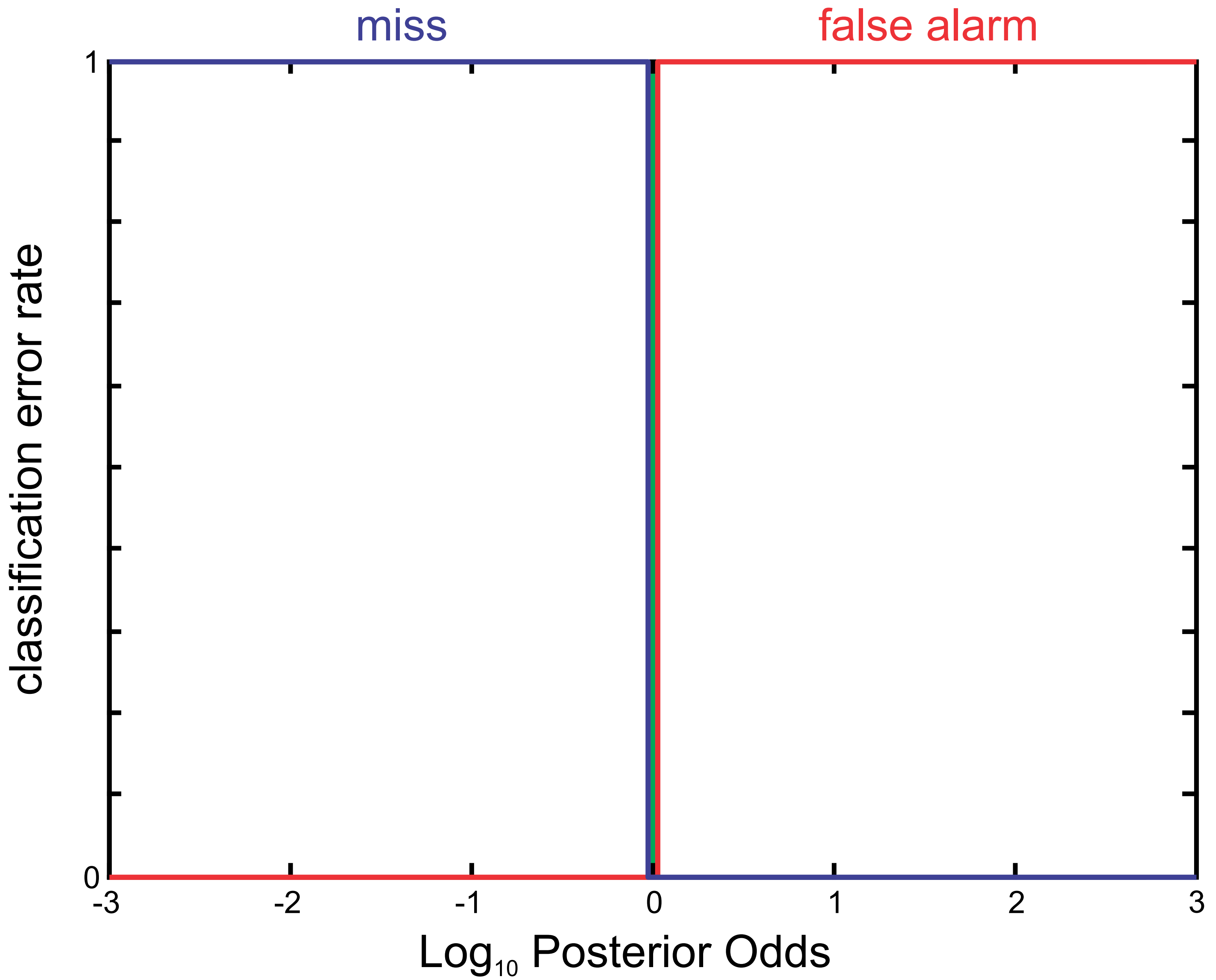
- The training data should also reflect the conditions of the case
  - in other applications the system has to be generalizable
  - in a forensic application only one trial matters: the comparison of the actual known-origin sample and questioned-origin specimen

Validation

- Correct-classification / classification-error rate is not appropriate
  - based on posterior probabilities
  - hard threshold rather than gradient

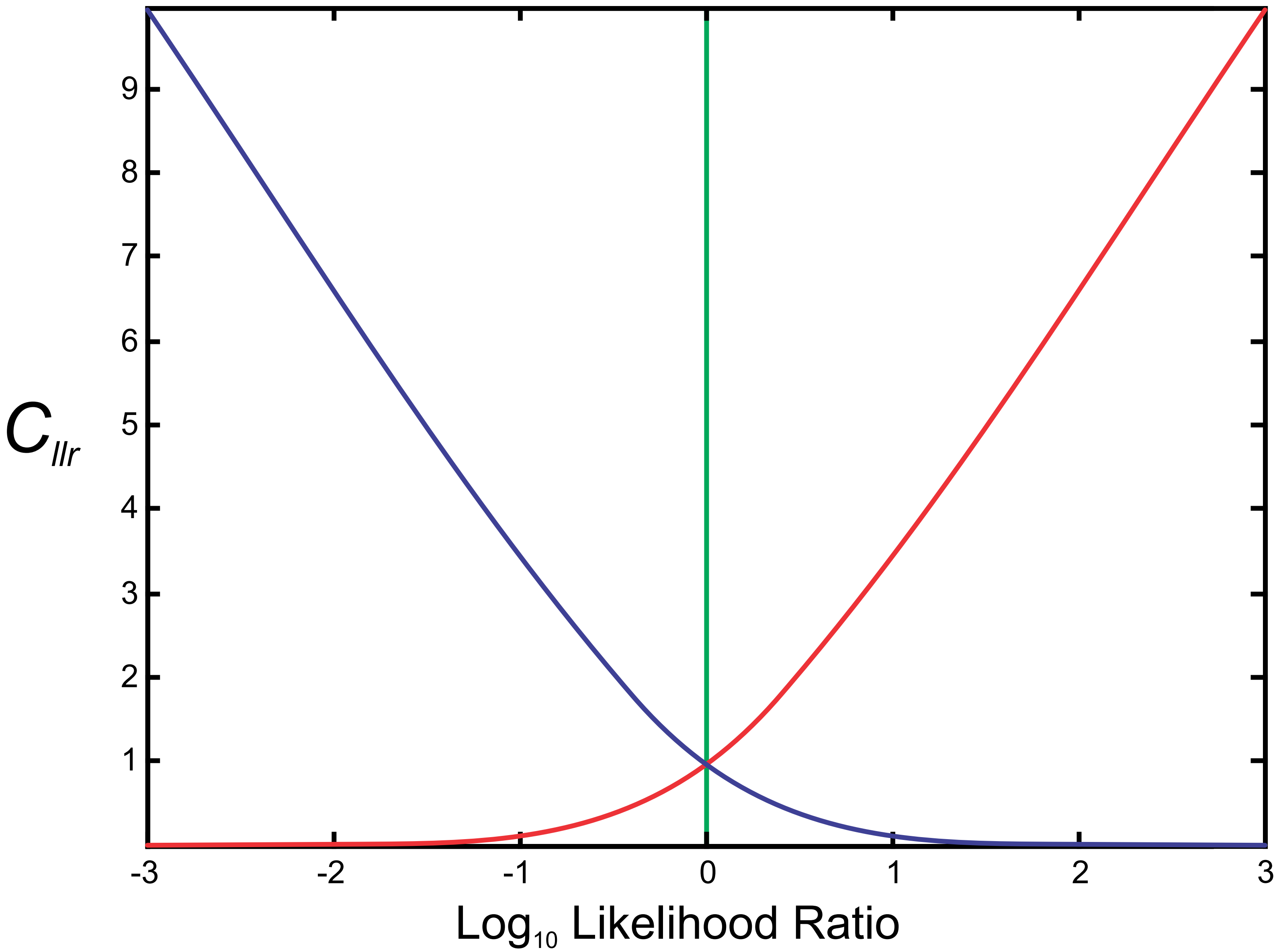
	decision	
fact	same	different
same	correct acceptance	false rejection
different	false acceptance	correct rejection

Validation



miss
false alarm
1
0
classification error rate
-3
-2
-1
0
1
2
3
Log10 Posterior Odds

Validation



Conclusion

- No binary decisions
- Likelihood ratio answering a specific question
- Question asked and data used to answer question must be communicated to court
- Empirical validation using data that reflect the conditions of the case
- Validation metrics consistent with the likelihood ratio framework

Thank You

http://geoff-morrison.net/