5th European Academy of Forensic Sciences

8th – 11th September 2009
Glasgow, Scotland, UK

Grzegorz Zadora[1], Daniel Ramos[2]

Evaluation of evidence value of refractive index – influence of selection of proper database

1) *Institute of Forensic Research, Krakow, Poland*

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Escuela Politecnica Superior,Universidad Autonoma de Madrid, Spain

Glass analysis for forensic purposes

SEMQuant results. Listed at 13:59:03 o
Operator: Z. Brozek-Mucha
Client: none
Job: szklo krzywa kalibracja
Spectrum label: icb005x 22

System resolution = 105 eV

Quantitative method: ZAF (4 iteration
Analysed all elements and normalised

Standards :

O K	Quartz 01/12/93
Na K	Albite 02/12/93
Al K	Al2O3 23/11/93
Si K	Quartz 01/12/93
K K	MAD-10 02/12/93
Pb M	PbF2 01/12/93

Elmt	Spect. Type	Element %	Atomic %
O K	ED	43.12	64.57
Na K	ED	5.22	5.44
Al K	ED	0.64	0.57
Si K	ED	27.87	23.77
K K	ED	6.00	3.68
Pb M	ED	17.15	1.98
Total		100.00	100.00

* = <2 Sigma

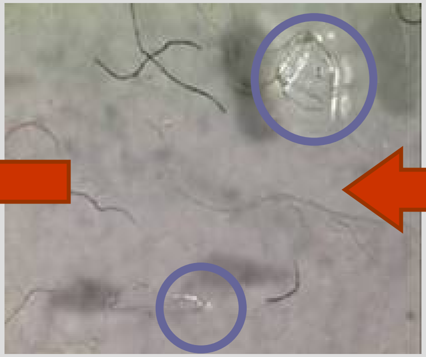
<0.2mm

Glass analysis for forensic purposes

RI_b – refractive index measured before annealing process

RI_a – refractive index measured after annealing process

$$\Delta RI = \left(RI_a - RI_b\right)$$

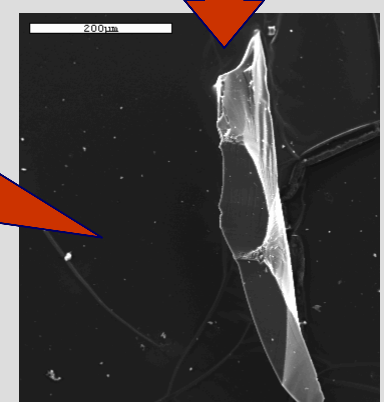


<0.2mm

Glass analysis for forensic purposes - comparison problem

Could they have come from the control sample?

Control sample



Recovered sample

Likelihood ratio

Important factors

Similarity of compared objects (evidence and control material).

Information about the rarity of physico-chemical properties determined for compared samples in the relevant population.

Sources of analytical errors: within and between source variability.

$$LR = \frac{Pr\left(E \mid \theta_p\right)}{Pr\left(E \mid \theta_d\right)}$$

$LR > 1$ **- support the prosecutor hypothesis H_p** $Pr\left(E \mid \theta_p\right) > Pr\left(E \mid \theta_d\right)$

$LR = 1$ **- support neither** $Pr\left(E \mid \theta_p\right) = Pr\left(E \mid \theta_d\right)$

$LR < 1$ **- support the defence hypothesis H_d** $Pr\left(E \mid \theta_p\right) < Pr\left(E \mid \theta_d\right)$

The larger (the lower) the LR value, the stronger the support for θ_p (θ_d)

LR – two levels of variation

Univariate data (RI) - normal distribution

$$LR \cong \frac{m^{1/2}\tau}{2^{1/2}\sigma}\exp\left\{-\frac{m(\bar{x}-\bar{y})^2}{4\sigma^2}\right\}\exp\left\{\frac{(z-\mu)^2}{2\tau^2}\right\}$$

LR NOR

Univariate data (RI) - kernel density estimation

$$LR = \frac{K\exp\left\{-\frac{(\bar{x}-\bar{y})^2}{2a^2\sigma^2}\right\}\sum_{i=1}^{k}\exp\left\{-\frac{(m+n)(w-r_i)^2}{2\left[\sigma^2+(m+n)s^2\lambda^2\right]}\right\}}{\sum_{i=1}^{k}\exp\left\{-\frac{m(\bar{x}-r_i)^2}{2\left(\sigma^2+ms^2\lambda^2\right)}\right\}\sum_{i=1}^{k}\exp\left\{-\frac{n(\bar{y}-r_i)^2}{2\left(\sigma^2+ns^2\lambda^2\right)}\right\}}$$

LR KDE

Glass analysis for forensic purposes

Evidence evaluation using LR values is related with the use of population databases as evaluation of evidence value requires process of the assessment of the rarity of the evidence and this information is also used in the aim of evaluation of between-object variability.

Therefore, the selection of a proper database (relevant population) is one of the crucial points during evaluation of evidence value of physicochemical data.

Glass analysis for forensic purposes - experiments

55 

82 

Background: 

Samples: 

Experiment ID: pl pl

Samples: 

Experiment ID: pl uk

Background: 

Samples: 

Experiment ID: ww

Samples: 

Experiment ID: wp

Glass analysis for forensic purposes - experiments

55  

56 

Background: 

Samples:  

Samples: 

Experiment ID: pw

Experiment ID: pp

Background:  

Samples:  

Samples: 

Experiment ID: ww

Experiment ID: wp

Glass analysis for forensic purposes - experiments

Same-source experiments

Fragments from sample A

Recovered sample

results from 2 fragments

Control sample

results from 2 fragments

Excpected: Support to the correct hypothesis: $LR > 1$

Misleading evidence: Support to the wrong hypothesis: $LR < 1$

Glass analysis for forensic purposes - experiments

Different-source experiments

Fragments from sample A

Control sample

All 4 fragments

Fragments from sample B

Recovered sample

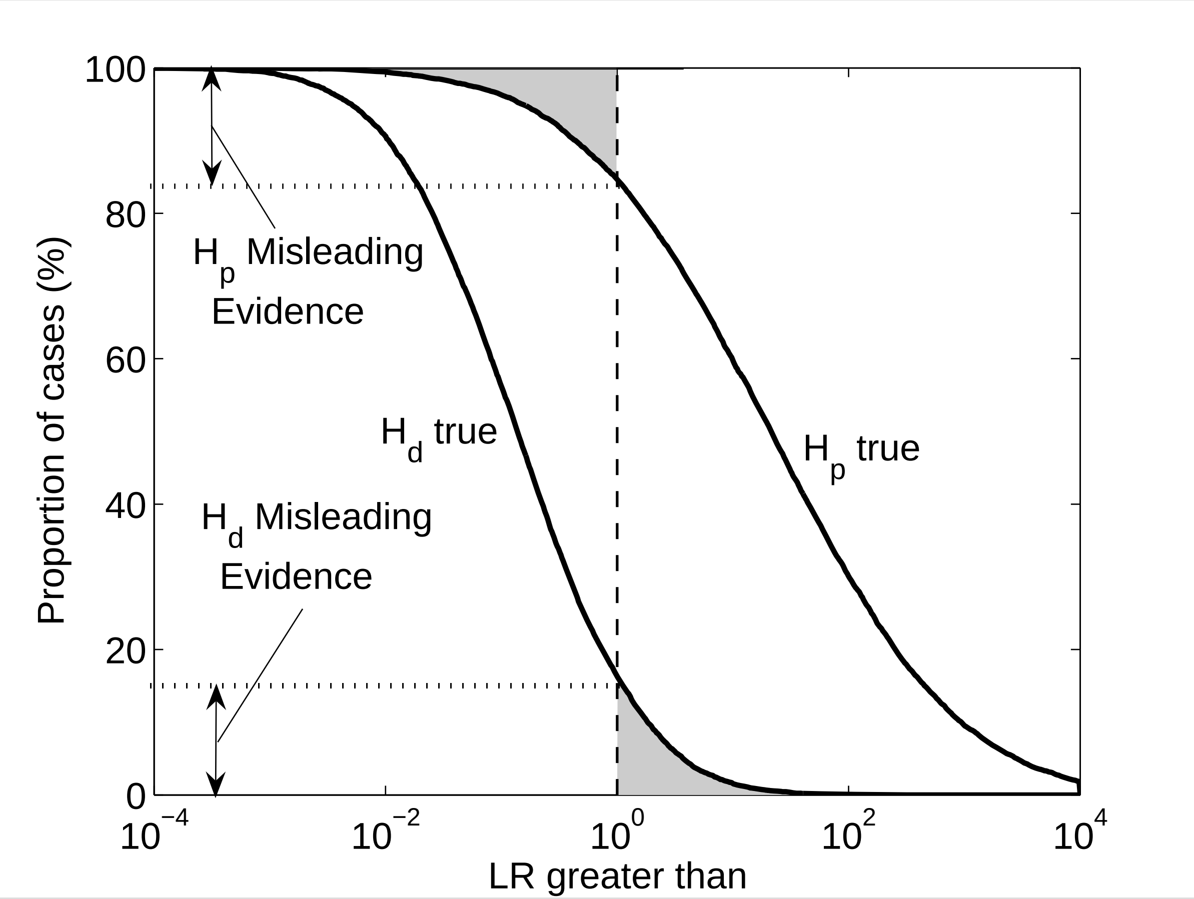
All 4 fragments

Excpected: Support to the correct hypothesis: $LR < 1$

Misleading evidence: Support to the wrong hypothesis: $LR > 1$

Glass analysis for forensic purposes

LR distributions and rates of misleading evidence



Glass analysis for forensic purposes - accuracy

- The LR has a *meaning* by itself
  - *Degree of support* to the previous opinion
  - LR is the weight of the evidence *E*

$$\frac{Pr(\theta_p)}{Pr(\theta_d)} \cdot \frac{Pr(E|\theta_p)}{Pr(E|\theta_d)} = \frac{Pr(\theta_p|E)}{Pr(\theta_d|E)}$$

Prior odds

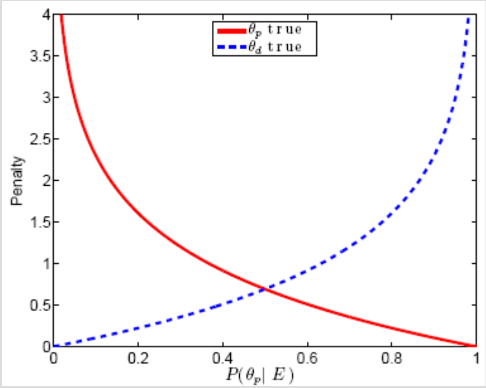
Likelihood ratio

Posterior odds

- Inferred posterior probabilities must be accurate
- But what's accuracy?

Empirical Cross-Entropy (ECE): evidence evaluation performance

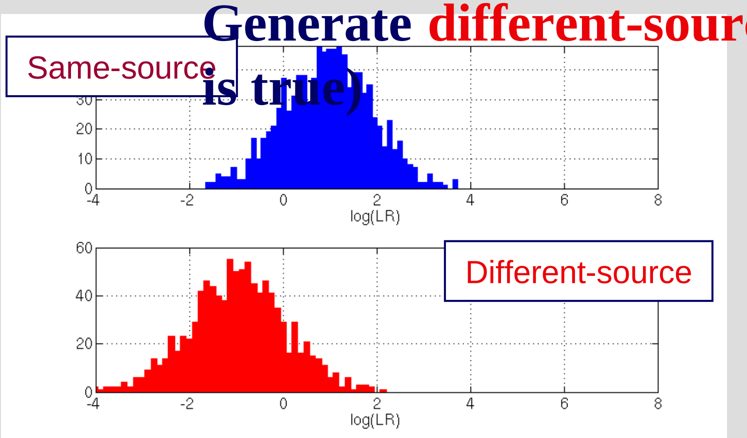
***ECE* is the prior-weighted average value of a strictly proper scoring rule**



Empirical approach: experimental test

Generate same-source comparisons (*θp* is true)

Generate different-source comparisons (*θd* is true)



$$ECE = -P(\theta_p)\frac{1}{N_p}\sum_{j\in\text{same-source}}\log_2 P(\theta_p|e_j) - P(\theta_d)\frac{1}{N_d}\sum_{j\in\text{diff-source}}\log_2 P(\theta_d|e_j)$$

1) It depends on the prior. The forensic scientist cannot compute its value.
2) Solution: the *ECE* plot. Prior-dependent representation.

Daniel Ramos (2007), *Forensic Evidence Evaluation Using Automatic Speaker Recognition Systems*, Ph.D. Thesis, Dept. of Computer Science, Univ. Autonoma de Madrid.

D. Ramos, J. Gonzalez-Rodriguez, G. Zadora, J. Zieba-Palus and C. G. G. Aitken (2007), *Information-theoretical comparison of likelihood ratio methods of forensic evidence evaluation*, Proceedings of International Workshop on Computational Forensics (in IAS 2007), pp. 411-416.

Empirical Cross-Entropy (ECE): evidence evaluation performance

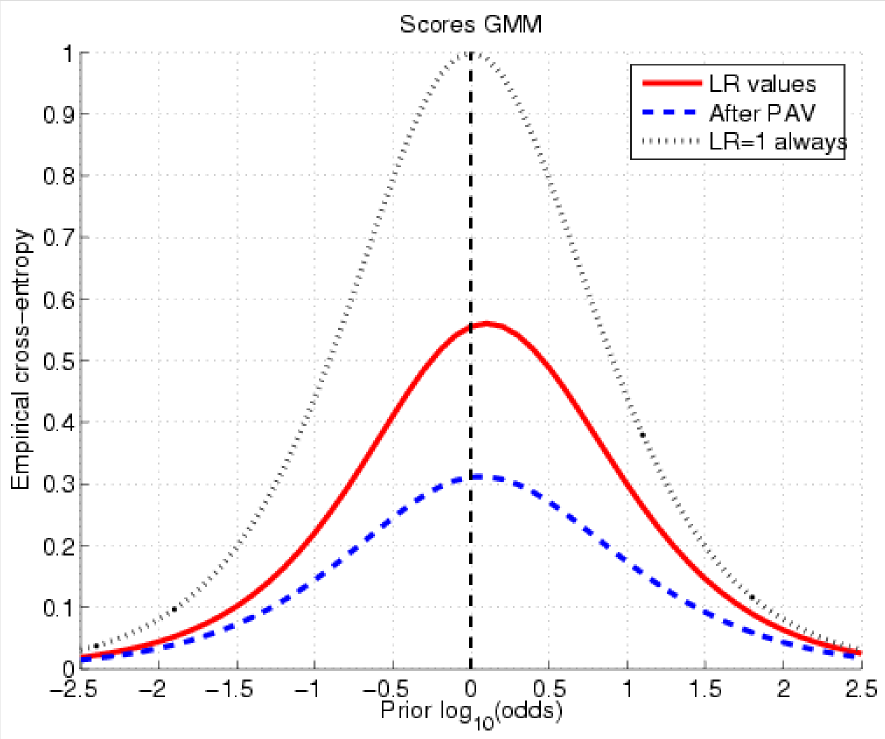
ECE curve (solid): overall performance

The higher its value, the worse the method

Calibrated (dashed): discriminating power

Difference among ECE and Calibrated is the *calibration* performance

Neutral, always LR=1 (doted): a method that does not take into account the evidence

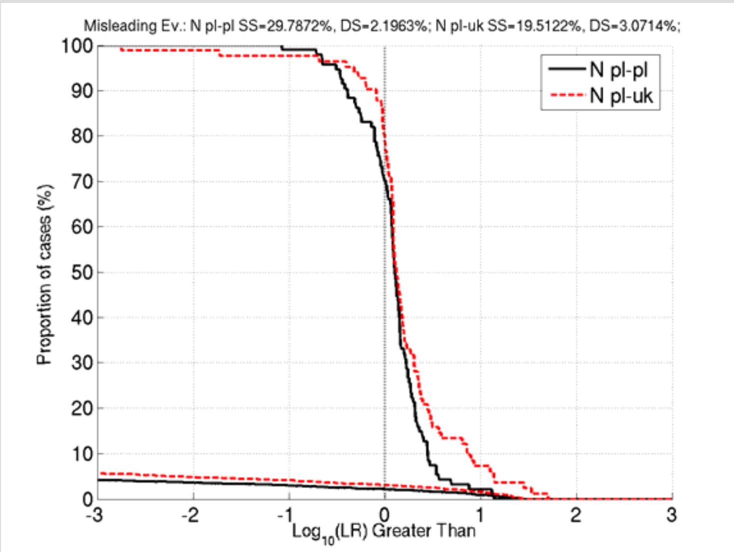


Glass analysis for forensic purposes - results

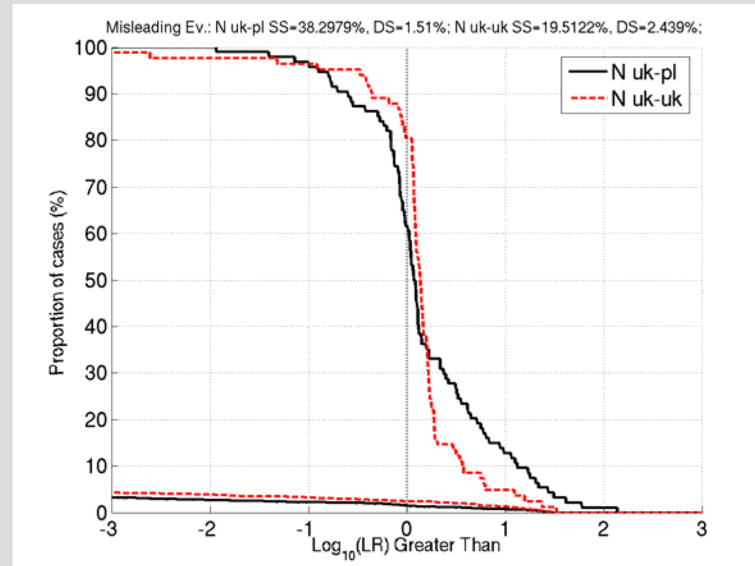
Background: 

Variable: RIb

Background: 



LR NOR



	False +ve	False -ve
Samples: 	2.2%	29.7%
Samples: 	3.1%	19.5%

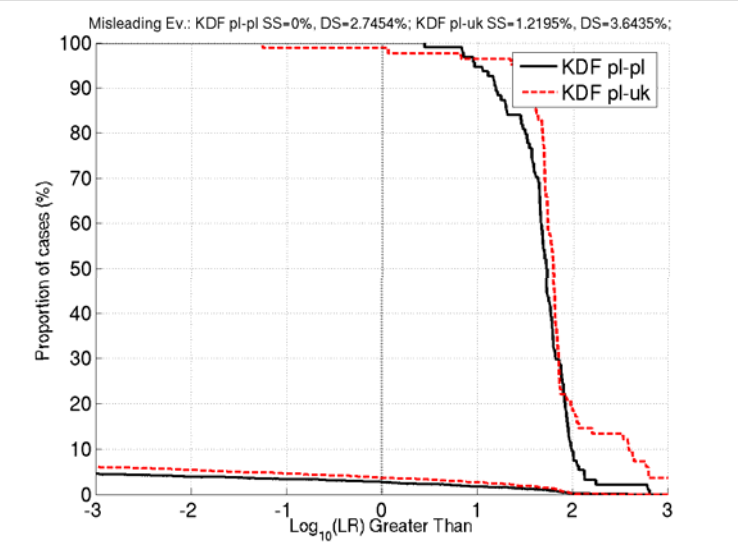
	False +ve	False -ve
Samples: 	1.5%	38.3%
Samples: 	2.4%	19.5%

Glass analysis for forensic purposes - results

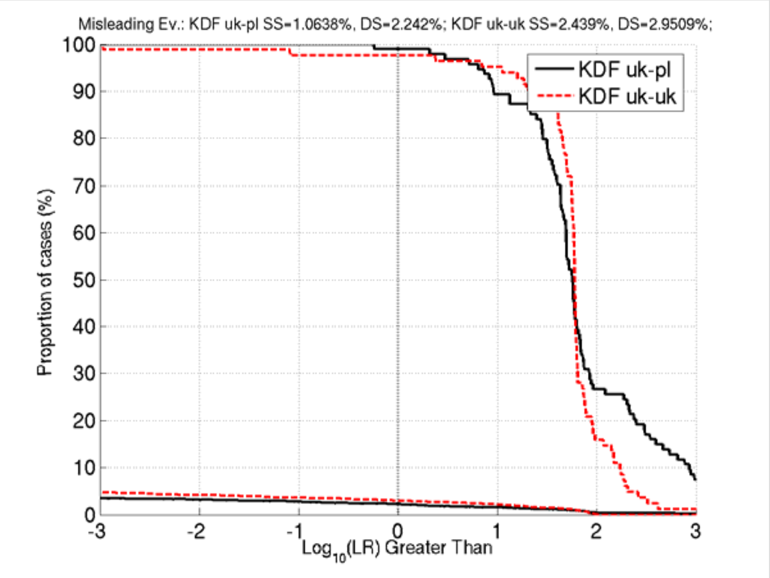
Background: 

Variable: RIb

Background: 



LR KDE



	False +ve	False -ve
Samples: 	2.7%	0.0%
Samples: 	3.6%	1.2%

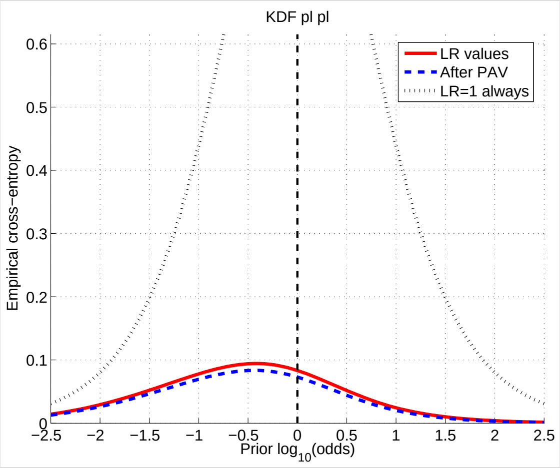
	False +ve	False -ve
Samples: 	2.2%	1.1%
Samples: 	3.0%	2.4%

Glass analysis for forensic purposes - results

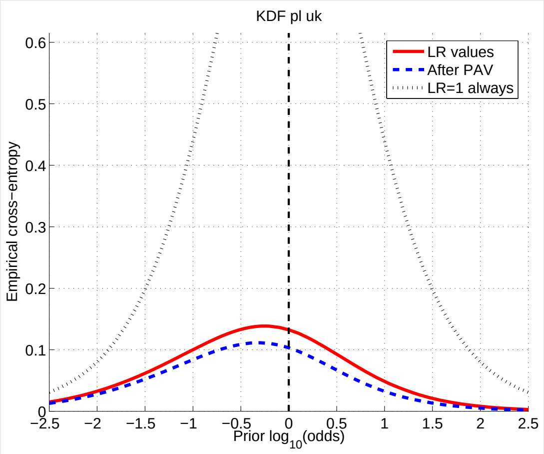
Samples: 

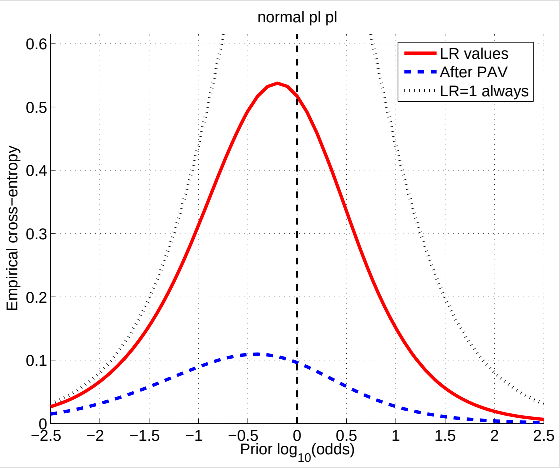
Background: 

Samples: 

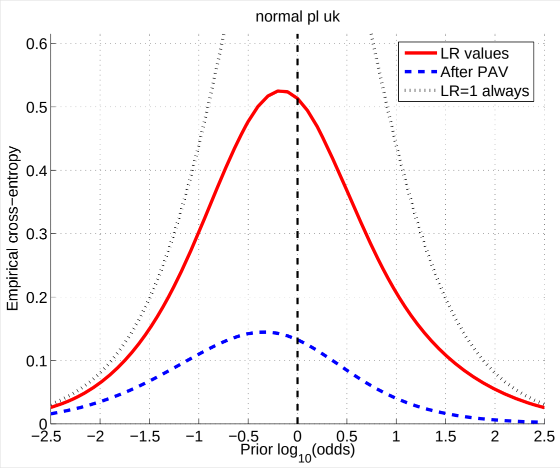


LR KDE





LR NOR

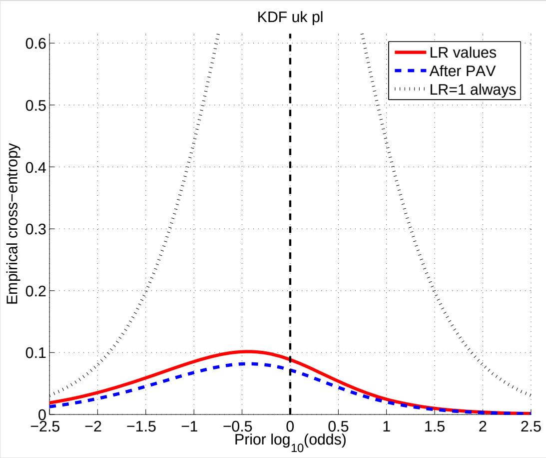


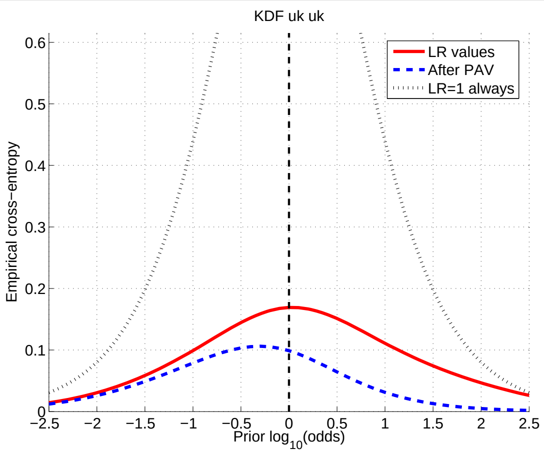
Glass analysis for forensic purposes - results

Background: 

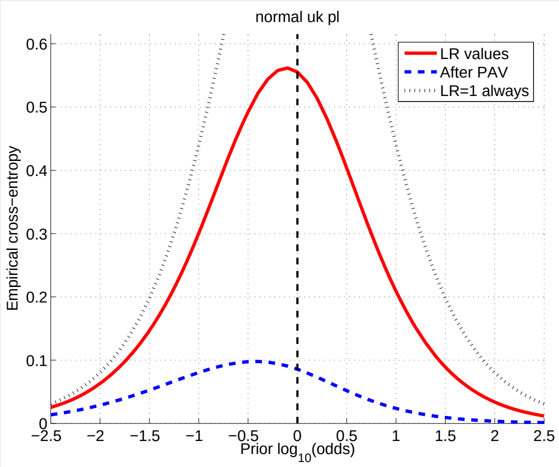
Samples: 

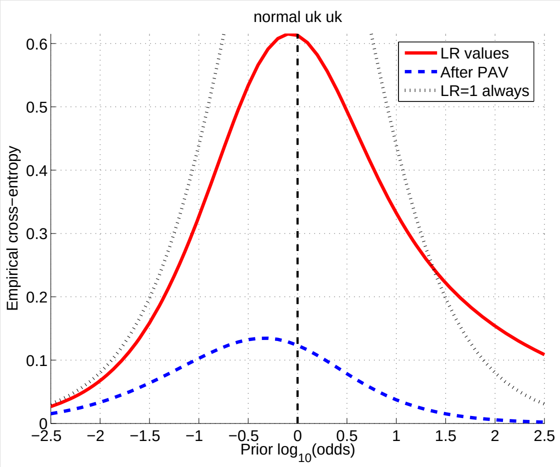
Samples: 





LR KDE





LR NOR

Glass analysis for forensic purposes - conclusion

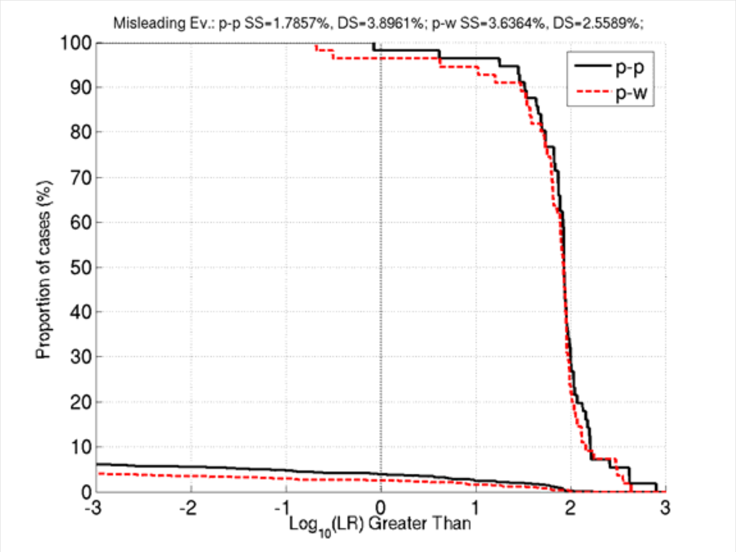
1) RIb variable seems quite robust to the variation among Polish and British float glass databases.

Glass analysis for forensic purposes - results

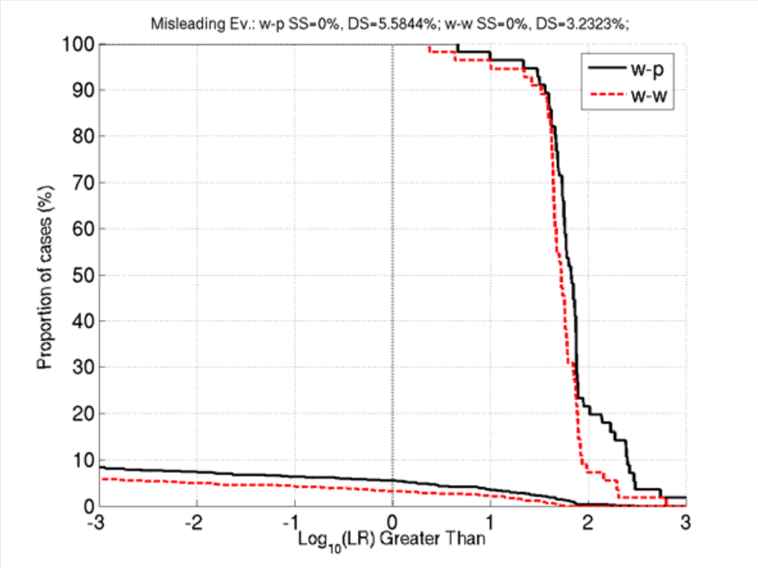
Background: 

Variable: RIb

Background:  



LR KDE



	False +ve	False -ve
Samples: 	3.9%	1.8%
Samples:  	2.6%	3.6%

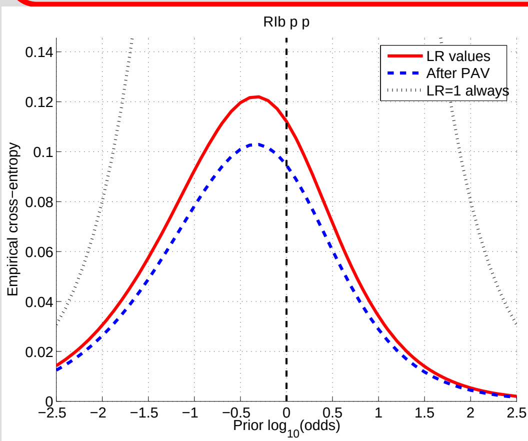
	False +ve	False -ve
Samples: 	5.6%	0.0%
Samples:  	3.2%	0.0%

Glass analysis for forensic purposes - results

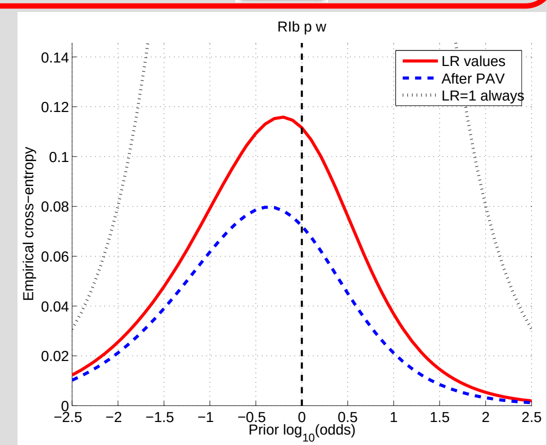
Samples: 

$\mathbf{RI_b}$

Samples:  



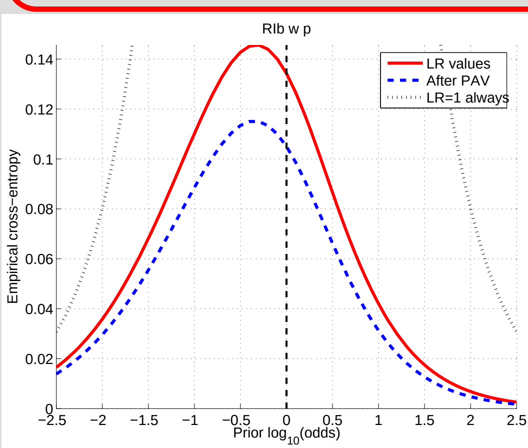
Background: 



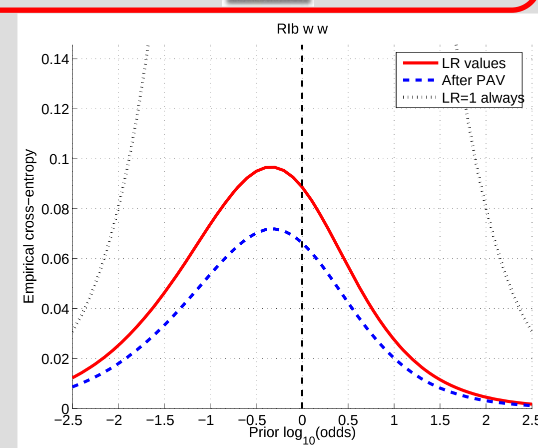
Samples: 

$\mathbf{RI_b}$

Samples:  



Background:  



Glass analysis for forensic purposes - conclusion

1) RIb variable seems quite robust to the variation among Polish and British float glass databases.

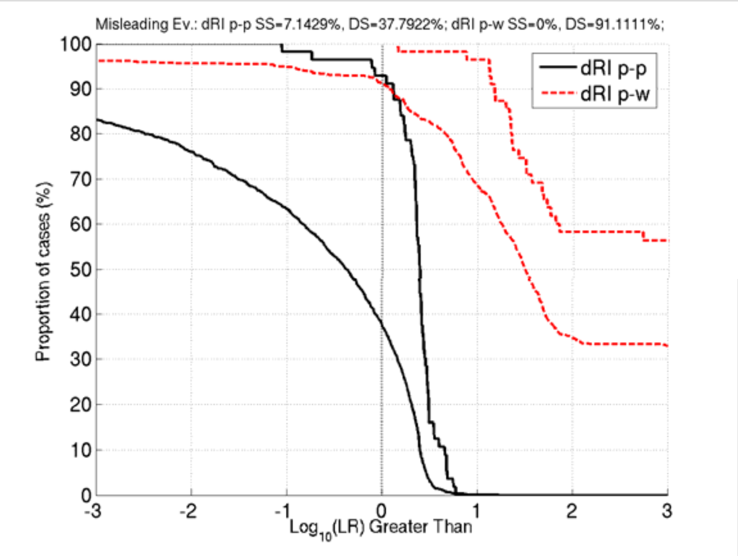
2) RIb variable seems quite robust to the variation among containers and float glass databases.

Glass analysis for forensic purposes - results

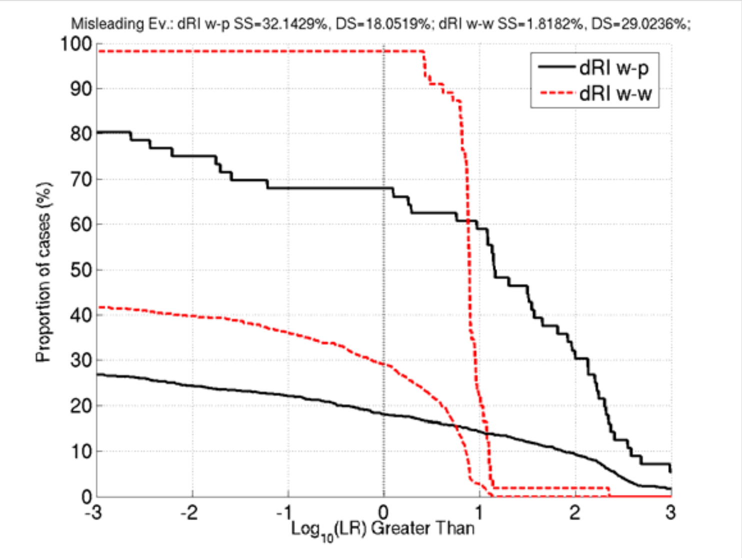
Background: 

Variable: ΔRI

Background:  



LR KDE



	False +ve	False -ve
Samples: 	37.8%	7.1%
Samples:  	91.1%	0.0%

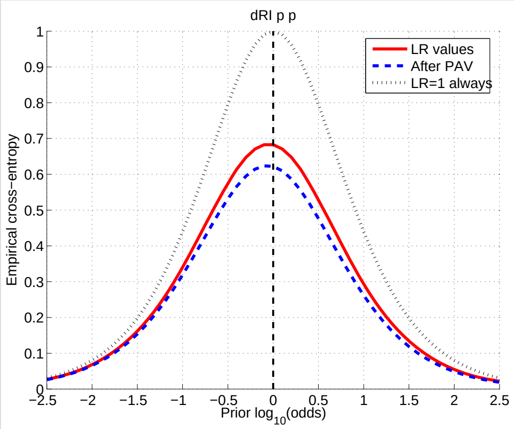
	False +ve	False -ve
Samples: 	18.1%	32.1%
Samples:  	29.0%	1.8%

Glass analysis for forensic purposes - results

Samples: 

ΔRI

Samples:  



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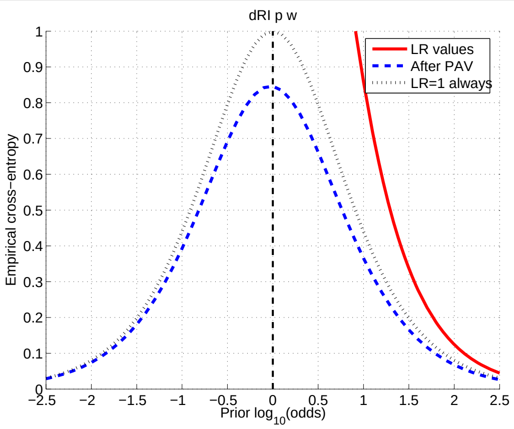
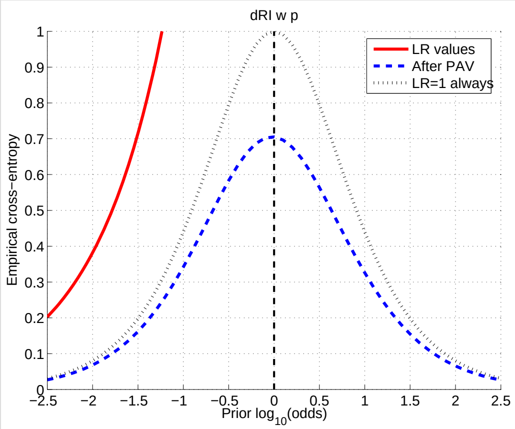


Samples: 

ΔRI

Samples:  



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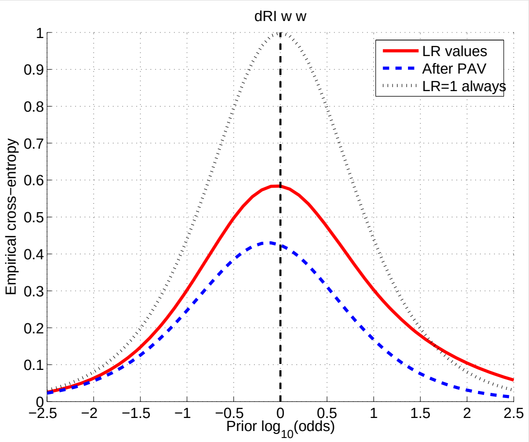

Glass analysis for forensic purposes - conclusion

1) RIb variable seems quite robust to the variation among Polish and British float glass databases.

2) RIb variable seems quite robust to the variation among containers and float glass databases.

3) dRI variable is very sensitive to the type of glass object analysed, which forces careful selection of the background database when dealing with such variable in comparison tasks.

Acknowledgments

The authors wish to thank Jim Haworth, Key Forensic Services, University of Warwick Science Park, Coventry, UK, for delivery of samples of British float glass

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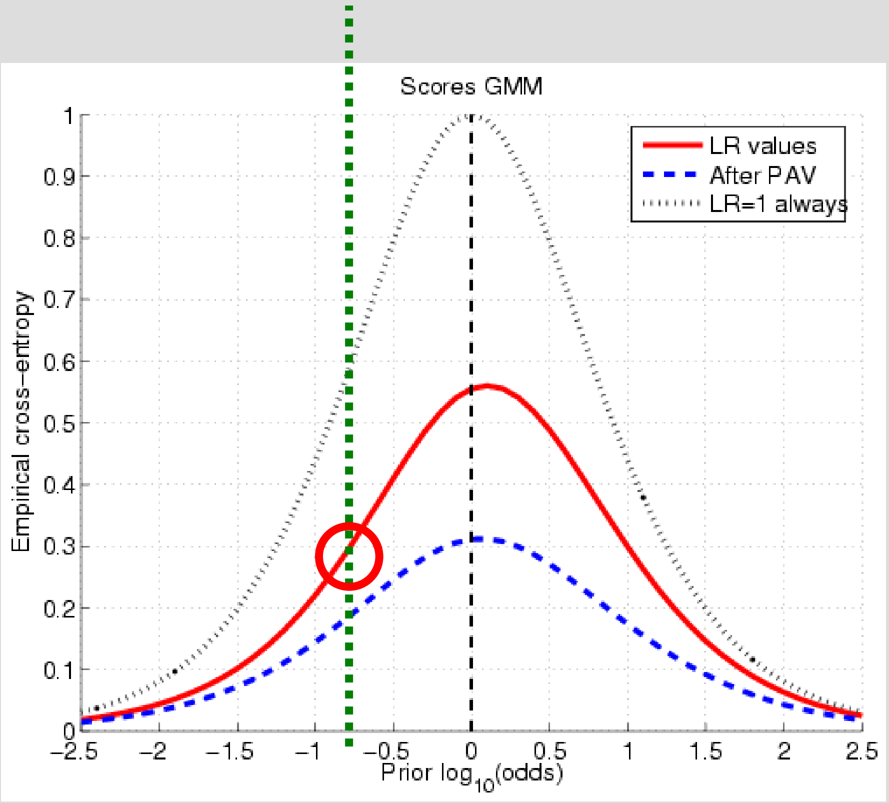
Empirical Cross-Entropy (ECE): evidence evaluation performance

ECE curve (solid): overall performance

The higher its value, the worse the method



Calibrated (dashed): discriminating power

Difference among ECE and Calibrated is the *calibration* performance

Neutral, always LR=1 (doted): a method that does not take into account the evidence

Separation of roles:

- Forensic scientist: *ECE* computation for a wide range of priors
  - Because the scientist cannot set the prior…
- Fact finder: prior establishment and measure of *ECE* in the plot