EVIDENTIAL REASONING
Chapter for the Handbook of Legal Reasoning

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CONTENTS

When a suspect appears in front of a criminal court, there is a very high probability that he will be found guilty. In the Netherlands, for instance, the conviction rate of suspects that appear in criminal courts is reported to be around 95% year after year.[1] In the United States, the conviction rate in federal courts has been roughly 75% and in Japan it has reached as high a rate as 99%.[2] This does not mean that fact-finders deciding about the facts of a criminal case have an easy job. Whether laypeople, such as jury members selected from the general public, or professionals, often experienced judges having completed postgraduate education, all face the difficulties associated with handling the evidence that is presented in court. What to do with conflicting testimonies? Does an established DNA match outweigh the testimony that the suspect was not on the crime scene? How to coherently interpret a large body of evidence? What to do with illegally obtained evidence? When is there enough evidence to convict 'beyond a reasonable doubt'?

The primary aim of this chapter is to explain the nature of evidential reasoning, the characteristic difficulties encountered, and the tools to address these difficulties. There is an extensive scholarly literature on these topics, and it is a secondary aim of the chapter to provide readers the means to find their way in historical and ongoing debates. Before diving into the literature, we set the stage by using two important and often encountered kinds of evidence as an illustration: eyewitness testimony and DNA profiling. Similarities and differences between these kinds of evidence are used to establish a list of central questions that structure the exposition that follows.

1 SETTING THE STAGE

Fact-finders—typically jurors and judges—aim to reconstruct what has happened in the crime on the basis of the evidence. We will use two central types of evidence to develop a list of central questions associated with evidential reasoning: eyewitness testimony and DNA analysis.

1.1 Eyewitness testimony

Eyewitness testimony has always been a central source of information in criminal proceedings. It typically takes the form of oral statements by the witness in court, in response to questions by the prosecution, the defense, the court, and sometimes, albeit rarely, the jury. Eyewitness testimony can also come in the form of written reports of oral examinations in the pre-court stages of the criminal investigation, normally by prosecuting officers and judges.

[1] Source: CBS, the Dutch central bureau of statistics, publishing its data at www.cbs.nl.
[2] **SOURCE TO BE ADDED**

Eyewitness testimony can provide detailed information about what has happened on the scene of the crime. Here is an example.

> Q: Can you describe what happened, that day?
>
> A: I was in the park and suddenly heard a lot of noise, very close by. I saw two men quarreling, shouting. Suddenly one of them pulled a gun, and I heard a shot. The other man fell to the ground. The shooter looked around, looked me in the eye, and then started to run.
>
> Q: Can you describe the shooter?
>
> A: He was a young men, in his twenties, I think. Tall, blonde, with a very white skin, and unusually blue eyes. He looked unhealthy, with bad teeth, like a drug addict. He was wearing an FC Groningen t-shirt, which surprised me as we were in the Vondelpark.

On the basis of eyewitness testimony, we can form a hypothesis about what has happened. Sometimes this hypothesis contains specific detail—as in the example—, still it remains a hypothesis. There are many reasons why the hypothetical events reconstructed on the basis of the testimony may not be true. Typical reasons against the truth of the events reported by an eyewitness include that a witness has wrongly interpreted what he saw, that time has distorted his memories, or that the witness is intentionally lying.

1.2 DNA profiling

DNA profiling has become an important tool in courts. DNA profiling has a strong scientific underpinning, and comes with precise statistical information. The evidential relevance of a DNA profile stems from the fact that, although most of the structure of DNA is shared among all human beings (more than 99%), the variations that do exist are very specific for each individual.

A profile is determined by analyzing a number of specific locations—the so-called loci—of a DNA molecule, and establish the type of structure found there. These types are called alleles, and typically consist of the number of repetitions of a small DNA structure at a location. For instance, one locus used in the profiles stored in forensic DNA databases in the USA is referred to as CSF1PO, and it can have alleles 5, 6, 7 and then up to 16, depending on how often the molecular sequence AGAT is repeated at that location.[3] Different countries use different sets of—what are called—core loci for their forensic DNA profile databases. For instance, the USA CODIS system has 13 core loci. As said, each specific DNA profile is rare, and reference databases of profiles are used to numerically measure how rare a profile really is. This is done by counting the number of occurrences of each allele at each core

[3] See `http://www.cstl.nist.gov/strbase/str_CSF1PO.htm`.

locus in the reference database, which gives an estimate of the proportional frequency of that allele at that locus in the population. The measured proportional frequencies for the individual alleles at the core loci are then multiplied to compute what is called the Random Match Probability of the DNA profile.[4] These Random Match Probabilities—and numbers mathematically related to them—are the numbers reported by forensic experts in courts, and the smaller they are, the higher the evidential value of the profile is taken to be. The sets of core loci have been chosen such that Random Match Probabilities are typically very small, for instance, in the order of 1 in 50 billion, amply exceeding the number of people on our planet. The use of more loci leads to smaller Random Match Probabilities. A key assumption underlying the model (used when multiplying the estimated probabilities of specific alleles) is that there are no dependencies among the alleles at different loci in the population considered. Scientists have found that this is not entirely true, as some dependencies have been established, for instance among the profiles within ethnic groups. It is also accepted that the independence assumption is hard to test in full generality, as that would require assessing more profiles than possible.

Suppose now that a trace of blood has been found on the scene of the crime, and that the found DNA profile matches that of the suspect's DNA. Using this evidence, we form the hypothesis that the suspect is the source of the blood trace, and the Random Match Probability associated with the profile provides a measure of the evidential strength of the match. It is a common misunderstanding to equate this number with the probability that the suspect is not the source of the trace. This well-known misunderstanding is referred to as the prosecutor's fallacy. The probability that the suspect is not the source of the trace can be determined from the Random Match Probability, after a correction for the prior odds that the suspect is the source.

The hypothesis that can be formed on the basis of a DNA match is very specific, and is limited to the suspect being the source of the trace. The hypothesis need not be true, in particular in the cases of an accidental match, the existence of an identical twin—that at a rate of a dozen or more twin births per 1000 live births[5] are not all that rare—, or a lab error.

1.3 Central questions

Using the two kinds of evidence as an illustration, we can now provide the list of central questions associated with evidential reasoning that we use to structure this chapter.

Question 1: How should we handle conflicting evidence? It often occurs that the evidence provides conflicting perspectives on the crime. For instance, a witness claims that the crim-

[4]Some special care is needed to accommodate for the fact that an allele can be from either part of the double helix that comprises our DNA.

[5]Source: `https://en.wikipedia.org/wiki/Twin#Statistics`.

inal has blond hair, but the suspect whose DNA matched that of the trace at the crime scene, has dark hair. What to do in case of such conflicts?

Question 2: How should we handle the strength of the evidence? Some evidence is stronger than other evidence. This is most obvious in the case of DNA evidence, where DNA profiles come with different Random Match Probabilities. But also some eyewitness testimonies are stronger than others. For instance, the description of a criminal by a witness who could only view the crime scene in bad lighting conditions, is of lesser value. How to address the strength of evidence?

Question 3: How should we coherently interpret the available evidence? A DNA profile match can support that the suspect is the source, and a witness can add information about how the crime was committed. In general, there is a lot of evidence that needs to be coherently combined in order to make sense of what has happened. How do we combine all information in a coherent whole?

Question 4: How should we collect, include, exclude evidence? During the collection of evidence all kinds of things can happen. A witness' answer to a question can be discarded when the prosecution's question is judged to have lead the witness to an unjustified position. The classic example is the question "When did you start hitting your wife?" before it has been established that the suspect has been hitting his wife in the first place. Also DNA material can have been collected illegally, for instance without the suspect's consent. Which rules exist that guide the collection, marshaling, inclusion and exclusion of the evidence?

Question 5: How should we decide about the facts given the evidence? When are we done? After a careful and exhaustive investigation in the pretrial and trial phases of the criminal proceedings, the question arises when a decision can be made and what that decision is. When is the burden of proof met? What is the meaning of "beyond a reasonable doubt"? When have we collected enough evidence to make a decision?

In the following sections, each of these questions is addressed. Before that, we discuss three normative tools that can help understand how to correctly handle the evidence.

1.4 Three normative frameworks

In this section, we discuss three normative frameworks for the correct handling of the evidence, as distinguished in the scholarly literature (Anderson et al., 2005; Kaptein et al., 2009; Dawid et al., 2011). The first framework discussed uses arguments as primary tool, the second scenarios, and the third probabilities.

1.4.1 Arguments

The first normative framework for the handling of evidence that we discuss uses arguments as primary tool. Arguments contain reasons that support or attack the conclusions

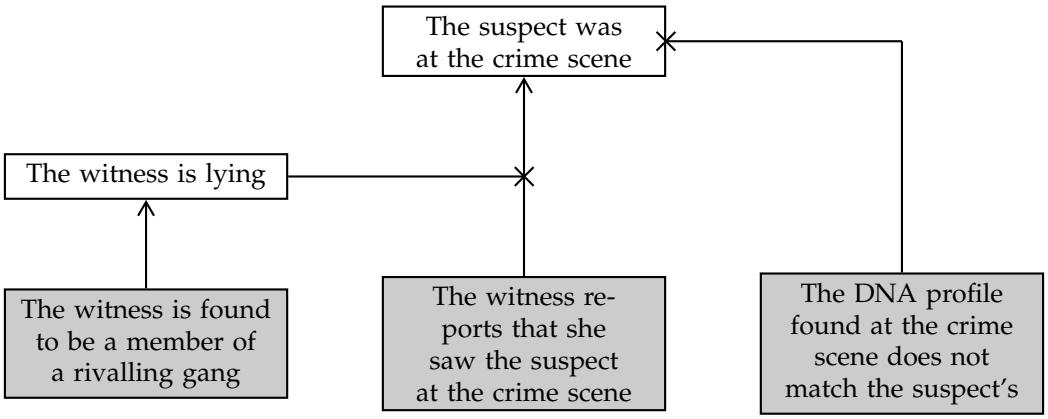


Figure 1: Arguments contain supporting and attacking reasons

considered. For instance, when a witness reports that she saw the suspect at the crime scene, there is a reason for the suspect having been at the crime scene. There is a reason attacking that conclusion when the DNA profile found at the crime scene does not match the suspect's. When it is found that the witness is a member of a rivalling gang, it is concluded that the witness is lying. This resolves the conflict of reasons since the lying of the witness attacks the support for the suspect being at the crime scene on the basis of the witness testimony. Figure 1 summarizes these reasons for and against conclusions in a diagram.

The analysis of the structure of arguments goes back to the early twentieth century when John Henry Wigmore developed his famous evidence charts (Wigmore, 1913, 1931). The work by the New Evidence Scholarship (Anderson et al., 2005) continued from Wigmore's insights. Independently, and not focusing on evidence in criminal cases, the structure of arguments for and against conclusions was formalized and computationally studied by the philosopher John Pollock (1987, 1995), who distinguished two kinds of attacking reasons. The first kind of attacking reasons—that he referred to as rebutting reasons—are reasons that support the opposite of the conclusion of the attacked reason. In the example, the non-matching DNA profile is a rebutting reason attacking the reason from the witness report since it supports that the suspect was not at the crime scene. The second kind of attacking reasons distinguished by Pollock, undercutting reasons, only attack the supporting connection of the attacked reason. In the example, the lying by the witness is an undercutting attack of the reason based on the witness report since it is not a reason that supports that the suspect was *not* at the crime scene. The work by Pollock stimulated an extensive literature on the formal and computational study of arguments for and against conclusions (van Eemeren et al., 2014).

1.4.2 Probabilities

The second normative framework for the correct handling of the evidence uses probabilities as main tool. The probability calculus is used to connect the probabilities of evidence and events, conditioned on each other. Consider for instance a trace found at the crime scene with a rare DNA profile of estimated frequency 1 in a billion, and let E be the evidence that the suspect's profile matches the trace's. We are interested in the hypothetical event H that the suspect is the source of the trace. Because the profile is rare, a match is not often found accidentally, only when the suspect actually is the source of the trace. Intuitively, finding a match therefore has a high evidential value for establishing that the suspect is the source of the trace.

This intuition can be made precise in the probability calculus, as follows. If the suspect is not the source, written as $\neg H$, the probability of still finding the match by accident is 1 in a billion:

$$\Pr(E|\neg H) = 1/10^9$$

Ignoring sources of error, e.g., made in the lab, we take it that finding a match is certain when the suspect is the source of the trace:

$$\Pr(E|H) = 1$$

The ratio $\Pr(E|H)/\Pr(E|\neg H)$ of these two conditional probabilities is called the likelihood ratio, in the example 10^9. The posterior odds $\Pr(H|E)/\Pr(\neg H|E)$ of a hypothesis after the evidence is taken into account can be found by multiplying the likelihood ratio with the prior odds $\Pr(H)/\Pr(\neg H)$ before the evidence is taken into account:

$$\frac{\Pr(H|E)}{\Pr(\neg H|E)} = \frac{\Pr(E|H)}{\Pr(E|\neg H)} \cdot \frac{\Pr(H)}{\Pr(\neg H)}$$

This likelihood ratio formula explains why the likelihood ratio is a useful measure for the evidential value of new evidence: if the likelihood ratio is greater than 1, the posterior odds of the hypothesis are larger than the prior odds. In other words, the evidence makes the hypothesis more strongly supported, and the larger the likelihood ratio is, the larger the difference between posterior and prior. In our example, the likelihood ratio is large, 10^9, indicating a high evidential value of finding the match, as expected by the rarity of the profile. When the likelihood ratio is 1, the evidence does not change the odds; and when it is smaller than 1, the evidence decreases the support of the hypothesis. Then the posterior odds are smaller than the prior odds.

The likelihood ratio holds in the probability calculus, and is closely related to the famous Bayes' theorem:

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

This formula shows how the posterior probability $\Pr(H|E)$ of the hypothesis given the evidence can be computed by multiplying the prior probability $\Pr(H)$ and the Bayes factor $\Pr(E|H)/\Pr(E)$.

The interest in probabilistic calculations as a tool for the good handling of the evidence has recently been stimulated by the statistics related to DNA profiling, and by some infamous miscarriages of justice that involved statistics, in particular the Lucia de Berk and Sally Clark cases (Dawid et al., 2011; Fenton, 2011; Schneps and Colmez, 2013). The interest is not new (Tillers, 2011), and goes in fact back to the early days of forensic science (Taroni et al., 1998). To what extent probabilistic calculations have a place in courts has always been, and remains the subject of debate.[6]

1.4.3 Scenarios

The third normative framework for the correct handling of the evidence centers around scenario analysis. In a scenario, a coherent account of what may have happened in a case is made explicit. Different scenarios are contrasted, and evaluated, by considering their plausibility and by checking to what extent they match and contradict the available evidence.

For instance, consider a murder case in which some skin tissue is found under the victim's nails. The former partner of the victim is considered a suspect because of the recent breakup. A hypothetical scenario then can be that, before the killing, the suspect had a fight with the murdered victim, who scratched the suspect so heavily that some skin tissue was left under his nails. The prosecution tests this scenario finding out that the DNA profile of the suspect matches that of the trace. The suspect's defense can report an alternative scenario that indeed the suspect had had a fight with the victim on the occasion of their breaking up, but that she is not the murderer as she was in the theater that specific night. As evidence, she produces proof that here bank card was used at the theater's counter. The prosecution agrees that their guilty scenario cannot be considered true beyond a reasonable doubt, and cannot close the case, until a drug-using robber arrested in another case breaks, and confesses having killed the victim who accidentally entered during a robbery.

We now have three scenarios:

S1: The victim's former partner killed the victim after a fight.

S2: The victim's former partner has had a fight with the victim, but has not killed him and was in the theater that night.

S3: The drug-dealing robber killed the victim when caught during a robbery.

[6] A recent instance of the debate concerns the R v T case, where the UK Court of Appeal restricted the use of Bayes' theorem in courts to cases with a solid statistical foundation such as DNA; see the 2012 special issue of Law, Probability and Risk; Vol. 4, No. 2. For a 1970s instance of the debate, see Finkelstein and Fairley (1970); Tribe (1971).

We also have three pieces of evidence:

E1: There is a match of the DNA profile of the trace and that of the victim's former partner.

E2: The victim's former partner's bank card was used at the theater that night.

E3: The drug-dealing robber confesses having killed the victim during a robbery.

The breakup murder scenario $S1$ explains the skin trace $E1$, but is contradicted by the use of the bank card $E2$, and again by the confession $E3$. The innocent former partner scenario $S2$ explains the skin trace $E1$ and the bank card use $E2$, and is independent from the confession $E3$. The caught robber scenario explains the confession $E3$, and is independent from the skin trace $E1$ and the bank card use $E2$. Considering these scenarios and this evidence, breakup murder scenario $S1$ is hard to believe, the innocent former partner and caught robber scenarios $S2$ and $S3$ seem to be true.

Attention for scenario analysis rose when it was realized that scenarios are helpful when considering a complex case and its evidence. The coherent explanation of the evidence provided by a scenario can be regarded as a sense-making tool for handling cases with a large dossier. In particular, legal psychology has contributed to our knowledge about the role of scenarios in handling the evidence (Bennett and Feldman, 1981; Pennington and Hastie, 1993). Scenarios were shown to be misleading, as experiments showed that a false scenario told in a sensible chronological order was more easily believed than a true scenario that was told in a random order. Still, the legal psychologists Wagenaar et al. (1993) emphasised the usefulness of scenario analysis for the rational handling of the evidence, using the technique in their work on debunking dubious case decisions. Scenario analysis is connected with inference to the best explanation (Pardo and Allen, 2008a).

1.5 Paper plan

The three normative frameworks for the handling of evidence, arguments, scenarios, and probabilities, are connected to the first three of the central questions that we have discussed:

Question 1: How should we handle conflicting evidence?

Question 2: How should we handle the strength of the evidence?

Question 3: How should we coherently interpret the available evidence? When are we done?

Although—as we shall see—each of the three normative frameworks provides relevant insights for answering each of these three questions, the first question about conflicting evidence is especially closely related to the arguments framework, the second question about

strength of the evidence in particular to the probabilities framework, and the third question about coherently interpreting the evidence most strongly to the scenarios framework.

In the following sections, these three questions will be discussed, consecutively, while emphasising the role of the three normative frameworks (Sections 2, 3 and 4). The remaining two questions are less strongly connected to the normative frameworks, and are discussed in Sections 5 and 6:

Question 4: How should we collect, include, exclude evidence?

Question 5: How should we decide about the facts given the evidence? When are we done?

2 CONFLICTING EVIDENCE

Legal cases arise because there are reasons pros and cons a position In many cases, the law and the facts are not in dispute. Consider a routine traffic violation such as speeding. If you are driving at 100 km/h, the speed limit is 50 km/h, and a police officer issues you a ticket, there is little to dispute. Yet, cases that are litigated in court are usually more complicated either because the interpretation of the law is disputed or because there are conflicting reconstructions of the facts. (For disputes about matters of law, see OTHER CHAPTER IN HANDBOOK). Conflicting reconstructions of the facts emerge when the two parties in a trial—the defense and the prosecutor in a criminal trial or the plaintiff in a civil trial—introduce evidence that support conflicting conclusions. For example, a witness for the prosecutor may assert she saw the defendant around the crime scene at the time of the crime, while the defense may introduce evidence that the genetic material found at the crime scene does not match the defendant's. When two or more pieces of evidence support contradictory reconstructions of the facts, it is not easy to decide which piece of evidence to trust or which reconstruction to believe. The need for a legal trial therefore arises.

evidential reasoning in the law is dialectical Legal trials often take the form of adversarial confrontations. Each party is given the opportunity to make its case on the basis of the evidence she thinks important. But, trials are not confined to the mere presentation of the evidence by the interested parties. Since the parties will advance conflicting reconstructions of the facts, the dialectical testing of the evidence is also crucial. Although one party may make a strong case, backed up by good evidence, the other party may come up with a stronger case, backed up by even better evidence. In the law, more often than not, reasoning toward factual conclusions is a dialectical process. The examination and cross examination of the evidence is the legal machinery that is used to identify which party has the stronger case.

2.1 Arguments

Args are for different, possibly conflicting positions (Van Eemeren et al 2014; not specific for evidence) ???

Dialectical aspect of arguments and Argument can support a certain conclusion (i.e. premises support a conclusion) An argument is a collection of statements in which one statement is the conclusion and the others are the premises functioning as evidence for the conclusion. Premises and conclusions, however, are contextual notions. Consider the collection of statements {I am getting wet; it is raining}. Which is the premise? Which is the conclusion? This depends on what is at issue. If the weather condition is at issue, getting wet is the premise functioning as evidence for the conclusion that it is raining. If, instead, one's physical condition is at issue, the fact that it is raining is the premise functioning as evidence for the conclusion that one is getting wet. In this sense, the conclusion of an argument is what the interlocutors disagree about, while the premises represent what the interlocutors take as evidence that can prove or disprove the conclusion.

Arguments can attack other arguments There are different ways in which two interlocutors can disagree as they put forward conflicting arguments. The argumentation theorist Pollock has distinguished two such ways, typically referred to in the literature as rebutting and undercutting (REFERENCE). These forms of conflict between arguments occur in everyday discussions, but occur also in a court of law while the prosecution and defense argue a case.

Rebutting: Arg2 leads to a different conclusion from Arg1 Let us begin with *rebutting*. Suppose A offers an argument for conclusion X, and B responds with an argument for conclusion Y, while X and Y cannot be both true, or in other words, X and Y are contradictory. When two arguments support contradictory conclusions, they rebut one another. Here is a legal illustration. In the British case, R v Adams [1996] 2 Cr App R 467, the victim was raped and the defendant's DNA matched with the traces of semen found on the victim's body. The prosecutor used the DNA match as a premise to support the conclusion that Adam raped the victim. But, Adam had an alibi—his girlfriend claimed he was with her when the crime occurred—and so the defense used the alibi as a premise to support the contradictory conclusion that Adam had nothing to do with the crime. This is an example of rebutting, because the two conclusions, each supported by a different piece of evidence, cannot be concurrently maintained.

Undercutting: Arg2 attacks the relation between Premises and Conclusion in Arg1 Turning now to *undercutting*, suppose A offers an argument for X consisting in premises P1,

P2, etc., while B shows that the premises do not support X, or at least, not as strongly as A thought. Here is an example. A prosecutor expert testifies that the defendant's DNA matches the crime scene DNA, and the prosecutor uses the expert testimony as evidence for the conclusion that the defendant visited the crime scene. But, suppose the expert for the defense testifies that the genetic profile used for the match is shared by millions of individuals. This information undercuts, or at least significantly weakens, the support that the DNA match lends to the conclusion that the defendant visited the crime scene.

Undermining: Arg2 attacks the premises on which Arg1 is based Besides rebutting and undercutting, some argumentation theorists (REFERENCES) identify a third way in which two arguments can conflict. This form of conflict is sometimes called *undermining*. Suppose A offers an argument for conclusion X consisting in premises P1, P2, etc., while B shows that one of the premises is false. For example, given the premise that the defendant matches the crime scene DNA, the prosecutor argues that the defendant visited the crime scene. The defense, on the other hand, points out that a laboratory error occurred and thus alleges that the premise in the prosecutor's argument, namely the DNA match, is false. If the laboratory made a mistake, the DNA match declared by the laboratory need not be a true match. This is a case of undermining because one of the premises in the proposed argument is false, or at least this is what one party in the dispute claims.

Wigmore's charts John Wigmore, as early as the beginning of the 20th century, devised a systematic method to chart arguments by identifying the various pieces of evidence and the relations of support and attack (REFERENCE). ILLUSTRATE REBUTTING, UNDERCUTTING AND UNDERMINING WITH WIGMORE CHARTS. In a court of law, the two parties in a trial aim to establish various conclusions, but the ultimate conclusion at issue is whether the defendant is guilty. The difficulty is that arguments aimed to establish the defendant's guilt can be intricate, and charting them with the Wigmore's method can be extremely laborious and complicated. SHOW A VERY COMPLEX WIGMORE CHARTS TO MAKE THE POINT THAT THEY ARE OFTEN UNREADABLE AND NOT INTUITIVE. Charting the arguments in a legal cases with Wigmore's charts might not be the best way to grasp a case as a whole. This might explain why, despite their clarity and precision, Wigmore's charts have never been popular among lawyers and practitioners.

references (Pollock 1995, Dung 1995; ?mention nonmonlog, Toulmin's anti-logicism)

2.2 Scenarios

Mutually inconsistent, different hypotheses/scenarios Instead of viewing evidential reasoning in the law as an intricate process of argument construction, studies in psychology

and cognitive science (REFERENCES) suggest that we tend to comprehend a legal case and the evidence presented therein by constructing comprehensive scenarios (or stories, narratives). On this perspective, the prosecutor puts forward a comprehensive scenario that comprises a reasonably detailed and complete reconstruction of how the defendant became involved in and carried out the crime. The scenario, of course, cannot be fabricated out of thin air, as it were, but should be backed up by good supporting evidence. The defense, in turn, may respond with an alternative scenario, also backed up by good supporting evidence. When two alternative scenarios are proposed, this resembles a case of rebutting. The difference is that rebutting sometimes may concern small-scale arguments with small-scale conclusions, while the conflict between scenarios concerns the entire prosecutor's and defense's cases. In criminal trial, the defense is not legally required to offer a full-fledged alternative scenario because the burden of proof is on the prosecutor and never shifts to the defendant. This does not mean, however, that the defense can simply be inherit. The defense must at least attempt to identify weaknesses in the prosecutor's case and raise reasonable doubts. ILLUSTRATE HOW THIS WORKS.

Conflicting scenarios can offer alternative explanations for the evidence

Comparative adequacy of alternative scenarios/hypotheses in explaining the evidence

2.3 Probabilities

We have seen how the premises of an argument can function as evidence favoring the conclusion. We can represent this relation probabilistically. We say that E is evidence favoring or supporting hypothesis H whenever E raises the probability of H, or more precisely, whenever taking into consideration E makes it more probable that H is true than it would be without taking into consideration E. The relation of evidential favoring or evidential support can also be described by means of likelihood ratios, that is, E is evidence favoring or supporting hypothesis H whenever the likelihood ratio $\frac{P(E|H)}{P(E|\neg H)}$ is greater than one. In fact, the two characterizations are equivalent, since the following holds:

$$P(H|E) > P(H) \textit{ iff } \frac{P(E|H)}{P(E|\neg H)} > 1.^{7}$$

Different, incompatible outcomes In a criminal trial, the prosecutor and the defense often disagree at trial as they put forward pieces of evidence that support contradictory hy-

[7] This holds because of Bayes' theorem:

$$\frac{P(H|E)}{P(\neg H|E)} = \frac{P(E|H)}{P(E|\neg H)} \times \frac{P(H)}{P(\neg H)}$$

potheses about what happened during the crime or who committed the crime. These can be as complex as the final proposition 'the defendant is guilty' or 'the defendant is not guilty', but also more circumscribed such as 'the defendant had contact with the victim' or 'the defendant was away when the crime occurred'. Let H_p and H_d be contradictory hypotheses and let E_p and E_d be pieces of evidence, respectively put forward by the prosecutor and the defense. The disagreement between the two parties can be represented probabilistically, as follows:

$$P(H_p|E_p) > P(H_p) \text{ and } P(H_d|E_d) > P(H_d),$$

or in terms of likelihood ratios,

$$\frac{P(E_p|H_p)}{P(E_p|\neg H_p)} > 1 \text{ and } \frac{P(E_d|H_d)}{P(E_d|\neg H_d)} > 1.$$

To illustrate, recall the earlier case in which Adams' DNA matched the traces of semen found on the victim's body (abbreviated M), but Adams also had an alibi provided by his girlfriend (abbreviated A). The match M favors the hypothesis CV that Adams has contact with the victim because M makes CV more probable. Similarly, the alibi A favors the hypothesis AW that Adams was away from the crime scene because A makes AW more probable. So, we have

$$P(CV|M) > P(CV) \text{ and } P(AW|A) > P(AW),$$

or in terms of likelihood ratios,

$$\frac{P(M|CV)}{P(M|\neg CV)} > 1 \text{ and } \frac{P(A|AW)}{P(A|\neg AW)} > 1.$$

Note that CV and AW are contradictory hypotheses. If the defendant was away from the crime scene, he could not have had any contact with the victim (at least, not when the crime occurred). This closely mirrors a case of *rebutting* between arguments. The only difference is that instead of having contradictory conclusions, here we have contradictory hypotheses, but this is only a difference in terminology.

Same hypothesis can receive different probability assignments depending on evidence (or interpretation thereof) We have seen how two parties in a trial can disagree when they offer evidence that support contradictory hypotheses. But disagreements may also arise with respect to the same hypothesis. As the prosecutor introduces evidence in support of an incriminating hypothesis, the defense can argue that the prosecutor evidence does not—in fact—support the hypothesis. This disagreement can be represented proba-

bilistically, as follows:

$$P(H_p|E_p) > P(H_p) \text{ but it is not the case that } P(H_p|E_p, E_d) > P(H_p),$$

or in terms of likelihood ratios,

$$\frac{P(E_p|H_p)}{P(E_p|\neg H_p)} > 1 \text{ but it is not the case that } \frac{P(E_p|H_p, E_d)}{P(E_p|\neg H_p, E_d)} > 1.$$

To illustrate, consider the hypothesis V that the defendant visited the crime scene at the time of the crime. Suppose the prosecutor witness testifies that she saw the defendant around the crime scene while the crime occurred (call this W_p), while a defense witness testifies that the prosecutor bribed the witness (call this W_d). We have:

$$P(V|W_p) > P(V) \text{ but it is not the case that } P(V|W_p, W_d) > P(V),$$

or in terms of likelihood ratios,

$$\frac{P(W_p|V)}{P(W_p|\neg V)} > 1 \text{ but it is not the case that } \frac{P(W_p|V, W_d)}{P(W_p|\neg V, W_d)} > 1.$$

This resembles a case of *undercutting* between arguments. Although the testimony by the prosecutor witness increases the probability that the defendant visited the crime scene, the testimony by the defense witness undercuts the reliability of this testimony.

Relative to the same hypothesis, likelihood ratios for different pieces of evidence can be positive or negative. ALREADY ADDRESSED EARLIER

If LR for E1 relative to H is positive, while LR for E2 relative to H is negative, E1 and E2 are in conflict ALREADY ADDRESS EARLIER

Comparison between the three frameworks IS THIS NEEDED?

3 EVIDENTIAL STRENGTH

3.1 Probability

Likelihood ratios can model evidential strength vs "posterior probability" (difference between the two) The probabilistic framework allows us to quantify the strength of the evidential favoring or support relation between evidence and hypothesis. The are different approaches in the literature (FITELSON REFERENCE HERE). One approach is to look at the difference between the probability of the hypothesis with and without considering the

evidence, that is, $P(H|E) - P(H)$. The larger the difference, the stronger the evidential support. An alternative approach is given by the likelihood ratio $\frac{P(E|H)}{P(E|\neg H)}$. For any value greater than one, the higher the likelihood ratio, the stronger the evidential support. Both the difference $P(H|E) - P(H)$ and the likelihood ratio tell how much a piece of evidence E can impact, upwards or downwards, the initial probability of a hypothesis H. There are subtle differences between the two approaches, but these should not concern us here.

Evidential strength is not measured in terms of the conditional probability of an hypothesis given the evidence, often referred to as *posterior probability*. It is not true that a strong evidential strength amounts to a high posterior probability. This depends on the probability of the hypothesis regardless of the evidence, often referred to as *prior probability*. The following table shows how the posterior probability varies depending on the prior probability, with a fixed likelihood ratio of 1,000:

$P(H)$	Likelihood Ratio	$P(H\|E)$
0.0001	1,000	0.09
0.001	1,000	0.5
0.01	1,000	0.9
0.1	1,000	0.99

The posterior probability of the hypothesis is not high if its prior probability is particularly low, and in particular, if the likelihood ratio is n and the prior probability is $1/n$ or lower, the posterior probability will not be greater than 0.5.

ASIDE: LJ Cohen?s challenge (negation, conjunction paradox) and the Bayesian response Identifying evidential strength with conditional probability leads to counterintuitive results, one of them being the *negation paradox* (REFERENCE TO LJ COHEN). To illustrate, if the probability that it will rain given that the stock market crashed is low, the probability that it will *not* rain given that the stock market crashed must be high. This is a fact about probability. If the probability of H given E is low, the probability of $\neg H$ given E must be high. This fact, however, led LJ Cohen to conclude that the probability calculus "creates evidence from ignorance" and thus cannot offer an adequate account of evidential strength. But this conclusion is too quick. Indeed, if we identify evidential strength with conditional probability, the market crashing would be strong evidence that it will not rain, and this is patently absurd. Yet, according to the probabilistic account of evidential strength presented here, the information that the stock market crashed is not strong evidence that it will not rain. Learning about the market crash neither raises nor lowers the probability that it will (not) rain. In other words, the difference $P(H|E) - P(H)$ is roughly zero and the likelihood ratio roughly one. Cohen's negation paradox, then, only suggests that we should not characterize evidential strength in terms of conditional probability.

DNA evidence illustration As an illustration, we now describe the evidential strength of a DNA match in probabilistic terms. The first step is to decide on the hypothesis of interest. If the hypothesis is that the defendant is guilty, the evidential strength will be expressed by the likelihood ratio $\frac{P(M|G)}{P(M|\neg G)}$, where M is the DNA match and G is the hypothesis of guilt. But, it is not obvious that a DNA match bears directly on guilt itself. This depends on what kind of genetic traces we are considering. If the presence of the traces is incompatible with the innocent conduct of whoever left them, the DNA match would bear directly on guilt. But that is not always the case. The psychologist Jonathan Koheler has distinguished different hypotheses that are progressively more circumscribed: the defendant is guilty; the defendant partook in the crime; the defendant visited the crime scene; the defendant left the crime traces; the defendant is the source of the traces. The truth of a more circumscribed hypothesis does not necessarily entail the truth of a less circumscribe one. The defendant could have visited the crime scene without partaking in the crime or could have being the source of the traces without leaving them. (REFERENCE)

In what follows, we shall focus on the most circumscribed hypothesis that the defendant is the source of the crime traces. The extent to which the DNA match support this hypothesis is expressed by the likelihood ratio $\frac{P(M|S)}{P(M|\neg S)}$, where M is the DNA match and S is the hypothesis that the defendant is the source. The higher the value of the ratio, the stronger the evidential support. Let us consider the numerator first. It is customary to put $P(M|S) = 1$ because if the defendant is the source of the crime traces, we expect that the genetic analyst would declare a match. This, to be sure, is a simplification, and we shall say more later in the chapter. Turning now to the denominator, it is customary to put $P(M|\neg S) = RMP$, where RMP is the probability that a random person, unrelated to the crime and to the defendant, would be found to have a matching DNA. This identification is plausible in the sense that the probability that a match would be reported assuming that the defendant was *not* the source is roughly the same as the chance that a random person—someone who had nothing to do with the crime or had no contact with the victim—would match anyway. The lower the RMP, the lower the denominator and thus the higher the likelihood ratio.

If we set aside certain complications on which we shall expand later, the evidential strength of a DNA match relative to the hypothesis S is as follows (Dawid, 2002; Balding, 2005):

$$\frac{P(M|S)}{P(M|\neg S)} = \frac{1}{RMP}.$$

In the Adams case we considered earlier, the RMP was 1 in 200 million, so the likelihood ratio would be:

$$\frac{P(M|S)}{P(M|\neg S)} = 200,000,000.$$

In the case, given that the likelihood ratio is such a high number, the DNA match relative

to hypothesis S has a great deal of evidential strength, although this does not immediately translate into a high probability of guilty or in a high probability of the hypothesis 'source'.

The likelihood ratio analysis presented here can be extended to other forms of trace evidence. For example, it can be extended to fingerprints: instead of a genetic match, we will have a match between fingerprint profiles. The difference with DNA evidence is that we do not have a Random Match Probability for fingerprint profiles (Zabell, 2005). Besides fingerprints, the same analysis can be used for blood types, glass evidence, and any other type of trace evidence. But, again, we would need an estimate of the Random Match Probability which we often lack.

Confusions may arise between likelihood (ratios) and posterior probability (i.e. prosecutor?s fallacy) There is an error people routinely make while reasoning with the RMP. The mistake is to think that since the RMP is low—that is, the probability that a random person would match is low—it follows that there is a low probability that the defendant is a random person (or that the defendant has nothing to do with the crime or is innocent). The inference from the premise 'it is unlikely that a random person would match' to the conclusion 'it is unlikely that someone who matches is a random person' is wrong. This is a confusion of $P(M|\neg S)$, which is indeed low if the RMP is low, with $P(\neg S|M)$, which need not be low at all. The application of Bayes' theorem can protect us from this confusion, as illustrated by the following table:

$P(\neg S)$	$P(M\|\neg S)$ (or RMP)	$P(\neg S\|M)$
0.9999999	1 in 100 million	0.1
0.99999999	1 in 100 million	0.5
0.999999999	1 in 100 million	0.9

If the probability that the defendant is *not* the source is high prior to considering the DNA match, this probability can still remain high even after taking into account the DNA match, or at least, no identification can be made between the probability of $\neg S$ and the RMP. (EXPLAIN MORE?) The confusion is an instance of a reasoning fallacy known in the probabilistic literature as the *inversion fallacy* and consists in confusing the probability of $P(E|H)$ and $P(H|E)$. In the legal literature, this confusion is known as the *prosecutor's fallacy* because this fallacy typically works to the advantage of prosecutors (Thompson and Shumann, 1987). We have just seen an example of it in DNA evidence cases, namely the confusion was between $P(M|\neg S)$ and $P(\neg S|M)$. MENTION COLLINS AS ANOTHER EXAMPLE?

Likelihood ratios can model sources of weakness/error/uncertainty (illustrate this through DNA evidence) Let us now address some of the complications we left out as we provided a probabilistic analysis of the evidential strength of a DNA match. The likelihood

ratio $\frac{P(S|M)}{P(\neg S|M)}$ was equated to $\frac{1}{RMP}$ but this overlooks certain important details. What M stands for is the lab report of a match, but the lab technician could make a mistake. She could not declare a match while in fact the defendant does match (*false negative*) or declare a match while in fact the defendant does not match (*false positive*). If we take false negatives into account, the numerator $P(M|S)$ must be lower than one. This has a negative impact on the strength of the evidence insofar as a lower value in the numerator will result in a lower likelihood ratio. Turning to false positives, since the laboratory or the technician performing the test could falsely report a match, the probability $P(M|\neg S)$ should be higher than the RMP. For example, a likelihood ratio as high as 1 billion reduces to about 100 if the laboratory error rate is just 1%.[8] More generally, false positives can have a negative impact on the strength of the evidence insofar as a higher value in the denominator will result in a lower likelihood ratio

There are other reasons why $P(M|\neg S)$ should be higher than RMP. If the DNA traces were synthesized and implanted, the defendant will not be the source, yet an identical DNA could still be found at the crime scene and a match would be reported (absent any laboratory error or random match). This is not a far-fetched possibility and is likely to become more common in the future (REFERENCE). Another reason why $P(M|\neg S)$ should be higher than the RMP is that the defendant could have an identical twin. The RMP does not take into account this possibility because it typically describes the possibility that a random person who is *unrelated to the defendant* would match. Interestingly enough, the probability that any defendant has an identical twin is not negligible because the frequency of identical twins is estimated to be 3 every 1000 births.

[8] To take lab errors into account, instead of a match M, we should properly speak of a reported match M_r. A reported match M_r can occur in two situations: when there is a true, factual match M_t or when there is a true, factual non-match $\neg M_t$. So, we have (Thompson et al., 2003):

$$P(M_r|\neg S) = P(M_r|M_t)P(M_t|\neg S) + P(M_r|\neg M_t)P(\neg M_t|\neg S).$$

Now, $P(M_t|\neg S)$ equals RMP, and thus $P(\neg M_t|\neg S)$ equals $1 - RMP$. Also, $P(M_r|\neg M_t)$ describes the laboratory's false positive rate, abbreviated by FP. Finally, $P(M_r|M_t)$ describes the laboratory's true positive rate, or the inverse of the laboratory's false negative rate, abbreviated FN. So, we have (Thompson et al., 2003) and (Buckleton, 2005a):

$$P(M|\neg S) = [(1 - FN) \times RMP] + [FP \times (1 - RMP)].$$

The formula above shows that in order to properly estimate the value of $P(M_r|\neg S)$, we need a statistical estimate of the DNA profile's RMP *as well as* the laboratory's error rates (false positive and negative rates). Now suppose a DNA profile has a frequency as low as of 1 in 1 billion. Suppose laboratory false positive and false negative rates equal 0.01. If the likelihood ratio is simply equivalent to $1/RMP$, then it would be 1 billion. With the new formulation, we have:

$$\frac{P(M_r|S)}{P(M_r|\neg S)} = \frac{1}{[(1 - 0.01) \times 0.000000001] + [0.01 \times (1 - 0.000000001)]} \approx 100.$$

The calculation is as follows:

$= \frac{1}{[(1-0.01)\times 0.000000001]+[0.01\times(1-0.000000001)]}$

$= \frac{1}{0.99\times 0.000000001+[0.01\times(0.999999999)]}$

$= \frac{1}{0.00000000099+0.00999999999}$

$= \frac{1}{0.01000000098} \approx 100$ See (Thompson et al., 2003) for more details.

More generally, DNA profiles are not distributed across the population of the earth with a fixed stable probability. It is not the case that each individual has the same probability of been assigned a genetic profile. Rather, DNA profiles are part of our genetic make-up, which we receive through evolution and natural selection. We did not receive our DNA through a random process. Naturally enough, people who are related are more likely to share the same DNA profile than people who are unrelated (Buckleton, 2005b; Weir, 2007). This is why forensic experts must qualify their statements by saying that the RMP applies to a population of individuals *unrelated to the defendant*. Another complication is that the RMP probability varies depending on the population of interest, Caucasians, African-Americas, Asians etc (REFERENCE).

To summarize, the different sources of uncertainty that may weaken the strength of a DNA match relative to the hypothesis that the defendant is the source of the crime traces are as follows:

(a) the match could be coincidental, that is, a random person could match;

(b) the laboratory test result could be mistaken (cf. false positives and false negatives);

(c) the genetic material could be synthesized and implanted;

(d) the defendant could have an identical twin; and

(e) the DNA profile could be more or less frequent depending on the racial group.

If we considered only the first factor, the likelihood ratio $\frac{P(S|M)}{P(\neg S|M)}$ for a DNA match would simply be $1/RMP$. As we take into account the other factors, the likelihood ratio becomes more complex. Part of the problem in considering the other factors is that the required numbers for assigning the right probabilities might not be available. The rate of identical twins is well-known and available and the false positive and negative rates of a laboratory might also be available, but we certainly do not know how often genetic material is synthesized and implanted on the crime scene. It is also not clear how to incorporate into a single likelihood ratio the fact that a DNA profile has varying frequencies depending in the racial group.[9]

[9]Furthermore, likelihood ratios allow for an even more precise statement of the strength of DNA evidence toward the proposition that the defendant was the source of the crime traces. So far we spoke as though there is such a thing as a genetic match between the defendant's DNA and a the crime trace DNA. As a matter of fact, laboratory results do not yield any reported match. Rather, they yield a congruence result between two DNA profiles, one from the defendant and one from the crime traces. The two profiles are never perfectly identical; they are more or less congruent (Kaye, 1993). Instead of a reported match, what we really have are two pieces of evidence: one is the laboratory test showing that the defendant has the genetic profile d and the other is a laboratory test showing that the traces have the genetic profile t; call them G_d and G_t. Instead of M, we can use the conjunction $G_d \wedge G_t$. The likelihood ratio can therefore written more explicitly as follows:

$$\frac{P(G_d \wedge G_t|S)}{P(G_d \wedge G_t|\neg S)}.$$

Mention the fiction of chains of independent evidence; perhaps postpone discussion to section on coherence

References (Carnap, Skyrms, Fitelson, Schum, Kaye, Thompson)

[The problem of the old evidence? The issue of evidential strength of a DNA match after a database search?]

3.2 Arguments

Difference between deductive and presumptive arguments [inductive, abductive, ampliative, defeasible; what have you]

Args are good when surviving scrutiny under critical questions (arg schemes; Walton et al ...)

Args win when they can defend themselves against attacks (Dung 1995)

Args win when they are better/stronger than/preferred over conflicting args

Pros and cons can be weighed (accrual)

(Mention ?Pollock's anti-probabilism)

3.3 Scenarios

4 COHERENTLY INTERPRETING THE EVIDENCE

4.1 Scenarios

Often criminal cases form a mosaic. A DNA match can support the hypothesis that the suspect is the source, and a witness can add information about how the crime was committed. There is a lot of evidence that needs to be coherently combined in order to make sense of what has happened. How do we combine all information in a coherent whole? Consider a fairly realistic, though still quite simplified, scenario:

> *Ennio*. A woman is found dead in the woods. The investigators recover remnants of semen on her body, which is severely wounded; they also recover blood stains in a parking lot near the woods. The blood type matches with

This new formulation might not change the actual calculations, but it does make the reasoning clearer (Robertson and Vignaux, 1995).

> victim's blood type and DNA. From the semen on the woman's body, a DNA profile is created. Forensic experts estimate that the DNA profile in question has a statistical frequency of 1 in 100 million. Through a database search, it turns out that an individual in the neighborhood, Ennio, has a matching DNA profile. Ennio is arrested and charged with murder.

Imagine you are the prosecutor and you are constructing an incriminating case against Ennio. To a first rough approximation, four basic pieces of evidence are available:

(*semen*) Semen traces on the victim's body;

(*blood*) Blood stains in the parking lot;

(*wound*) Wounds from a knife on victim's body;

(*genetic match*) DNA match between Ennio and semen.

From the prosecutor's point of view, the four pieces of evidence above tend to establish, or at least they make a *prima facie* case in support of four hypotheses, as follows:

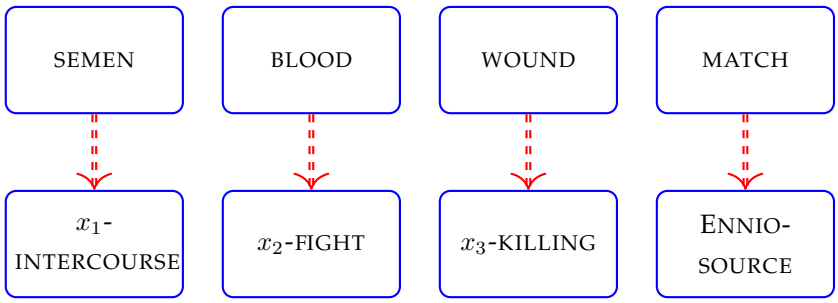
(x_1-*intercourse*) individual x_1 had intercourse with victim;

(x_2-*fight*) individual x_2 had violent fight with victim in parking lot;

(x_3-*killing*) individual x_3 killed victim with a knife;

(Ennio-*source*) Ennio is the source of the crime scene DNA.

The prosecutor, in constructing his incriminating case, can advance the four inferences:



The inference from the genetic match to the hypothesis that Ennio is the source of the crime scene DNA was discussed earlier while examining the evidential strength of DNA evidence. The acceptability of the other hypotheses (i.e. intercourse; fight; killing) depends on a number of case-by-case details: whether the semen on the victim's body was in a quantity, location, and arrangement that indicate intercourse; whether the wound on the victim's body was caused by a human artifact, e.g. a knife, and whether this caused the victim's death; etc. Without dwelling on unnecessary details, let's assume that forensic experts, on the basis of their experience, are willing to claim that the hypotheses in question can be established, at least *prima facie* and until objections are raised by the defense.

In order to make a unified case, the prosecutor can advance advance a *unification hypothesis*, as follows:

$$x_1 = x_2 = x_3 = \textit{Ennio}$$

The four initial hypotheses existed in isolation. They still left open the possibility that whoever had intercourse with the victim might be a different person from whoever fought with or killed the victim. They still left open the possibility that different people participated in the crime. The unification hypothesis, instead, identifies Ennio as the (only or main) perpetrator. The unification hypothesis, together with the others, asserts that Ennio had sexual intercourse with the victim, fought with the victim and finally killed her with a knife.

We now have a coherent and unifying case against the defendant Ennio. What is the ground to assert the unification claim? A number of considerations could weigh in here: when examined by forensic experts, the crime traces suggest the presence of one perpetrator only; the crime could, in principle, be committed by one person only; Ennio would have had the physical force to commit the crime alone; etc. Depending on the information available, the unification hypothesis will be more or less strongly supported. The evidential support for the unification hypothesis cannot be traced back to any single piece of evidence. The support for the unification claim heavily rests on holistic considerations based on cohesiveness. Putting everything together, the prosecutor's unified case against Ennio can be described as follows:

> The perpetrator had or attempted to have sexual intercourse with the victim in the parking lot (which explains the perpetrator's semen on the victim's body); a fight ensued during which the victim was wounded (which explains the blood stains in the parking lot); finally, the perpetrator killed the woman with a knife (which explains the wounds on the victim's body) and hid her body in the woods. Ennio is the perpetrator: he has a matching DNA profile whose frequency is as low as 1 in 100 millon.

Good properties of scenarios: completeness, plausibility (here??), coverage (see Pennington and Hastie)

Scenario schemes (Schank, Bex)

Arguments

Inference to the best explanation (Allen/Pardo?)

WORRY: Confused about this one; why is it under coherence?) [Answer BV: Otherwise nothing remains here.]

4.2 Probability

Hierarchy of propositions (Evett et al)

Combining difference pieces of evidence using probability

Multiplying likelihood ratios and question of independence among difference pieces of evidence We first need a general account of how to model the *combination* of two pieces of evidence E1 and E2, each supporting, with its own degree of strength, the same hypothesis H. If the strength of a single pieces of evidence E depends on how much it impacts $P(H)$, the same applies to the combination of two pieces of evidence. Bayes' theorem shows us how the combination of E1 and E2 impacts the probability $P(H)$, as follows:

$$\frac{P(H|E1, E2)}{P(\neg H|E1, E2)} = \frac{P(E1 \wedge E2|H)}{P(E1 \wedge E2|\neg H)} \times \frac{P(H)}{P(\neg H)}.$$

If E1 and E2 are independent and do not influence one another, we have:

$$\frac{P(H|E1, E2)}{P(\neg H|E1, E2)} = \frac{P(E1|H)}{P(E1|\neg H)} \times \frac{P(E2|H)}{P(E2|\neg H)} \times \frac{P(H)}{P(\neg H)}.$$

$$\frac{P(H|E1, E2)}{P(\neg H|E1, E2)} = LR1 \times LR2 \times \frac{P(H)}{P(\neg H)}.$$

Suppose, in a criminal case, DNA evidence shows that the crime traces match with defendant's DNA. The DNA match has a likelihood ratio, relative to hypothesis S, of 1,000. Another piece of evidence, independent of the DNA evidence, shows that the crime scene blood type is the same as the defendant's blood type. Suppose the likelihood ratio is now just 10. So, the combined evidential strength of the two pieces of evidence is $1,000 \times 10 = 10,000$. This is an example of how two pieces of evidence converge toward the same hypothesis.

This seems a largely unsolved problem for probabilistic accounts (and for the others accounts as well)

The BN connection

5 INTRODUCTION AND EXCLUSION OF THE EVIDENCE

So far we have examined how inferences can be drawn from the evidence. We now turn to the process of acquiring and presenting evidence in the context of trial proceedings. A system in which the parties have complete freedom in the acquisition and presentation of

the evidence at trial would be very simple and efficient, and yet, not without problems. Suppose a prosecutor or plaintiff found evidence favoring the defendant but decided not to disclose it nor present it at trial because of reasons of self interest. The withholding of the evidence would hinder the discovery of the truth and be unfair toward the defendant. The defendant, to be sure, might discover the evidence himself but that would require the monetary resources which indigent defendants typically do not have. So, because the divergent interests of the parties can hinder the discovery of the truth and put indigent defendants at an unfair disadvantage, legal rules are be in place to correct the imbalances between the parties in a trial.

This section illustrates certain legal rules for the acquisition, introduction and exclusion of the evidence. Since an exhaustive examination of the topic cannot be undertaken here, a few illustrative examples, mostly from the federal law of the United States, will be discussed.

Rules of discovery The *rules of discovery* regulate the acquisition of the evidence by the parties and the disclosure of the evidence between the parties, but do not regulate the introduction of the evidence at trial. We shall address the introduction (and exclusion) of the evidence at trial in due course.

Rule 26(b)(1) of the Federal Rules of Civil Procedure, for example, mandates that any relevant evidence, both in favor and against the defendant, must be disclosed by the party who possesses it upon request of the other party. The rule places defendants and plaintiffs on an equal footing insofar as both are under the obligation to disclose relevant information upon request. This arrangement, at least in theory, encourages the widest possible scrutiny of the facts prior to the confrontation at trial so that a trial by ambush is avoided. A party, however, may abuse Rule 26(b)(1) and use it to artificially delay the proceedings or force a settlement. Consider a plaintiff who is suing a hospital for malpractice and requests under rule Rule 26(b)(1) that the defendant disclose all email conversations of the past ten years. Retrieving and disclosing this information has staggering costs, in the order of millions of dollars, given that the number of email messages exchanged every day in a company is considerable. Since the party complying with the request of discovery must also bear the costs, the plaintiff might well make the discovery request not because there could be relevant information, but simply as a mere tactic to burden the defendant or force it to settle. This abuse indicates that the discovery costs should be allocated differently, although it is not easy to decide how.

By contrast, discovery rules in criminal cases are different from civil cases. In Brady v. Maryland (1963), 373 U.S. 83, the US Supreme Court ruled that, in criminal cases and upon request, the prosecution must disclose exculpatory evidence that is crucial for the defendant's case, while the defense is under no such obligation. The asymmetry between

defense and prosecution is justified by the different degrees of harm that may result if an error is committed at the detriment of the defendant or the prosecutor. A wrongful conviction, after all, will result in the defendant's unjust loss of liberty or even life, whereas a wrongful acquittal is thought to be less harmful. In civil trials, instead, the stakes are not so high for defendants, so the asymmetry between the parties is not so pronounced. EXAMPLE OF ABUSE OF DISCOVERY RULES IN CRIMINAL CASES.

We cannot address the complexity of the issues surrounding discovery rules. The above discussion, however, suggests two complications should be born in mind. The first is that acquiring evidence is costly. Introducing as much evidence as possible, both for and against the defendant, is a worthy objective, and yet, the discovery costs can be significant and should be allocated fairly. Should the costs be allocated to the parties according to the resources available to each? Should the party that initiates the litigation or the losing party bear the costs? The answer is not straightforward. The second complication is that in criminal cases the protection of innocent defendants against wrongful convictions takes priority over the scrutiny of the evidence. According to the Brady rule, it is the prosecution, but not the defense, who should disclose evidence of innocence. If the discovery of the truth was paramount, why not force the defense to disclose evidence of guilt? As far as discovery rules are concerned, the objective of collecting evidence and discovering the truth is weighed against the pragmatic limitations of the system, such as the limited economic resources of the litigants, but also against the moral imperative of protecting innocent defendants from wrongful convictions.

Exclusionary rules Rules of discovery apply to pre-trial proceedings, but if a case goes to trial a new question arises. What evidence can be presented at trial and what evidence is instead inadmissible? The basic rule here—shared by the jurisdiction of any country—is that relevant evidence is admissible and irrelevant evidence is inadmissible. Rule 401 of the Federal Rules of Evidence defines relevant evidence as 'evidence having any tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence'. It is customary to distinguish two dimensions operating in this definition: materiality and probative value (Fisher, 2008; Méndez, 2008). A piece of evidence is probative of a fact, provided the evidence makes the fact more (or less) probable than it would be in absence of the evidence. This is no different from the probabilistic characterization of evidential favoring, according to which a piece of evidence E supports a hypothesis H provided $P(E|H) > P(H)$ (SEE EARLIER SECTION OF THIS CHAPTER).

Incidentally, note that the word 'fact' can be misleading. In ordinary language, a fact is an occurrence or state of affairs that is true. If we say 'that's a fact', we are referring to something that is—or at lest, we take to be—unquestionably true. In legal jargon, instead,

a fact is sometimes understood to be a proposition that can be true or false. In this sense, facts at no different from hypotheses that can be true or false.

Besides the probative value of a piece of evidence relative to a fact (or a hypothesis), the materiality of the evidence is also important. A fact is material for establishing the action or crime under examination if it is of consequence to the determination of the action or crime. Whether or not a fact is of consequence to the determination of the action or crime depends on the substantive law which determines what facts should be proven in order to establish what crimes. EXAMPLE NEEDED HERE. Also, a fact is material if it is intermediary, that is, it is a fact that if true would help prove or disprove certain elements of the crime. EXAMPLE NEEDED HERE. Finally, a fact is material if it is evidentiary. For example, it is important to know whether the witness for the prosecutor was in fact present at the time of the crime. This has little to do with what the perpetrator did or with the crime itself, but it is an evidentiary fact that is important to ascertain. REFERENCE MISSING.

By combining probative value and materiality, we arrive at the following definition. A piece of evidence is relevant for establishing the commission of a crime if and only if the evidence is probative of a fact that is material for the crime. Relevance is a question of logic and common sense; it is not a legal question. There are no legal rules that prescribe the conditions under which an item of evidence is relevant or not. Logic and common should suffice here. REFERENCES HERE. EXPLAIN MORE? If the evidence is relevant, then it must in principle be admissible unless there is an exclusionary rule that rules it inadmissible. So, once the question of relevance is settled, admissibility becomes a strictly legal question whose answer depends on the law of the particular jurisdiction.

Countries in the common law tradition, especially the United States, have a very elaborate system of exclusionary rules. There exists also a specific branch of law, called Evidence Law, which consists of rules of the exclusion of otherwise relevant evidence. There are historical reasons why exclusionary rules are intricately developed in common law countries, but not in others, and this might have mostly to do with the institution of the jury. REFERENCE HERE. There have also been voiced against the presence of exclusionary rules. After all, the exclusion of relevant evidence from trial proceedings is likely to result in a loss in accuracy of the trial system. But, as we shall see, exclusionary rules are in place to contain certain prejudicial effects that the introduction of certain item of evidence may cause.

In general, any relevant evidence is admissible unless it is deemed inadmissible on the basis of specific rules of exclusion. The Federal Rules of Evidence (abbreviated FRE) reads:

> All relevant evidence is admissible, except as otherwise provided by the Constitution of the United States, by Act of Congress, by these rules, or by other rules prescribed by the Supreme Court pursuant to statutory authority. Evidence which is not relevant is not admissible. (FRE 402)

We shall now consider three well-established exclusionary rules that apply to trial pro-

ceedings in US federal courts: prejudice; character evidence; and hearsay.

Prejudice To begin with, rule 403 of the FRE establishes that:

> Although relevant, evidence may be excluded if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury, or by considerations of undue delay, waste of time, or needless presentation of cumulative evidence. (F.R.E. 403)

The rule requires the judge to perform a balancing test between the probative value of the evidence and certain negative or detrimental effects (prejudice, confusion, waste of time, etc.) that would be more or less likely to occur if the contested piece of evidence were to be introduced. This is a curious rule whose standard of application is far from being well defined. For instance, what are the items that are intended to be balanced? The degree of probative value with the likelihood of prejudice, confusions, waste of time, etc.? Or, the degree of probative value with the degree of harm associated with prejudice, confusion, waste of time? Does the balancing test include all three variables at once? REFERENCES NEEDED.

We do not hope to settle these question here. It is noteworthy, however, that the rule in question requires the judge to balance an epistemic value, such as the probative value of the evidence, with non-epistemic values or disvalues, such as prejudice, confusion and waste of time. Some have questioned whether any balancing test across epistemic and non-epistemic values is at all possible because it would be like comparing apples and oranges (Taruffo, 2009). On the other hand, balancing tests are ubiquitous in the law of evidence and procedure. In 4th Amendment case law about (un)reasonable searches and seizures, for example, two competing goals must be reconciled. One goal is the state's need to collect evidence and the other is the citizen's right not to have their privacy rights violated. The Supreme Court solution, in some cases, is to adopt a balancing-test. REFERENCES NEEDED HERE. It is an interesting question on its own whether the "balancing strategy" is the only, or the most appropriate strategy to undertake in case of a value conflict.

Character evidence We now turn to Rule rule 404(b) of the FRE about character evidence:

> Evidence of other crimes, wrongs, or acts is not admissible to prove the character of a person in order to show action in conformity therewith. (F.R.E., 404(b))

Character evidence concerns the previous conduct of the defendant, not the specific conduct under examination at trial. One reason why character evidence is considered inadmissible might be that it is irrelevant. Insofar as trials are *not* about what the defendant did prior to the alleged crime, character evidence is irrelevant. But, excluding character evidence on this ground would be too drastic. There is no doubt that past offenders are more

likely to reoffend than those without a criminal record REFERENCE NEEDED HERE. If this is correct, character evidence must count as relevant, at least insofar as the definition of relevant evidence from the FRE, rule 401, is concerned. The reason why character evidence is excluded, then, cannot be its lack of relevance. The problem with character evidence is of another sort. Although it is relevant, character evidence can have significant prejudicial effects on the decision making process. This is true especially in a jury trial in which the the jurors might take the defendant's criminal record as unduly strong evidence that the defendant did engage in criminal conduct one more time. The problem with character evidence, then, is that the lay jurors might exaggerate its probative value.

It is, however, far from uncontroversial that character evidence should be excluded from trials. The exclusion of character is mostly a feature of the common law tradition, but even in the common law there are exceptions to the rule, and some scholars have recently argued that character character evidence should be admissible (Redmayne, 2002).

Hearsay Together with the exclusion of character evidence, the exclusion of hearsay evidence is a well-entrenched rule in the common law. Rule 802 of FRE established that hearsay evidence is not admissible unless provided otherwise by the FRE themselves or some other legal provision. DEFINITION OF HEARSAY. There are countless exceptions to the hearsay rule, and some of these are described in rule 803 of the FRE. EXAMPLE OF THE EXCEPTIONS.

There are at least a couple of rationales for the exclusion of hearsay evidence. One rationale is that it is unreliable. A witness who saw the crime and can recount what she saw in court seems a more reliable source of information than a second hand-witness who can only recount what another witness told her about the crime. It is because of the more indirect chain of transmission of information that hearsay evidence might be less reliable. The more intermediaries in the chain, the more corrupt the information at the end of the chain. REFERENCES NEEDED. Another reason why hearsay evidence is excluded is that it cannot be scrutinized or cross examined. If witness 1 testifies in court that witness 2 told witness 1 that the defendant did so and so during the crime, the witness that should be cross examined is witness 2, and instead the witness who is testifying in court is witness 1. This setting undermines the right of defendants to confront their accusers and cross examine them. REFERENCES. MORE EXPLANATION NEEDED HERE.

Exclusionary rules, free proof, rules of weight THIS PARAGRAPH WILL DISCUSS ALTERNATIVES TO THE SYSTEM OF ADMISSIBILITY RULES. ONE ALTERNATIVE IS FREE PROOF, WHICH MEASN TO INTRODUCE AS MUCH EVIDENCE AS POSSIBLE WITHOUT ANY RULE OF EXCLUSION OR VIRTUALLY NO RULE OF EXCLUSION. THE OTHER ALTERNATIVE IS HAVING RULES OF WEIGHT, RULES THAT DETER-

MINE HOW THE EVIDENCE SHOULD BE WEIGHTED AND ASSESSED. THE SYSTEM OF ADMISSIBILITY RULE SITS SOMEWHERE IN THE MIDDLE.

6 WHEN CAN WE CONVICT?

Once all the evidence has been introduced at trial, examined and cross-examined, it comes a time when the fact-finders—either a trained judge or the jurors themselves—have to make a decision. Convict or acquit? The decision must be based on the evidence presented, and not on human sympathy or hatred, and it must be based on the law governing the case. This still leaves open an important question. What decision criterion governs the decision? This criterion, in criminal trials, is known as the *beyond a reasonable doubt* standard and it is adopted in many countries even outside the common law countries. MORE EXPLANATION HERE (TALK ABOUT FRANCE GERMANY ITALY SPAIN) If the fact-finders are persuaded of the defendant's guilt beyond a reasonable doubt, they should convict, or else they should acquit. This rises a host of difficult questions. What does it mean to establish guilt beyond a reasonable doubt? When is a doubt reasonable or unreasonable? Can the standard be given a more precise meaning and characterization? We can only begin to scratch at the surface of these questions and point the reader toward existing literature.

Informal clarifications Explications of when a doubt is reasonable or unreasonable abound. In Commonwealth v. Massachusetts Webster (1850), proof beyond a reasonable doubt is equated to 'reasonable and moral certainty' (295, 59 Mass., 320). Another paraphrase is that proof beyond a reasonable doubt is such that 'a reasonable person would not hesitate to act upon it in the most important of his own affairs,' or again, proof beyond a reasonable doubt must cause 'an abiding conviction in the minds of the jurors.' These paraphrases might not be that unhelpful, and if so, the U.S. Supreme Court is quite right when it says that 'attempts to explain the term "reasonable doubt" do not result in making it any clearer' (Holland v. United States (1954), 348 U.S. 121, 140).

Another strategy for clarifying proof beyond a reasonable doubt is to identify certain constraints that the standard should satisfy, avoiding the trouble of proving a precise definition. Following this strategy, the Supreme Court of Canada in R. v. Lifchus (1997) listed some platitudes which are worth stating:

> (-) the standard of proof beyond a reasonable doubt is inextricably intertwined with that principle fundamental to all criminal trials, the presumption of innocence;
>
> (-) the burden of proof rests on the prosecution throughout the trial and never shifts to the accused;

> (-) a reasonable doubt is not a doubt based upon sympathy or prejudice; rather, it is based upon reason and common sense;
>
> (-) it is logically connected to the evidence or absence of evidence;
>
> (-) it does not involve proof to an absolute certainty; it is not proof beyond any doubt nor is it an imaginary or frivolous doubt; and
>
> R. v. Lifchus (1997) at 335.

Most would find the Court's remarks unobjectionable. The Court did not only explicate when a doubt is 'reasonable,' but it also explicitly linked the criminal standard to other related notions, such as the presumption of innocence, the burden of proof, the presence and absence of evidence, reason and common sense. These connections are important and help us see the role that the standard proof beyond a reasonable doubt plays in the criminal trial.

Probability-based account For those who seek a more analytic characterization of the standard, these informal clarifications might be unsatisfactory. Legal scholars have tried to give more analytic characterizations and we shall consider three such attempts. In the existing literature, one prominent view is legal probabilism. It is the view that establishing guilt beyond a reasonable doubt means to establish that the defendant's *probability of guilt*, given the total evidence presented at trial, meets a threshold, say, 0.99 or 0.999 (Kaplan, 1968; Kaye, 1999; Tillers and Gottfried, 2007). Consequently, a doubt would be reasonable or unreasonable depending on a measurable probability.

This definition is simple, crisp and elegant, but a too literal interpretation of it is obviously problematic. If a probabilistic threshold is understood as a criterion which the fact-finders should mechanically apply whenever they confront the decision to convict or acquit, two difficulties arise. The first difficulty is that assigning a probability value to guilt itself might not be feasible. This difficulty, however, can be sidestepped if we understand legal probabilism less mechanistically. The legal probabilists can defend their proposal by conceding that they are not offering a recipe that should be directly implementable in court. Assigning probabilities to propositions, they could say, is an idealized process, a regulative ideal which can improve trial proceedings. In this spirit, setting a probabilistic criterion for criminal convictions would only be a way to theorize about the meaning and function of the criminal standard of proof. REFERENCE HERE.

The second difficulty is that it is not clear where, exactly, the threshold should be placed: is it 0.99, 0.89, 0.899, 0.999, or what? The difficult here is not so much with identifying a precise numerical value. After all, a range of acceptable values instead of a precise threshold could still be used. The problem here is rather, where to place the bar, whether the bar corresponds to a precise value or an interval of acceptable values? IN response to

this question, David Kaplan used a relative assessment of the disutilities associated with convicting an innocent, D_i, and with acquitting a guilty defendant, D_g. Suppose the probability of guilt and innocence equals P_g and P_i such that $P_g = 1 - P_i$. To convict—Kaplan suggests—the jury must be believe that

$$P_g D_g > (1 - P_g) D_i.$$

The inequality represents a situation in which the expected disutility resulting from acquitting a guilty defendant is larger than the disutility resulting from convicting an innocent defendant. So, given the inevitable possibility of error, such a situation would be one in which convicting is less harmful than acquitting, so that conviction is justified. As one can see, this is an application of the more general statistical decision theory based on maximization of expected utility or the minimization of expected loss. REFERENCES HERE.

The inequality holds only if P_g reaches a certain value. From the inequality, by algebra, we have

$$\frac{P_g}{1-P_g} > \frac{D_i}{D_g}.$$

This formula gives a precise indication of how high the probability of guilt must be to justify a guilty verdict, relative to the ratio between D_i and D_g. If we consider that the disutility of convicting an innocent is as harmful as the disutility of acquitting an innocent, i.e., $D_g = D_i$—as it might be the case in a civil case—, the lower bound for P_g must be at least $\frac{1}{2}$. If, instead,we think that $\frac{D_i}{D_g} = \frac{9}{1}$—as it might be more appropriate in a criminal case—, the lower bound for P_g must be at least 0.9. More complicated models are also possible, but the basic idea is that the probability required for a conviction will be a function of weighing certain social and economic costs that would result from erroneous decisions.

Scenario-based account Some scholars suggested that we should elaborate a theory of legal reasoning which departs from the probabilistc approach and which does not ignore trial procedures broadly construed (Cohen, 1977; Nesson, 1979; Thomson, 1986; Walton, 2002; Stein, 2005; Pardo and Allen, 2008b; Ho, 2008; Haack, 2011). The key notion here seems to be plausibility rather than probability. Ronald Allen (2010) recently suggested that that '[no] plausible alternative to a plausible story of guilt [should be] the rule of decision in criminal cases' and that '[i]n criminal cases, fact finders find guilt if there is a plausible story of guilt and no plausible story of innocence; otherwise, they find innocence.'

The plausibility-based approach is appealing, but the obvious problem is that the notion of a 'plausible story' or of a 'plausible alternative to a plausible story' is wholly underdefined. SAY MORE HERE Still, if the notion of plausibility is hard to define precisely, it seems closer to how jurors actually reason in trial proceedings, whereas the notion of probability, despite its mathematical underpinnings, is hard to relate to actual trial proceedings: jurors do not naturally quantify guilt, and it is difficult to quantify it even if we wanted to.

We face a trade-off: probability is a formally developed notion, but it is removed from trial proceedings and common-sense reasoning; plausibility lacks a well-established theory, but it is closer to trial practice.

Argumentation-based account

7 SUMMARY AND CONCLUSION

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