- CRIMINAL LAW WEBINAR SERIES –
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UNDERSTANDING STATISTICS IN CRIMINAL CASES

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UNIVERSITY OF TORONTO MISSISSAUGA

INTRODUCTION TO STATISTICS

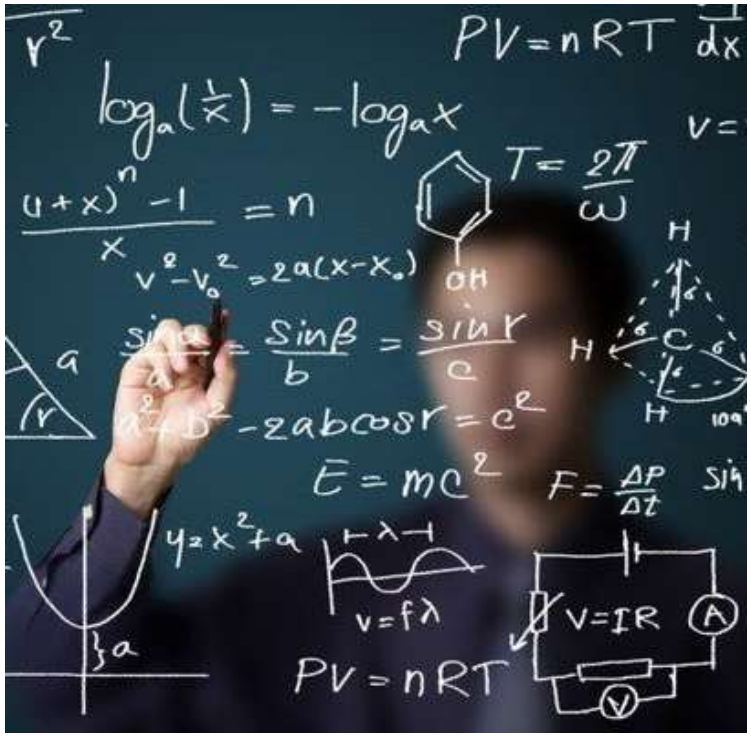
- What are statistics?
  - Common usage: numerical fact

- Statistics:

  "A group of methods used to collect, analyze, present, and interpret data and to make decisions."

  (Mann, 2007)

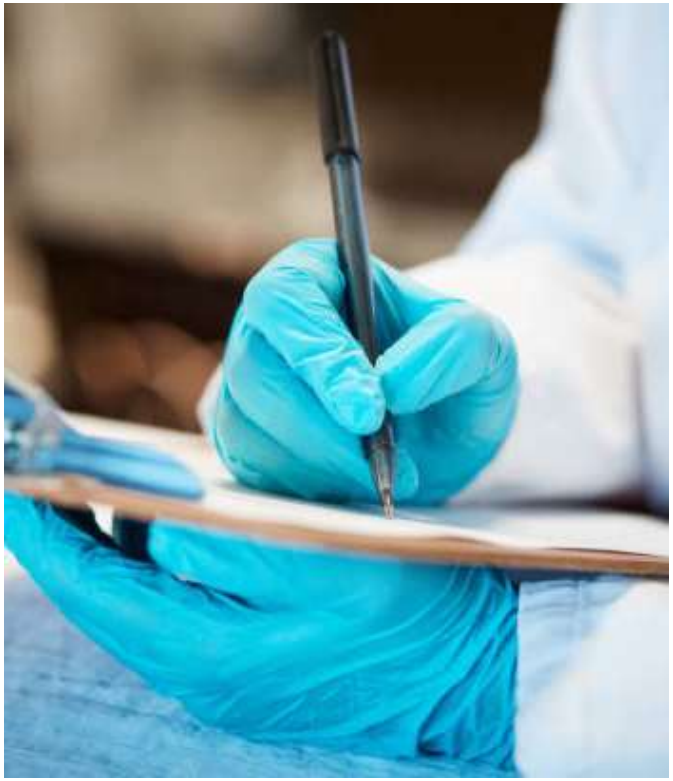
- Many decisions made under conditions of uncertainty
  - Statistical methods allow for scientific and intelligent decision-making



Source: cantorsparadise.com

INTRODUCTION TO STATISTICS

- Conventional view of the scientific method:
  - Observation/sampling to develop a hypothesis
  - Development of a prediction
  - Testing of prediction
  - Interpretation of results
    - Not consistent with prediction = hypothesis rejected
    - Consistent with prediction = hypothesis not rejected
- **N**ull hypothesis (H_0): Hypothesis of **no** difference/effect
- Alternate hypothesis (H_a): Hypothesis of the existence of difference/effect



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INTRODUCTION TO STATISTICS

- Similarity to criminal trials: presumption of innocence until proven guilty beyond a reasonable doubt
  - Statistical hypothesis test: null assumed true until it is demonstrated that it is unlikely to be so
    - (But in science: null = no difference/effect)
- Example:

  (H_0): Accused is innocent

  (H_a): Accused is guilty

- Prosecutor: provide evidence to allow trier of fact to **reject** the null hypothesis
  - Insufficient evidence: **fail to reject** the null hypothesis
    - Accused acquitted

INTRODUCTION TO STATISTICS

- Statistical testing relies on probability
- Science is comparative
  - Variability in all actions and processes
    - Usually of no practical significance
    - Important to quantify and account for this variability in forensic science contexts
- How do we know if our results are meaningful?
  - Statistical tests
    - Method of determining the probability of obtaining the observed outcome if a specific hypothesis (usually the null) is true

Source: gettyimages.com

INTRODUCTION TO STATISTICS

- Probability:

  Numerical measure of likelihood of an event

- When probability is known, decisions can be made about hypotheses
  - Using criteria that are uniformly used and understood

- Problem with use of probabilities: chance of making a wrong decision about the hypothesis
  - Type I error: inappropriate rejection of the null
  - Type II error: inappropriate rejection of the alternate

Type I Error
Source: tenetfloridaphysicianservices.com

Type II Error
Source: babycenter.ca

TABLE 23.4. Possible Outcomes of a Criminal Trial and a Statistical Hypothesis Test.

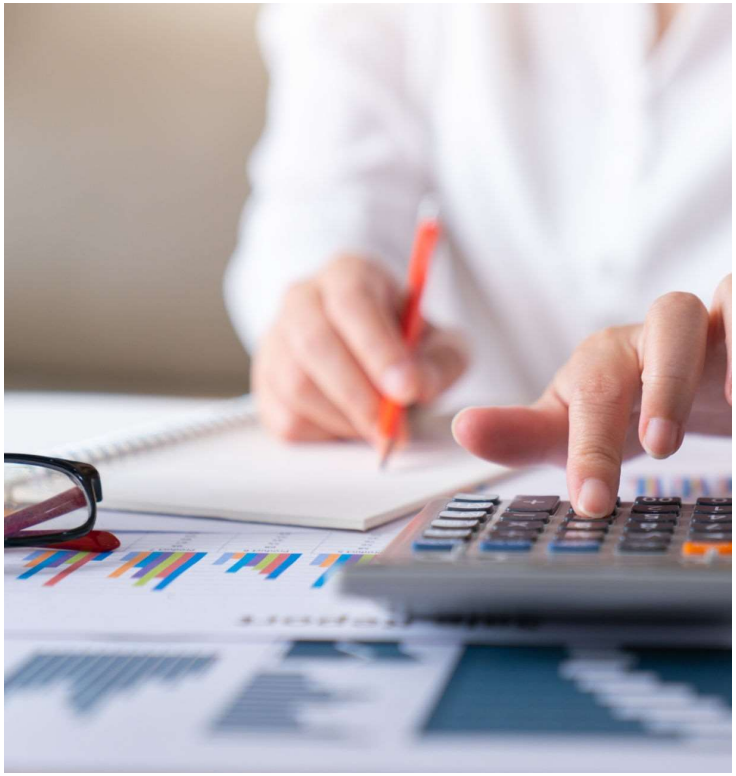
		Truth	
		H_0 false	H_0 true
Test conclusion	Fail to reject H_0	Type II error: acquit a guilty defendant	Correct: acquit an innocent defendant
	Reject H_0	Correct: convict a guilty defendant	Type I error: convict an innocent defendant

Source: Weir (2016)

INTRODUCTION TO STATISTICS

- Statistical hypothesis testing
  - Probability of Type I error = level of statistical significance
- Level of statistical significance set by researcher
  - Standard level of statistical significance:

    $\alpha = 0.05$
    - No scientific/biological/legal reason for this standard
      - Is a 5% chance of inappropropriately rejecting the null too risky?
        - Can modify level of statistical significance
        - What chance of Type I error is appropriate?



Source: gettyimages.com

INTRODUCTION TO STATISTICS

- Probability values (*p*-values)
  - Output ("result") of statistical test
    - Compared to level of statistical significance (α) to quantify **strength of evidence against null hypothesis**
- *p*-value < 0.05 = reject the null hypothesis = may hear "results are statistically significant"
- *p*-value > 0.05 = fail to reject the null hypothesis = may hear "results are not statistically significant"
- Sometimes *p*-value incorrectly interpreted as probability that null is true
  - This is a mistake
  - "Appeal to Ignorance" Fallacy
    - Error of assuming null hypothesis is true based on a failure to reject the null hypothesis

CASE STUDY: Wrongful conviction of Guy Paul Morin

- October 3, 1984, 9-year-old Christine Jessop missing
  - Remains found 3 months later, sexually assaulted and stabbed
- Morin draws police attention; “a weird-type guy”
- Center of Forensic Sciences (CFS): microscopic hair analysis
  - 1985: Morin arrested, charged with murder
    - Appealed and new trial ordered (1990)
    - 1992: found guilty, appealed, released on bail pending appeal
    - 1995: DNA excluded Morin as perpetrator

Source: Toronto.citynews.ca

- Experts exaggerated strength of hair and fibre comparison evidence and did not disclose limitations, i.e., evidence cannot support a positive identification as a “match”; only exclude a suspect

CASE STUDY: Wrongful conviction of Guy Paul Morin

- ‘Appeal to Ignorance’ Fallacy
  - Error of assuming null hypothesis is true based on failure to reject the null hypothesis
- Recall null hypothesis = no effect/no difference
  - But a failure to reject the null does not mean that null is true!
- Limitations of this scientific testing
- Fallacy shifts responsibility to prove innocence onto the accused
  - Be cautious of burden of proof, false dichotomies, and confirmation bias
  - Trier of fact should not apply standard of reasonable doubt to individual pieces of evidence (See: *R. v. Morin*, [1988] 2 S.C.R. 345)

PROBABILITY ASSESSMENTS IN COURT: COMMON ERRORS IN INTERPRETATION

- Probabilistic methods developed as a way of objectively quantifying the significance of forensic evidence
  - Provides a balanced view for trier of fact
- Understanding probabilistic conceptions of evidential value difficult
  - Bayesian frameworks
    - May lead to misunderstanding statistical evidence
- Common error: Transposed Conditional Fallacy
  - "The Prosecutor's Fallacy"

Source: sthint.com

INTRODUCTION TO BAYES' THEOREM

- Consider a defendant in a trial, who may or may not be guilty

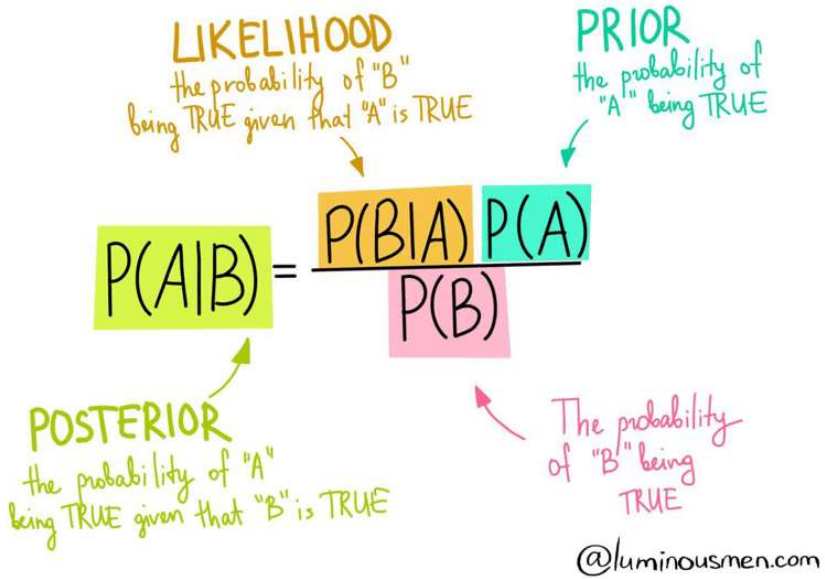
  Defendant is guilty: *G* Uncertainty (probability) of guilt: *P(G)*

- Uncertainty will fluctuate over the course of a trial and as evidence is presented
  - Depends on information (I) available at the time

- Additional evidence (E) comes to light at the trial – e.g., DNA match

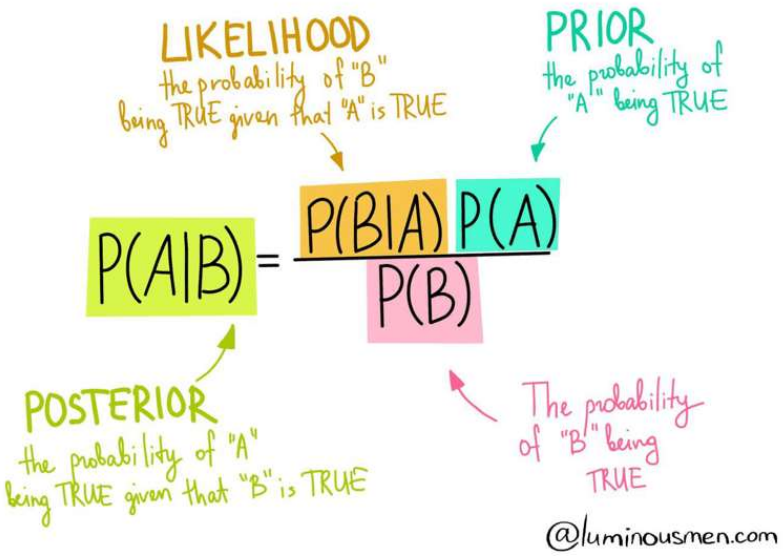
INTRODUCTION TO BAYES' THEOREM

- This example demonstrates how conditional probabilities are utilized in common discourse
  - One step further…
- Bayes' Theorem (Bayes, 1763)
  - Third law of probability for dependent events
  - Uses conditional probabilities
- Permits revision of measures of uncertainty of truth based on new measures
  - From prior (initial) to posterior (final) probabilities on the basis of data



INTRODUCTION TO BAYES' THEOREM

- Prior probability
  - Initial estimate of probability that event A has occurred
    - Subjective
- Observed data/information
  - Information relevant to probability that event A occurred is obtained
- Posterior probability
  - Prior probability + observed information combined to update probability event A occurred given Event B occurs



PROSECUTOR'S FALLACY: BASIC PRINCIPLES

- Consider the following:
  - Prosecutor produces evidence
    - E.g., DNA from defendant matches DNA from crime scene
  - Expert called to testify:
  - *"if the defendant is innocent, the chance of this observation is remote; 1 in 100,000. "*
    - "Random match probability"
    - Implicit invitation to conclude that ***P(innocence)* < 1 In 100,000**
      - i.e., Defendant is guilty
  - Error of logic has occurred
    - What if defendant in prison at time of the crime? ➔ ***P(guilt) = 0***

CASE STUDY: Wrongful conviction of Sally Clark

- "The Sally Clark Case" (United Kingdom)
  - Example of inaccurate statistics, Prosecutor's Fallacy

- Sally Clark convicted of smothering her two infant children

  (1996: Christopher)

  (1998: Harry)

- Pediatrician (Meadows) testified for the Crown
  - *"Chances of two cot deaths (SIDS) happening in this family was vanishingly small – 1 in 73 million"*
    - 1 in 73 million probability she was NOT guilty
    - Problematic; misunderstands probability theory

- Prosecutor's Fallacy

CASE STUDY: Wrongful conviction of Sally Clark

Recall:

Prosecutor's Fallacy: assumption that…

probability of Event A (given Event B occurred)

=

probability of Event B (given Event A occurred)

- *R. v. Clark*: <u>incorrect</u> assumption that…

  There is a 1 in 73 million chance the babies died of natural causes (SIDS)

  =

  There is a 1 in 73 million chance that the mother did not kill them

CASE STUDY: Wrongful conviction of Sally Clark

- Understanding correct statistical applications
  - 2 rare events to examine:
    - 2 babies died of natural causes
    - 2 babies were murdered
- Need reasonable estimate of probability ratio(s)
  - Bayesian inference → **likelihood ratios**
    - Considering the likelihood of 2 SIDS deaths, and the likelihood of 2 murders, the likelihood Sally is guilty is 4%
      - It is ~95% more likely SIDS was COD for each (Carriquiry, 2018)
- Conviction overturned (2003)
  - Implications …

Source: gettyimages.ca

CASE STUDY: Kathleen Folbigg

- From this emerged “Meadow’s Law” (discredited)
  - “*One sudden infant death in a family is a tragedy, two is suspicious, and three is murder unless proven otherwise”*
  - Impacted investigations and future cases
    - E.g., Kathleen Folbigg, Angela Cannings and more …
    - Expert witness cited Meadow’s Law
- *R. v. Folbigg* (Australia)
  - Four children died one after another between 1989-1999 (Caleb, Patrick, Sarah, Laura)
  - Convicted in 2003
    - Flawed statistical evidence, Prosecutor’s Fallacy
  - Served 20 years before being pardoned

Source: time.com

CASE STUDY: Troy Brown

- Similar case example but with DNA evidence
- 1994: 9-year-old girl raped
- Neighbour (Brown) convicted; sentenced to life with possibility of parole after 10 years
- Random match probability utilized by State's expert (Romero)
  - "1 in 3 million random people would have same DNA profile as the rapist"
    - Implicit invitation to conclude that

      ***P(innocence)* < 1 In 3,000,000 (<0.00003%)**

      - i.e., Defendant is guilty

The random match probability is not the same as the probability of the defendant being the source ("a match")

Prosecutor's Fallacy:

probability of some evidence being found (given innocence)

$\neq$

probability of innocence (given some evidence found)

CASE STUDY: Troy Brown

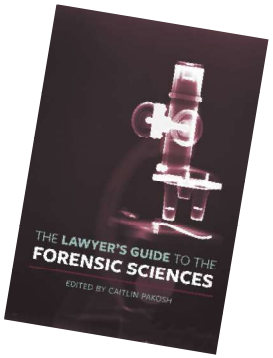
- Mueller Report

"... The Mueller Report does not dispute Romero's opinion that only 1 in 3,000,000 people would have the same DNA profile as the rapist. Mueller correctly points out, however, that some of Romero's testimony—as well as the prosecutor's argument—suggested that the evidence also established that there was only a .000033% chance that respondent was innocent. The State concedes as much. Brief for Petitioners 54. For example, the prosecutor argued at closing the jury could be "99.999967 percent sure" in this case. App. 730. And when the prosecutor asked Romero, in a classic example of erroneously equating source probability with random match probability, whether "it [would] be fair to say … that the chances that the DNA found in the panties—the semen in the panties—and the blood sample, the likelihood that it is not Troy Brown would be .000033," id., at 460, Romero ultimately agreed that it was "not inaccurate" to state it that way, id., at 461–462…"

See: McDaniel v. Brown, 558 U.S. 120 (2009)

IMPORTANCE OF STATISTICAL COMPREHENSION FOR LEGAL PROFESSIONALS

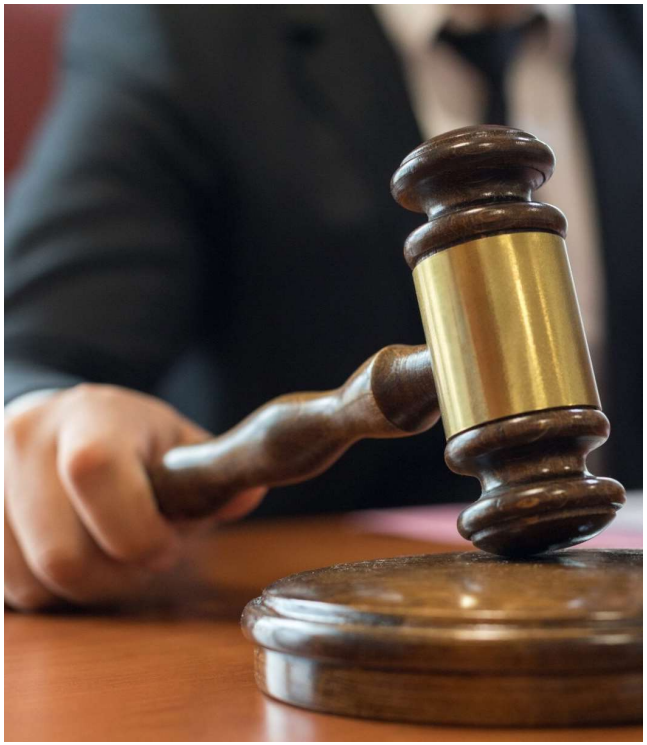
- Legal professionals must understand and be able to explain statistical evidence
  - And associated interpretations
- If not:
  - Misunderstandings
    - Possible wrongful convictions
    - *"…According to the Innocence Project, based in New York City, 'unvalidated or improper forensics' is the second leading contributing cause of wrongful convictions (47%) after 'eyewitness misidentification' (72%) …*
      … 'unvalidated or improper forensics' involves testimony that presents inaccurate statistics, gives statements of probability or frequency in the absence of valid empirical data … or concludes/suggests that evidence is uniquely connected to the defendant without empirical data to support such testimony…"



(see: Pakosh, 2016)

RESOURCES FOR LEGAL PROFESSIONALS

- Testimony involving probability or probabilistic conceptions of evidence
  - Analysis by qualified statistician (Canadian universities)
- Recommended readings
  - Introductory statistics text:
    McKillup, S. Statistics Explained: An Introductory Guide for Life Scientists. Cambridge; New York: Cambridge University Press, 2011.
  - Referenced in presentation
    - Pakosh C, editors. The lawyer's guide to the forensic sciences. Irwin Law; 2016
      - Chapters: 1, 2, 22, 23
    - Aitken CGG, Taroni F. Fundamentals of statistical evidence – a primer for legal professionals. Int J Ev Proof. 2008; 12(3): 181-207.
    - Raghavan L, Donohue MP, The presentation of probability to the jury. FDCC Quart. 2011; 169-177.



Source: canadianunderwriter.ca

RESOURCES FOR LEGAL PROFESSIONALS

- Importance of ongoing statistical education for legal professionals
- National Academy of Sciences (2009)
  - Importance of educating legal professionals to ensure reliability of forensic evidence:

    "...In addition, lawyers and judges often have insufficient training and background in scientific methodology, and they often fail to fully comprehend the approaches employed by different forensic science disciplines and the reliability of forensic science evidence that is offered in trial. Such training is essential, because any checklist for the admissibility of scientific or technical testimony is imperfect. Conformance with items on a checklist can suggest that testimony is reliable, but it does not guarantee it…
    … Law schools should enhance this connection by offering courses in the forensic science disciplines, by offering full credit for forensic science courses taken in other colleges and by developing joint degree programs. And judges need to be better educated in forensic science methodologies and practices…"

  - See: Pakosh (2016) for further detail on Canadian academic situation

THANK YOU.

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