WHY A CONVICTION SHOULD NOT BE BASED ON A SINGLE PIECE OF EVIDENCE: A PROPOSAL FOR REFORM

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ABSTRACT: This article illustrates a serious flaw in the conventional legal approach enabling a conviction based solely on one piece of evidence. This flaw derives from a cognitive illusion referred to as "the fallacy of the transposed conditional." People might assume a low error rate in evidence only leads to a small percentage of wrongful convictions. We show that, counterintuitively, even a very low error rate might lead to a wrongful conviction in *most* cases where the conviction is based on a single piece of evidence. Case law has indicated some awareness of this fallacy, primarily when considering the random match probability for DNA evidence. However, there is almost no awareness of the significance of this fallacy in assessing other types of evidence not considered probabilistic or of the significance of laboratory errors in DNA testing. We show that mistakes do happen with all key types of evidence: fingerprints, DNA, confessions, and eyewitness testimony. We then demonstrate the tremendous impact that even a small probability of error has on our confidence in a conviction. In the end, we propose legislative reform that would make it impossible to convict someone on the basis of any single piece of evidence linking him to a criminal offense.

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Following studies conducted in recent decades, there is no longer any reason to doubt that innocent persons are actually convicted of crimes, or that, in some of these cases, the wrongful conviction is based upon a single piece of evidence.[1] Some might assume that a low error rate for evidence—such as a fingerprint, a DNA sample, a confession, or the testimony of an eyewitness—only leads to a small percentage of wrongful convictions. However, we shall show that, counterintuitively, even a very low error rate for evidence might lead to a wrongful conviction in *most* cases where the conviction is based on a single piece of evidence. Given this danger of convicting the innocent, the theory proposed herein is that, as a society, we should no longer allow defendants to be convicted on the basis of any single piece of evidence.

Our argument relates to what is termed "the fallacy of the transposed conditional."[2] In the legal community, this has been commonly referred to as "the prosecutor's fallacy."[3] It describes a situation where the fact finder in a trial mistakenly confuses the probability of the evidence given guilt or innocence with the inverse conditional probability crucial for the purposes of reaching a fateful legal verdict—namely, the probability of guilt or innocence given the evidence.[4] In Bayesian language, in order to determine the probability of guilt-innocence given the evidence (as opposed to the probability of the evidence given guilt-innocence), the prior probability of guilt must be taken into account—namely, the probability of guilt without the key evidence against the suspect.[5] For example, when there is a single piece of identification evidence for a conviction, the prior probability could be very low, because, apart from this single piece of evidence, any other person could be the perpetrator. The prior probability in such cases might be as low as the number one divided by the size of the population. When such a low prior probability is ignored, the cognitive illusion reaches extreme proportions and the error by the fact finder could be enormous. We establish our theory also without the use of Bayesian concepts, *inter alia*, by translating probabilities into frequencies in a manner that illustrates this fallacy.

Up until now, only the buds of this theory have been visible—and only in relation to scientific evidence.[6] The legal community has been wary of falling into the trap of this fallacy as it concerns the random match probability in DNA testing.[7] The weight of the evidence regarding the random match

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1. *See infra* Part I.

2. Persi Diaconis & David Freedman, *The Persistence of Cognitive Illusions*, 4 BEHAV. BRAIN SCI. 317, 333 (1981).

3. State v. Spann, 617 A.2d 247, 258 (N.J. 1993); William C. Thompson & Edward L. Schumann, *Interpretation of Statistical Evidence in Criminal Trials: The Prosecutor's Fallacy and the Defense Attorney's Fallacy*, 11 LAW & HUM. BEHAV. 167, 170 (1987).

4. Thompson & Schumann, *supra* note 3, at 170–72.

5. *Id.* at 170–71 n.2.

6. Gonzalez v. Metro. Transp. Auth., 174 F.3d 1016, 1023 (9th Cir. 1999) (discussing the "Bayes' theorem problem" concerning a random unannounced testing for drugs and alcohol); *see also* Ishikawa v. Delta Airlines, Inc., 343 F.3d 1129, 1131 (9th Cir. 2003) (random unannounced testing for drugs and alcohol); *supra* note 3 (for statistical evidence).

7. *See infra* note 156.

probability is not measured independently, but is balanced against the other evidence in the particular case.[8] However, the possibility of a laboratory error, which is much more likely than a random match and is, therefore, much more significant, is examined independently from the other evidence without considering the danger of a conviction based on a single piece of evidence.[9] Counterintuitively, an error rate of only one mistake in every ten thousand tests in a specific laboratory could lead to a wrongful conviction in *most* cases where a conviction is based on a single piece of evidence.

The situation is even worse regarding fingerprint evidence. Not only is there a tendency, as with DNA testing, to ignore the possibility of an error, there is also a tendency to ignore the possibility of a random match between fingerprints (or at least the possibility of a result similar to a random match).[10] As we shall see below, the conventional attitude towards this evidence is erroneous, misleading, and dangerous.

This article does not limit its discussion to scientific evidence. It also tries to convince the reader that nonscientific evidence can raise the possibility of a mistaken conviction that is so great that it should be forbidden when based on a single piece of evidence.

In a previous paper, one of the authors of this article tried to show that to avoid the terrible injustice of convicting innocent persons based on false confessions, "strong corroboration" should be required as an essential condition for any conviction based on a confession: strong, independent, and significant evidence connecting the defendant to the offense with which he is charged.[11] Here, the authors apply their proposed theoretical model to confessions as well, in order to support further the conclusion that a person should not be convicted solely on the basis of a confession. We also examine identification by means of eyewitness testimony in order to establish the proposed theory's application to nonscientific evidence.

In addition, we warn against the special danger of finding suspects through systematic searches of, for example, fingerprint or DNA databases. A concrete example of this danger, from which we shall attempt to draw important lessons, was provided recently in the case of the mistaken identification of Brandon Mayfield.[12] This same danger exists for nonscientific evidence, such as confessions and eyewitness testimony.

This article therefore proceeds as follows: in Part I, we briefly examine the danger of convicting innocent persons; in Part II, we propose a general theory; in Parts III, IV, V, and VI, the general theory is applied to two major forms of scientific evidence (DNA and fingerprints) and two key types of nonscientific evidence (confessions and eyewitness testimony). We show that errors are made with all these forms of evidence, demonstrating the danger of

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8. *See infra* Part II.D.

9. *Id.*

10. *See infra* Part III.A.

11. Boaz Sangero, Miranda *is Not Enough: A New Justification for Demanding "Strong Corroboration" to a Confession*, 28 CARDOZO L. REV. 2791 (2007).

12. *See infra* Part III.B.

convicting an innocent person when relying solely on any one of them. Finally, we propose legislation to prohibit convictions based on any single piece of evidence.

I. THE TERRIBLE DANGER OF CONVICTING THE INNOCENT

Among the injustices inflicted upon individuals by society, the conviction of an innocent person would seem to be the greatest of all. Society itself suffers harm from a wrongful conviction because the real criminal remains at large.

In the past, there has been a tendency to doubt that a significant number of innocent persons are convicted of crimes. In England, a conservative approach prevailed for a long time that denied such a phenomenon.[13] This approach was severely shaken upon the disclosure of the renowned cases referred to as the Birmingham Six[14] and the Guildford Four[15]—the wrongful convictions of Irish individuals who fell victim to "predatory" British investigators. Following the revelations of these cases, the Runciman Commission was appointed and, as a result of its 1993 report,[16] the English approach was altered considerably. Thus, for example, the Criminal Cases Review Commission (CCRC) was established—an independent public body whose role is to examine cases where a claim is raised that an innocent person has been convicted.[17] The CCRC conducts its own inquiries and transfers suitable cases to the courts for reconsideration.[18] In a number of these cases (dozens each year), convicts have been acquitted and released from prison.[19]

In the United States, studies have also been published demonstrating the existence of a significant number of wrongful convictions.[20] However, skeptics remained doubtful.[21] That is, until the advent of DNA testing. Since the establishment of Benjamin N. Cardozo School of Law's Innocence Project in 1992,

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13. *See, e.g.*, CLIVE WALKER & KEIR STAMER, JUSTICE IN ERROR 16 (Blackstone Press 1993) (acknowledging this approach, while expressing reservations about it).

14. R. v. McIlkenny, (1991) 93 Cr. App. R. 287.

15. R. v. Richardson, The Times, Oct. 20, 1989, 1989 WL 651412 (C.A. Crim. Div. 1989).

16. ROYAL COMM'N ON CRIMINAL JUSTICE REPORT: PRESENTED TO PARLIAMENT BY COMMAND OF HER MAJESTY, JULY 1993, ISBN 0101226322, Cm. 2263 (HMSO London 1993) [hereinafter Runciman Commission Report].

17. CCRC Web Site, http://www.ccrc.gov.uk.

18. *Id.*

19. *Id.*; Lissa Griffin, *The Correction of Wrongful Convictions: A Comparative Perspective*, 16 AM. U. INT'L L. REV. 1241, 1275–78 (2001).

20. *See, e.g.*, Hugo Adam Bedau & Michael L. Radelet, *Miscarriages of Justice in Potentially Capital Cases*, 40 STAN. L. REV. 21 (1987); Arye Rattner, *Convicted but Innocent: Wrongful Conviction and the Criminal Justice System*, 12 LAW & HUM. BEHAV. 283 (1988); Richard A. Leo & Richard J. Ofshe, *The Consequences of False Confession: Deprivations of Liberty and Miscarriages of Justice in the Age of Psychological Interrogation*, 88 J. CRIM. L. & CRIMINOLOGY 429 (1998).

21. *See, e.g.*, Gerald M. Caplan, *Questioning Miranda*, 38 VAND. L. REV. 1417, 1457 (1985); Laurie Magid, *Deceptive Police Interrogation Practices: How Far Is Too Far?,* 99 MICH. L. REV. 1168, 1190 (2001).

more than two hundred prisoners convicted of murder or rape and sentenced to life imprisonment or death have been exonerated on the basis of DNA evidence.[22] This represents about two thirds of the cases examined![23] Some of the mistaken convictions had been based on a single piece of evidence.[24]

Following the extraordinary findings of the Innocence Project, it is no longer a question of whether or not wrongful convictions occur but, rather, to what extent they occur, how they can be minimized, and what needs to be done when they are discovered. In many previous studies, attempts have been made to address a specific cause for the conviction of innocent persons—usually one particular type of evidence, such as eyewitness testimony.[25] This article stresses that a common factor in a great number of these unfortunate cases is that the wrongful conviction was based on a single piece of evidence. By relying on models of logic and mathematics well accepted in other fields, such as the field of medical diagnosis, we try to show, *inter alia*, that the only way to significantly reduce the terrible danger of convicting innocent persons is to refrain entirely from basing any conviction on a single piece of evidence.

II. THE PROPOSED GENERAL THEORY

A. The Impact of a False Positive in Medical Diagnosis

We start with an example that appears quite surprising. Let us assume that there is a home kit for performing an HIV test and that the manufacturer reports an average false positive rate of 0.1% when this kit is used. Namely, if a thousand healthy people are tested with the kit, only one of them would get a false positive indicating that he is a carrier of the HIV virus. A random person, Mr. Smith, is tested with the kit, and the result is positive. What is the probability that he is actually an HIV carrier?

Most people would answer this kind of question by saying that there is a 99.9% likelihood that the unfortunate Mr. Smith is a carrier of the HIV virus

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22. *See* Innocence Project Web Site, www.innocenceproject.org; BARRY SCHECK ET AL., ACTUAL INNOCENCE: FIVE DAYS TO EXECUTION AND OTHER DISPATCHES FROM THE WRONGLY CONVICTED 246 (Doubleday 2000); Keith A. Findley, *Learning from Our Mistakes: A Criminal Justice Commission to Study Wrongful Convictions*, 38 CAL. W. L. REV. 333 (2002); Elizabeth V. Lafollette, State v. Hunt *and Exculpatory DNA Evidence: When Is a New Trial Warranted?*, 74 N.C. L. REV. 1295 (1996); David De Foore, *Postconviction DNA Testing: A Cry For Justice From The Wrongly Convicted*, 33 TEX. TECH. L. REV. 491 (2002); Karen Christian, *"And the DNA Shall Set You Free": Issues Surrounding Postconviction DNA Evidence and the Pursuit of Innocence*, 62 OHIO ST. L. J. 1195 (2001).

23. SCHECK ET AL., *supra* note 22, at xiv.

24. *See, e.g.*, *id.* at 53 (discussing the wrongful conviction of Walter T. Snyder, based only on the testimony of an eyewitness); U.S. DEP'T OF JUSTICE, NAT'L INST. OF JUSTICE, CONVICTED BY JURIES, EXONERATED BY SCIENCE: CASE STUDIES IN THE USE OF DNA EVIDENCE TO ESTABLISH INNOCENCE AFTER TRIAL 42–43 (1996), *available at* www.ncjrs.gov/pdffiles/dnaevid.pdf (discussing the wrongful conviction of Terry Leon Chalmers); SCHECK ET AL., *supra* note 22, at 146 (discussing the wrongful conviction based only on the testimony of a snitch).

25. *See infra* Part VI.

and only a 0.1% possibility that a false positive has occurred.[26] Is this true? There is a big difference between conditional probability and inverse conditional probability. The answer to the question, "what is the probability of a positive test result given that the person tested is healthy?" is 0.1%. But we are asking an entirely different question; "what is the probability that the person tested is actually a carrier of the virus given a positive test result?"

Let us assume that Mr. Smith is in a low-risk group (he practices safe sex, does not use intravenous needles, does not require blood transfusions, etc.) and that in this risk group the frequency of the HIV virus is one case in ten thousand. In the professional jargon, it is said that the base rate (the frequency in a specific population) of the virus in this low-risk population group is 1 in 10,000.

If 10,000 people from Mr. Smith's low-risk group were to be tested with the home kit, the result would be positive in 11 cases: 10 cases of error (false positives) for healthy persons (9,999 x 0.1% ≅ 10), together with one person who is actually a carrier (because, in this low-risk group, 1 out of 10,000 people is a carrier).[27] Surprisingly, and contrary to our first intuition, it appears that, although the test shows Mr. Smith to be a carrier, the probability that this is actually the case is only 1/11, or about 9%; whereas the probability of a false positive is 10/11, or about 91%. Hence, a test that might be considered quite accurate for members of a high-risk group can be expected to be misleading for members of a low-risk group.[28]

The medical field uses a system of biostatistical concepts: "positive predictive value" is defined as the probability of disease given a positive test result.[29] This probability is calculated not just by taking the test results into consideration, but also the false positive rate and the prior probability that the tested person would be sick (without considering the test findings), which is determined by his risk group.[30] The positive predictive value distinguishes between conditional probability and inverse conditional probability and accurately describes the relationship between them. From a quantitative perspective, it may be directly calculated by means of Bayes' Theorem.

Before applying Bayes' Theorem, we should clarify that the theory proposed in this article is not dependent upon it, and readers who are not interested can skip over the mathematical explanation. Bayes' Theorem, which was

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26. Ward Casscells, Arno Schoenberger & Thomas B. Grayboys, *Interpretation by Physicians of Clinical Laboratory Results*, 299 NEW ENG. J. MED. 999–1000 (1978).

27. We assume that there is no possibility of a false negative, that is, that the test will never come up negative for a carrier.

28. It would seem that the problem arises even for high-risk groups, although it is not as severe. Suppose Smith is in a risky group in which 1 out of every 100 people is a carrier. Then, doing the test on 10,000 people will give 110 positives—the 100 that are carriers and the 10 false positives. For anyone who tests positive, the odds are only 100/110 that he is, in fact, a carrier, which is lower than the 99.9% that one would conclude by the incorrect method.

29. Douglas G. Altman & J. Martin Bland, *Diagnostic Tests 2: Predictive Values*, 309 BRIT. MED. J. 102, 102 (1994).

30. *See id.*

formulated in the eighteenth century,[31] is very important in applied probability theory and may be expressed literally, in odds form, as follows:

(1) Posterior Odds = Likelihood Ratio × Prior Odds [32]

In Mr. Smith's case, the accuracy of the test (99.9%) is a component of the likelihood ratio. The likelihood ratio here is the quotient of two conditional probabilities. The numerator is the probability that the test result will be positive given that the person tested is a carrier, while the denominator is the probability that the test result will be positive given that the person tested is not a carrier. If we assume that the probability of a false negative (a negative test result for a carrier) is zero, then the likelihood ratio (denoted by LR), is as follows:

(2) LR = 1 / 0.001 = 1,000

The prior odds are the probability that a person is a carrier divided by the probability that he is not a carrier, *without* taking the test result into account. Regarding Mr. Smith, who belongs to a low-risk group, with a base rate of 1/10,000, the prior odds (denoted by PO) are:

(3) PO = 0.0001 / (1 – 0.0001) ≅ 0.0001 [33]

The posterior odds are the probability that a person is a carrier divided by the probability that he is not a carrier, given a positive test result. We shall now insert the above figures into Bayes' Theorem:

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31. Thomas Bayes, *An Essay Towards Solving a Problem in the Doctrine of Chances*, 53 PHIL. TRANSACTIONS ROYAL SOC'Y LONDON 370 (1763), *reprinted in* FACSIMILES OF TWO PAPERS BY BAYES (W. Edwards Deming ed., 1940).

32. *See, e.g.*, COLIN AITKEN & FRANCO TARONI, STATISTICS AND THE EVALUATION OF EVIDENCE FOR FORENSIC SCIENTISTS 95 (2d ed. Wiley 2004); A. Philip Dawid, *Bayes's Theorem and Weighing Evidence by Juries*, 113 PROCEEDINGS OF THE BRITISH ACADEMY 71, 72–75 (2002). As a mathematical expression, Bayes' Theorem in odds form can be explained as follows: In general, P(A|B) denotes the probability of A given B. In the case of the medical diagnosis, we are dealing with two alternative hypotheses and a given occurrence. The first hypothesis is that the person tested is a carrier (denoted by "H"). The second hypothesis is that the person is healthy (denoted by "H1"). The given occurrence is a positive test result (denoted by "D").

The likelihood ratio is defined as: $\text{likelihood ratio} \equiv \frac{P(D \mid H)}{P(D \mid H1)}$. The prior odds are defined as: $\text{prior odds} \equiv \frac{P(H)}{P(H1)}$. The posterior odds are defined as: $\text{posterior odds} \equiv \frac{P(H \mid D)}{P(H1 \mid D)}$. Therefore, Bayes' Theorem, written in odds form, is as follows: $\frac{P(H \mid D)}{P(H1 \mid D)} = \frac{P(D \mid H)}{P(D \mid H1)} \times \frac{P(H)}{P(H1)}$; or, in the accepted literal form as: posterior odds = likelihood ratio × prior odds.

33. The denominator is supposed to complete the numerator to 1, since the probability that a person is a carrier and the probability that he is not a carrier are complementary probabilistic occurrences.

(4) Posterior Odds = Likelihood Ratio × Prior Odds = 1,000 × 0.0001 = 0.1

The posterior odds—which are what we are looking for in order to accurately evaluate Mr. Smith's situation—are 1/10. In other words: in 11 cases where the test result is positive for someone from this particular low-risk group, only one person will actually be a carrier, and the test will be erroneous in 10 cases. This is, in fact, the result that we arrived at in the previous section without directly using Bayes' Theorem, but by adopting its underlying rationale.[34]

Our initial—very mistaken—intuition that, since the test's accuracy is 99.9%, there is only a 0.1% probability that Mr. Smith is not a carrier (whereas the actual probability of error, 10/11, is about 910 times greater), derives from what is referred to in psychological literature as the "base rate fallacy" or "base rate neglect."[35] This may also be referred to as the fallacy of the transposed conditional: instead of answering the question of what is the probability that a person is healthy given a positive test result (10/11 = 90.91%), we answer the opposite question of what is the probability of getting a positive test result given that a person is healthy (1/1000 = 0.1%). In Bayesian language, the source of this fallacy is that the prior odds in Bayes' Theorem are ignored and, as a result, the posterior odds are equated with the likelihood ratio. As Kahneman and Tversky have written: "The failure to appreciate the relevance of prior probability in the presence of specific evidence is perhaps one of the most significant departures of intuition from the normative theory of prediction."[36]

Lawyers and judges have also fallen into the trap of these cognitive fallacies when, by relying on a single piece of evidence, they ignore the prior odds and fail to distinguish between conditional probability and inverse conditional probability.

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34. According to the definition of the posterior odds, and since the occurrences in the numerator and the denominator are complementary, it is possible to calculate the probabilities of both health and illness given a positive test result, as follows:

$$P(\text{Health} \mid \text{Positive test}) = \frac{1}{1 + \text{posterior odds}} = \frac{1}{1 + 0.1} = 10/11$$

$$P(\text{Illness} \mid \text{Positive test}) = \frac{\text{posterior odds}}{1 + \text{posterior odds}} = \frac{0.1}{1 + 0.1} = 1/11$$

35. Maya Bar-Hillel, *The Base-Rate Fallacy in Probability Judgments*, 44 ACTA PSYCHOLOGICA 211, 211 (1980); Maya Bar-Hillel, *Subjective Probability Judgments*, *in* 22 INTERNATIONAL ENCYCLOPEDIA OF THE SOCIAL & BEHAVIORAL SCIENCES, 15,247, 15,247–51 (Neil J. Smelser & Paul B. Baltes eds., 2002); Amos Tversky & Daniel Kahneman, *Evidential Impact of Base Rates*, *in* JUDGMENT UNDER UNCERTAINTY: HEURISTICS AND BIASES 153, 153–60 (Daniel Kahneman, Paul Slovic & Amos Tversky eds., 1982).

36. Daniel Kahneman & Amos Tversky, *On the Psychology of Prediction*, 80 PSYCHOL. REV. 237, 243 (1973).

B. From Medical Diagnosis to Legal Decision

As in the case of medical diagnosis, discussed above, when evaluating scientific evidence presented before a court of law, both falling for the transposed conditional fallacy and false positives are possible. As we shall see, the legal community is only aware in certain cases of the significance of prior information (the other evidence) in examining the probability of error, whereas, in many other cases, it does not consider this.[37]

When we explore the special danger of a conviction based on a single piece of evidence, we can draw lessons from the medical diagnosis problem discussed above. Indeed, some researchers believe that cognitive illusions are reduced when frequencies are presented instead of the probability of an isolated incident.[38] We can also treat the special problem of a single piece of evidence by using Bayes' Theorem (appearing in equation (1) above), with certain adjustments.

In a legal examination, the given occurrence is a positive result in scientific evidence. The probability of being a carrier is replaced by the probability of guilt, whereas the probability of health is replaced by the probability of innocence. In the medical field, the prior probability can be discerned from the base rate. In the legal field, the prior probability is the judge's assessment of whether or not the accused committed the crime, without taking into account the main (scientific) evidence, but based, rather, on other evidence.[39]

We should remember that the question the court must resolve is the probability of guilt given a positive test result (such as a fingerprint match). Science is unable to resolve this question, but can provide a limited answer (to the extent of the test's accuracy) to another question—the probability of a positive test result given guilt. Therefore, in order to answer the first question, it is essential to take into account the prior probability, which is discerned from the presence or absence of other evidence.

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37. Jonathan J. Koehler, *When Do Courts Think Base Rate Statistics Are Relevant?*, 42 JURIMETRICS J. 373 *passim* (2002) (discussing the actual question of when the courts think that prior statistical information is relevant).

38. Ulrich Hoffrage et al., *Communicating Statistical Information*, 290 SCIENCE 2261, 2262 (2000); *see also* Gerd Gigerenzer & Ulrich Hoffrage, *How to Improve Bayesian Reasoning Without Instruction: Frequency Formats*, 102 PSYCHOL. REV. 684 *passim* (1995).

39. State v. Spann, 617 A.2d 247, 254 (N.J. 1993); Koehler, *supra* note 37, at 375–77; *see also* Michael J. Saks & D. Michael Risinger, *Baserates, the Presumption of Guilt, Admissibility Rulings, and Erroneous Convictions*, 2003 MICH. ST. L. REV. 1051 *passim* (2003).

There has been a debate over the use of Bayes' Theorem in court.[40] One major criticism is against the quantification of evidence that contains a subjective element of judgment and estimation.[41] Another major criticism against the use of Bayes' Theorem in criminal law is that this might erode the presumption of innocence.[42] Some courts have rejected the use of Bayes' Theorem in a criminal trial,[43] while other courts have been more amenable to its use, subject to certain restrictions.[44] We use the logic of Bayes' Theorem as another means to show that a conviction based on a single piece of evidence is uncertain. It should be made clear, as we shall demonstrate below, that the thesis of our article is not influenced by this debate, and our proposed theory is not dependent on the adoption of Bayes' Theorem in the field of law.[45]

C. The Danger of Conviction Based on a Single Piece of (Scientific) Evidence

1. *General*

Let us assume an expert has determined that fingerprints taken from the scene of a crime are identical to those of a defendant. To simplify this example, let us assume it is impossible for the defendant's fingerprints to have reached the crime scene in a manner unrelated to the commission of the offense (that is, ignoring the possibility that the fingerprint could have been left by the defendant innocently or planted there by someone else). Let us further assume that the error rate for these tests conducted by this expert is one error in every 10,000 tests. Is it right to convict the defendant solely on the basis of

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40. *Compare* Michael O. Finkelstein & William B. Fairley, *A Bayesian Approach to Identification Evidence*, 83 HARV. L. REV. 489 (1970) (initiating the debate and proposing the use of Bayes' Theorem in a criminal trial) *with* Laurence H. Tribe, *Trial by Mathematics: Precision and Ritual in the Legal Process*, 84 HARV. L. REV. 1329 (1971) (constituting the main response to this approach). *See also* Alex Stein, *Judicial Fact-Finding and the Bayesian Method: The Case for Deeper Skepticism About Their Combination*, 1 INT'L J. EVIDENCE & PROOF 25 (1996) (continuing the debate 25 years later); Ward Edwards, *Influence Diagrams, Bayesian Imperialism, and the* Collins *Case: An Appeal to Reason,* 13 CARDOZO L. REV.1025 (1991) (supporting the use of mathematics during a trial, in general, and "Bayes nets," in particular, though not dealing with the types of cases considered in the present article—convictions based on a single piece of evidence).

41. Tribe, *supra* note 40, at 1358–59.

42. Tribe, *supra* note 40, at 1372–75; Stein, *supra* note 40, at 35–37;40 *see also* Rinat Kitai, *Presuming Innocence*, 55 OKLA. L. REV. 257 (2002) (discussing the presumption of innocence). It should be noted and emphasized that, in our opinion, *only admissible evide*nce should be taken into account for calculating the prior odds (exactly as with the likelihood ratio). Another problem is that of naked statistical evidence. *See* ALEX STEIN, FOUNDATIONS OF EVIDENCE LAW 64–106 (Oxford University Press 2005). As Stein shows, several known paradoxes (Lottery; Preface; Gate Crasher; Blue Bus; and Prisoners in the Yard) demonstrate that we should not rely solely on "naked statistical evidence"—probabilistic evidence unrelated to the facts of the case. *Id.*

43. R. v. Adams, [1996] 2 Cr. App. R. 467; R. v. Adams, [1998] 1 Cr. App. R. 377.

44. *Spann*, 617 A.2d at 262–64.

45. Tribe, *supra* note 40, at 1377 & n.155 (not rejecting the "exception of using evidence as to frequencies in order to negate a misleading impression of uniqueness that expert opinion might otherwise convey," and other uses by the defense (as opposed to the prosecution) for the purpose of creating reasonable doubt).

this evidence? Is it correct to believe that if we convict 10,000 persons under identical circumstances—with no other inculpatory evidence—we will make an error in only one case?

If we were to compare the fingerprints found at the scene of the crime to the fingerprints of all 300 million U.S. residents, we would get approximately 30,000 false matches. It is obvious that—in the absence of any other inculpatory evidence—we cannot conclude that the defendant is the actual criminal. Thus, with scientific evidence alone, in the overwhelming majority of cases, a false conviction will result.

We should also remember that the defendant should be acquitted if, at the conclusion of a criminal trial, a reasonable doubt remains as to his guilt. When someone is charged solely on the basis of a single piece of scientific evidence, we propose an alternative thesis: that the evidence is not accurate enough, on its own, to establish a conviction. If the scientific evidence does not possess an error rate that is sufficiently low—and absent any other inculpatory evidence—we cannot be sure that we have the right person in custody.

Let us examine what error rate should be required of identification evidence so that a conviction beyond a reasonable doubt may be solely based on such evidence. Let us assume that only the residents of a particular country are taken into consideration (for such an assumption, we must already rely on some other evidence, but we shall assume that it—and only it—does exist). In order to establish a conviction beyond a reasonable doubt on a single piece of scientific evidence, we should demand that the error rate be significantly lower than 1/N (N being the number of residents in the country). Because, even if the error rate is 1/N (for example, in the U.S., a rate of 1/300,000,000), there would be on average one person other than the defendant with a positive test result. In the absence of any other inculpatory evidence, the probability that each one of them is the culprit is 50%, and this is not sufficient for a criminal proceeding.

Of course, we may (and should) take additional evidence into consideration, thus reducing the list of potential suspects—for example, to assume that the perpetrator lives in the same city as the victim or make assumptions about the perpetrator's sex and age. Let us assume that, in this manner, we reduce the list of potential suspects to 100,000 people. A satisfactory error rate of the test still needs to be much lower than 1/100,000. In order to establish such a low error rate, we would have had to examine the work methods of the laboratory in question in at least 100,000 cases, and it is reasonable to assume that no existing laboratory has conducted so many tests (not to mention the fact that it could not have erred more than once).

To the extent that we reduce the list of potential suspects, a less accurate test may suffice. However, in order to do reduce the list, we must find and rely on additional evidence, and the scientific evidence is no longer isolated.

Moreover, if there is evidence in the defendant's favor distancing him from the crime, then we should demand a very high level of accuracy from the scientific evidence, even if the list of potential suspects is reduced. If the evidence in the defendant's favor is strong and convincing, (such as a solid alibi)

we can almost be sure that we have a laboratory error. In Bayesian language, strong exculpating evidence reduces the prior odds. Therefore, it is very important to examine and take into account evidence in the suspect's favor—like the failure to identify him in a lineup—even if it is not particularly strong, and not allow the glare of scientific evidence to blind us.

The belief that, if we convict 10,000 people under a test with 99.99% accuracy, we will make an error in only one case derives from the fallacy of the transposed conditional. When we fall into the trap of this fallacy, instead of answering the relevant question—what is the probability of innocence given a match—we answer another question—what is the probability of a match given innocence. The latter probability is low (0.01% in our example), but that low probability does not point unambiguously to the guilt of the person matched. Indeed, when the populations are large, even that low probability can implicate many people besides the particular defendant who is matched to the crime solely through the scientific measurement.

We shall now demonstrate these concepts by means of Bayes' Theorem. We will show the enormous significance of not only the likelihood ratio but also the prior odds when using any single piece of (scientific) evidence for the purposes of a conviction. Let us assume that we require a posterior odds threshold of 100 as a minimal value for a conviction beyond a reasonable doubt—which is the necessary standard of proof in a criminal trial.[46] This means that from among 101 convictions, we will get one false conviction. Let us take a look at Table 1, which applies different numerical values to Bayes' Theorem:

Table 1. Probability of Guilt Under Bayes' Theorem

Prior Odds x	Likelihood Ratio =	Posterior Odds	Probability of Guilt Given the Evidence[47]
("50:50") 1	100	100/1	99.09%
1/10	1,000	100/1	99.09%
1/100	10,000	100/1	99.09%
1/1,000	100,000	100/1	99.09%
1/10,000	1,000,000	100/1	99.09%
1/100,000	10,000,000	100/1	99.09%
1/1,000,000	100,000,000	100/1	99.09%
1/100,000	10,000	0.1/1	9.09%

46. Coffin v. United States, 156 U.S. 432, 453, 460–66 (1895).

47. $P(\text{Innocent} \mid \text{Evidence}) = \frac{1}{1 + \text{posterior odds}}; P(\text{Guilt} \mid \text{Evidence}) = \frac{\text{posterior odds}}{1 + \text{posterior odds}}$

Table 1 illustrates how even a slim possibility of error in the match data leads to the practical impossibility of proving guilt beyond a reasonable doubt solely on the basis of that scientific evidence (that is, in the absence of any other evidence impacting the prior odds). We see, for example, that when the prior odds of guilt are 1 in 10,000 (or 1 in a number greater than 10,000), only scientific evidence with an error rate lower than one in a million tests leads us to our objective—posterior odds of guilt of 100. We know of no scientific evidence with an error rate so low, and it is doubtful that we will ever possess evidence that accurate. Moreover, when there is evidence in the suspect's favor (such as an alibi or a failure to identify the suspect in a lineup), the prior probability could be very low—one in millions.[48] In such cases, the laboratory accuracy of the scientific evidence for the purposes of a conviction should be, at worst, one error in several hundred million cases.

Furthermore, the last entry in Table 1 shows what we can expect when we use evidence that is not as accurate, with an error rate of 1 in 10,000. In such a case, if the prior probability of guilt is 1 in 100,000, then the posterior odds are only 0.1. In other words: in 91% of the cases (characterized by a prior probability of 1/100,000), a conviction based on scientific evidence (with a rate of one error in 10,000 cases) will be a false conviction.

It should be made clear that the likelihood ratio—the probability of a positive test result given guilt divided by the probability of a positive result given innocence—is determined according to the possibility of an erroneous scientific finding. As we shall see below, the most common mistake regarding DNA evidence is in treating the possibility of a random match as the only source of error—and calculating the likelihood ratio accordingly—while ignoring the possibility of laboratory error. The most common mistake regarding fingerprint evidence is to ignore both the possibility of a random match and the possibility of an error. Taking both possibilities into account further strengthens our thesis that a person should not be convicted on the basis of a single piece of (scientific) evidence.

The burden of proof regarding the possibility of error should also be addressed. In our opinion, the onus is on the prosecution—which is requesting to make inculpatory use of scientific evidence—to provide the court with reliable information as to the possibility of error for the relevant test in the specific laboratory where it was performed. First of all, this burden derives from the general burden of proof imposed on the prosecution in a criminal trial. Secondly, knowledge of the error rate is a condition for the admissibility of the scientific evidence, as follows from the *Daubert* ruling.[49] As already indicated, we find it hard to believe that any test can achieve an accuracy of only one error in a million. Laboratory workers and technicians are human and humans make errors from time to time, as we shall see below when we discuss DNA and fingerprint evidence.

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48. R. v. Adams, [1996] 2 Cr. App. R. 467 (The expert testifying on the defense's behalf, Prof. Donnelly, calculating a prior probability of 1 in 3,600,000).

49. Daubert v. Merrell Dow Pharm. Inc., 509 U.S. 579, 594 (1993); *see* STEIN, *supra* note 40, at 196.

2. *The Inherent Limitation of a Single Piece of Evidence*

In the absence of other evidence linking the defendant to the crime—apart from the scientific evidence—the prior odds are low and do not allow for proof of guilt (posterior odds) beyond a reasonable doubt. As long as there is a possibility of testing error—even if only slim—the basic theory shows the unlikelihood that there will be objective scientific evidence that alone could serve as the basis for conviction. Just as the rate of error is particularly high among the low-risk group in the above example of the HIV test, so it is for any single piece of scientific evidence of a person's guilt: the rate of error is particularly high when there is no other inculpatory evidence.

In many cases, the prior odds do not seem as objective as the scientific evidence. That is, the decision maker's belief in the defendant's guilt or innocence, based on the remaining evidence, is not easy to quantify. This is not a problem of math or logic that can be resolved by a non-Bayesian statistical approach. It is a genuine theoretical problem correctly expressing our uncertainty about the defendant's guilt.

The method of inductive probability developed by Jonathan Cohen may provide another way to reach the conclusion that a single piece of evidence is not sufficient.[50] This method is based on the elimination of alternative explanations for a fact, and proof of the final conclusion as the only acceptable possibility that remains.[51] According to this approach, the "beyond a reasonable doubt" standard—as required in a criminal trial—is not met by a specific degree of proof (such as 99%), but rather by disproving any reasonable alternative other than the defendant's guilt.[52] For the purposes of our discussion, we will note that by this method as well, it is still possible to prove the theory proposed in this article. The reason is that if a single piece of evidence is only capable of identifying the suspect as one member of a group of people, each of whom (on his own) could have committed the crime, then according to the inductive method as well, we need additional evidence to disprove the possibility that the other members of the group committed the crime. Furthermore, we need additional evidence to disprove the possibility of a testing error in the initial evidence.

D. A Critique of the Proposed Theory—The Case-Specific Argument

The famous second report of the National Research Council's Committee on DNA Forensic Science, discussed below in the special section devoted to DNA evidence, states that "[t]he question to be decided is not the general error rate for a laboratory or laboratories over time but rather whether the laboratory doing DNA testing in this particular case made a critical error."[53] According to

50. *See* L. JONATHAN COHEN, THE PROBABLE AND THE PROVABLE 247–52 (1977).

51. *Id*. at 250; *see also id.* at 121–229.

52. *Id.* at 250.

53. NAT'L RESEARCH COUNCIL, THE EVALUATION OF FORENSIC DNA EVIDENCE 85 (1996) [hereinafter NRC-II].

this approach—which is well accepted in judicial practice regarding DNA and, apparently, also fingerprint evidence—general statistics for laboratory error are irrelevant to the particular case being tried in a court of law.[54] Therefore, these statistics should not be included in the likelihood ratio. Moreover, according to this view, the court examines whether or not a testing error has occurred independently from the remaining evidence in the case, and only the random match probability of the genetic profile needs to be examined alongside the other evidence.[55] This entails an assumption (in our opinion, fallacious) that the court is able to meticulously examine the manner in which the evidence was produced and the compliance with testing procedures, and to determine—beyond a reasonable doubt and in isolation from the other evidence—that an error did not occur in the specific case before it. Another variation of this assumption is to transfer the burden to prove the occurrence of an error to the defendant, who has no real chance of meeting this burden.

In our opinion, this case-specific approach is mistaken. First of all, it is undoubtedly correct to make a distinction between circumstances where the error rate is relatively high and circumstances where the error rate is relatively low.[56] Thus, for example, when the fingerprints taken from a crime scene are of low quality, the probability of error will be greater than in circumstances where the fingerprint quality is high. This type of data should be included in the error rates for the test, as part of a complete methodology for assessing the risk in different types of cases, particularly in the specific case pending before

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54. See *infra* notes 212–14 (DNA evidence); Michael J. Saks & Jonathan J. Koehler, *The Coming Paradigm Shift in Forensic Identification Science*, 309 SCIENCE 892, 894–95 (2005) (fingerprint evidence).

55. R. v. Adams, [1998] 1 Cr. App. R. 377 (instructions to the jurors: "[T]hat would involve them perhaps in asking themselves at the outset whether they accepted wholly or in part the DNA evidence called by the Crown. If the answer to that was "no", or uncertainty as to whether the answer was "yes" or "no", then that would be the end of the case. If, however, the jury concluded that they did accept the DNA evidence wholly or in part called by the Crown, then they would have to ask themselves whether they were satisfied that only X white European men in the United Kingdom would have a DNA profile matching that of the rapist who left the crime stain. It would be a matter for the jury, having heard the evidence, to give a value to X. They would then have to ask themselves whether they were satisfied that the defendant in question was one of those men. They would then go on to ask themselves whether they were satisfied that the defendant was the man who left the crime stain, bearing in mind on the facts of this case the obvious discrepancies between the victim's description of her assailant and the appearance of the appellant, the victim's failure to identify the appellant on the identification parade and the evidence of the appellant and the witnesses called by him. Consideration of this last question would of course involve the jury in assessing all the points made concerning the victim's opportunity to see her assailant, the likelihood of her description being accurate or inaccurate in all the circumstances, the significance of her failure to identify the appellant, the strength and weakness of the evidence given by the appellant and his witnesses, and all other matters relied on by the defence.").

56. David J. Balding & Peter Donnelly, *Inferring Identity from DNA Profile Evidence*, 92 PROC. NAT'L. ACAD. SCI. 11,741, 11,744–45 (1995). These authors recognize the significance of the probability of a false positive in a DNA test, but believe that a way must be found to estimate it for a given case pending before the court, in accordance with the special circumstances of that case. *Id.* In their opinion, the data from blind tests (which are similar to real cases because the laboratories do not know that they are being tested) are more relevant. *Id.*; *see also* Peter Donnelly & Richard D Friedman,. *DNA Database Searches and the Legal Consumption of Scientific Evidence*, 97 MICH. L. REV. 931, 948 n.57 (1999).

the court. If we do not know the probability of error in a specific case, we cannot know the strength of the evidence against the suspect.

Secondly, the case-specific approach facilitates erroneous convictions by totally ignoring the prior probability of guilt.[57] That is to say, in examining the question of whether or not a mistake has been made, the case-specific argument does not take into account the other evidence in the specific case or the significance of its absence. This argument cannot stand, because the less evidence we have against a suspect (the prior odds)—and it is possible that there is even evidence indicating his innocence—the greater the chances of an error in a conviction based on the main (scientific) evidence (posterior). Therefore, it is wrong to ignore the prior probability when seeking an answer to the question of whether or not an error has occurred in a specific case. Thompson, Taroni and Aitken have called the mistaken neglect of the probability of a laboratory error in a DNA test the "false positive fallacy."[58] In Koehler's opinion as well—in the context of DNA—this is a variation of the "base rate fallacy."[59] A similar critique has been leveled against the disregard of statistics concerning errors in fingerprint comparisons.[60]

Thirdly, some errors are unavoidable. Thus, for example, we shall see below that two fingerprints could be so similar that four experts will mistakenly declare that they are from the same source. Such errors still occur and remain undetected when all testing procedures—which the court is supposed to oversee—are complied with. Sometimes, even when it becomes clear that an error has occurred in a DNA test, its source still remains unclear.[61] Hence, it is unreasonable to assume that a court of law will locate the source of an error even before the error itself has been discovered.

Fourthly, contrary to the claim of the supporters of the case-specific approach, it is very difficult, and perhaps even impossible, to distinguish between theoretical errors in the scientific methodology and human errors in the testing.[62] This is because a scientific test inherently entails a subjective assessment by the expert performing it, both during the stages of the testing itself and at the point when conclusions are drawn from it. Even when errors are detected, this is a matter of hindsight. It is the nature of errors that they do occur from time to time, even when the prosecution's expert truthfully testifies that he acted in compliance with accepted testing procedures and adhered to all safety measures. Unfortunately, some laboratory errors stem from the combination of inadequate training and unscientific practices among some laboratory

57. William C. Thompson et al., *How the Probability of a False Positive Affects the Value of DNA Evidence*, 48 J. FORENSIC SCI. 47, 49–51 (2003).

58. *Id.* at 51.

59. Jonathan J. Koehler, *Why DNA Likelihood Ratios Should Account for Error (Even When a National Research Council Report Says They Should Not)*, 37 JURIMETRICS J. 425, 431 (1997).

60. Saks & Koehler, *supra* note 54.

61. *See infra* note 177 and surrounding text.

62. Saks & Koehler, *supra* note 54. at 894.

workers, together with the pressure put on workers by police investigators and laboratory heads to find a test match.[63]

As we shall see below, the case-specific approach is mistaken regarding all evidence, and not just scientific evidence.

E. The Increased Risk of a Database Search

In the fields of biometrics and computerized pattern recognition, problems of verification and problems of identification are distinguished.[64] With verification, an answer must be given to the question of whether two biometric samples—such as a fingerprint, facial image, voice recording, iris image, etc.—have the same human source.[65] In law enforcement, for example, verification (also known as "one-to-one"[66]) is the method used when a comparison is made between fingerprints taken from the crime scene and the fingerprints of a suspect who the police have found on the basis of other evidence. With identification, the question is whether the source of a specific biometric sample is also the source of one of many samples found in a database.[67] Identification (also referred to as "one-to-many"[68]) is the method used, for example, when a fingerprint database is searched in an attempt to find a suspect whose fingerprints match those found at the scene of the crime.

Identification is much more problematic than verification. Under given conditions of proximity, when the error rate of the verification is very low and the database is not very large, the identification error rises in a linear relation to the size of the database.[69] This derives both from the fact that many comparisons are run, as well as the fact that the bigger the size of the database the bigger the chances are that samples will be found similar to the sample found at the crime scene—so similar that they even mislead the expert.

This is the reason that automated fingerprint identification systems (AFIS) are not designed to perform identification, but only to provide a list of candidates whose samples are compared with samples from the crime scene, by an expert, in order to verify or rule out a match.[70] As we shall see below—when discussing the Mayfield case—experts are not immune from error.

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63. *Id.* at 893.

64. James L. Wayman, *Error-Rate Equations for the General Biometric System*, IEEE ROBOTICS & AUTOMATION MAGAZINE, Mar. 1999, at 35.

65. Joaquin Gonzalez-Rodriguez et al., *Bayesian Analysis of Fingerprint, Face and Signature Evidences with Automatic Biometric Systems*, 155 FORENSIC SCI. INT'L 126, 127 (2005).

66. *See* Wayman, *supra* note 64, at 35.

67. Gonzalez-Rodriguez et al, *supra* note 65, at 127.

68. *See* Wayman, *supra* note 64, at 35.

69. *See* John Daugman, *The Importance of Being Random: Statistical Principles of Iris Recognition*, 36 PATTERN RECOGNITION 279, 287–88 (2003) (equation 13 and its surrounding discussion). For a more general description of the possibilities for error in biometric systems, see Wayman, *supra* note 64.

70. Robert Epstein, *Fingerprints Meet* Daubert*: The Myth of Fingerprint "Science" is Revealed*, 75 SO. CAL. L. REV. 605, 626 n.119 (2002).

The problem of a systematic search and the danger of numerous false positives are also familiar in other contexts, such as polygraph tests[71] and drug[72] and alcohol tests,[73] which are conducted randomly and not on the basis of evidence or prior suspicion. Similarly, widespread testing among the populace for the detection of a rare disease like the HIV virus will yield many false positives in low-risk groups.[74] This is also the case with mammograms for the detection of breast cancer.[75] In medicine, there is a great awareness of the danger in widespread database searches. However, in the field of criminal law, unfortunately, we believe there is only little such awareness.

One area in which some awareness does exist of the danger posed by a database search is DNA testing. This relates only to the possibility of a random match. Those who take a cautious approach (NRC-I)[76] believe that the results of the search should not be used as evidence, but only as a means for finding suspects. For the purpose of determining the guilt of a given suspect who has been found through a database search, other evidence should be used that might include an additional DNA test based on loci other than those used to identify the suspect.[77] Others (the NRC-II[78] report and Stockmarr[79]) argue that the weight of the evidence obtained through such a search is diminished and that the likelihood ratio should be divided by the size of the database.[80] According to a third approach—that of Balding and Donnelly—not only is the weight of the evidence not reduced with an increase in the size of the database but, rather, it actually increases, since a possible match is negated for all remaining subjects in the database.[81]

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71. U.S. CONG., OFFICE OF TECH. ASSESSMENT, SCIENTIFIC VALIDITY OF POLYGRAPH TESTING: A RESEARCH REVIEW AND EVALUATION—A TECHNICAL MEMORANDUM, OTA–TM–H–15, at 5–6, 98–99 (1983).

72. J. L. Gastwirth & Wesley O. Johnson, *Screening with Cost-Effective Quality Control: Potential Applications to HIV and Drug Testing*, 89 J. AM. STAT. ASS'N 972, 972 (1994).

73. Richard S. Schottenfeld, *Drug and Alcohol Testing in the Workplace—Objectives, Pitfalls and Guidelines*, 15 AM. J. DRUG & ALCOHOL ABUSE 413 (1989); *see* Gastwirth & Johnson, *supra* note 72.

74. Klemens B. Meyer & Stephen G. Pauker, *Screening for HIV: Can We Afford the False Positive Rate?*, 317 NEW ENG. J. MED. 238 (1987).

75. Joann G. Elmore et al., *Screening Mammograms by Community Radiologists: Variability in False-Positive Rates*, 94 J. NAT'L CANCER INST. 1373, 1376–77 (2002).

76. NAT'L RESEARCH COUNCIL, DNA TECHNOLOGY IN FORENSIC SCIENCE 124, 129 (1992) [hereinafter NRC-I].

77. *See infra* Part IV (clarifying the nature of DNA testing).

78. NRC-II, *supra* note 53 at 161.

79. Anders Stockmarr, *Likelihood Ratios for Evaluating DNA Evidence When the Suspect Is Found Through a Database Search*, 55 BIOMETRICS 671 (1999).

80. Stockmarr found a mathematical basis for this position. *Id*.

81. David J. Balding & Peter Donnelly, *Inference in Forensic Identification*, 158 J. ROYAL STAT. SOC'Y 21, 29–30 (1995); David J. Balding & Peter Donnelly, *Evaluating DNA Profile Evidence When the Suspect is Identified Through a Database Search*, 41 J. FORENSIC SCI. 603, 604 (1996); Donnelly & Friedman, *supra* note 56, at 984.

This apparent dispute among members of the relevant scientific community found its way into a legal hearing in *United States v. Jenkins*.[82] *Jenkins* held that the various experts had answered different questions and that the dispute was therefore one of relevance, which is a matter for the court to decide.[83] However, the treatment of the danger in a database search only relates to the possibility of a random match, and there is a failure to address the possibility of an error in the testing.[84] In our opinion, Stockmarr's analysis—whereby the evidentiary strength is weakened as the size of the database increases—is more relevant to a legal decision because when the database is relatively large, the laboratory error rate is significantly higher than the possibility of a random match.

Furthermore, a database search might lead to a significant increase in the number of cases where we rely on a single piece of evidence for a conviction—because at the beginning there is no other evidence leading to the suspect, and because even if no other evidence is found later on, the law enables a conviction on the basis of a single piece of evidence, as we shall show

F. Interim Summary

The general theory proposed in this article is that, if we do not want to bury our heads in the sand and ignore the reality of the mistaken conviction of innocent persons, we must not convict on the basis of any single piece of evidence. This is because of the possibility of error inherent to all evidence and the tremendous importance of the presence or absence of additional evidence.

As we have shown, an extremely high degree of accuracy is required for evidence, on its own, to convict a person. It is hard to believe that any evidence has such a low error rate. If we convict when there is only a single piece of evidence, we will make an error in most of these cases. Therefore, we propose that a requirement for "strong corroboration" be legislated as an essential condition for a conviction on the basis of any piece of evidence.

It is very difficult—nearly impossible—to be convincing about such a general theory, which carries dramatic implications for the entire criminal justice system, without discussing specific kinds of evidence. Therefore, in an attempt to persuade readers that the proposed theory is correct, both in its application to the specific forms of evidence mentioned and to other types of evidence (which we are unable to discuss because of space limitations), we will proceed to a discussion of four major types of evidence adduced in criminal trials. These include two scientific forms of evidence (fingerprints and DNA) and two nonscientific forms of evidence (confessions and eyewitness identifications).

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82. 887 A.2d 1013 (D.C. 2005).

83. *See id.* at 1025–26 ("In reality, each formula answers a distinctly different question"; "Determining what evidence is and is not relevant is a hallmark responsibility of the trial judge.").

84. Thompson et al., *supra* note 57, at 52.

However, before we turn to an in-depth discussion of these four types of evidence, we would like to deal with two questions that readers might be asking themselves. First, do cases really exist in which people are convicted based on a single piece of evidence, or is this phenomenon so rare that it may be ignored? Even in such cases, is there actually additional, "informal" evidence that influences the probability of guilt?

Because the law unfortunately allows a person to be convicted based on a single piece of evidence, this is something that does occur from time to time. In the following sections, we will present actual examples of such convictions for each of the types of evidence discussed, but it is useful to cite several examples here.[85] Many readers will be familiar with additional examples from their own legal systems. The Innocence Project,[86] and similar projects developed throughout the world in recent years, have proven the innocence of hundreds of wrongfully convicted prisoners. Some of these convictions were based on a single piece of evidence.[87] In addition, if the law is not changed as

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85. In Jones v. State, 172 Md. App. 444 (2007), Charnard Demon Jones was convicted of sexual offenses and sentenced to thirty years imprisonment based on a single piece of DNA evidence obtained through a database search. His claim that the conviction was based on a single piece of evidence was of no avail. *Id.* at 462. In Mack v. State, 75 P.3d 803 (Nev. 2003), Daryl Mack was convicted of murder based solely on DNA evidence that was obtained by running some samples through a database, *id.* at 804. He was sentenced to death and executed on April 26, 2006. The Office of the Clark County Prosecuting Attorney (Indiana), http://www.clark prosecutor.org/html/death/US/mack1019.htm. The case of Gary Leiterman has been discussed in the following two articles. Simon A. Cole & Michael Lynch, *The Social and Legal Construction of Suspects*, 2 ANN. REV. LAW & SOC. SCI., 39, 48–49 (2006); William C. Thompson, *Tarnish on the "Gold Standard": Understanding Recent Problems in Forensic DNA Testing*, 30 CHAMPION, Jan.–Feb. 2006, at 10, 14 [hereinafter Thompson, *Gold Standard*]. Gary Leiterman was convicted of the murder of Jane Mixer, after being identified as one of two persons whose DNA was found matching the DNA sample on the victim's clothing through a database search. *Id.*; This case is especially problematic since the second person who was identified by the DNA evidence was a four-year-old child at the time of the murder. *Id.* Furthermore, it became clear that both DNA profiles had been processed in the same laboratory and on the same day as the DNA profile of the victim, so that there was a reasonable possibility of a mixing or cross-contamination of the samples. *Id.* In R. v. Adams, [1996] 2 Cr. App. R. 467, a person was accused and convicted of rape solely on the basis of DNA evidence, while other evidence actually pointed to his innocence, such as the failure of the victim to identify the defendant as the rapist, the victim's description of the rapist as a young man in his twenties while the defendant was forty years old, and an alibi that was not refuted. Michael Lynch & Ruth McNally, "*Science," "Common Sense," and DNA Evidence: A Legal Controversy about the Public Understanding of Science*, 12 PUB. UNDERSTANDING SCI. 83, 87–88 (2003). *See also* People v. Brooks, 345 Ill. App. 3d 945 (2004) (convicting for armed robbery based on a fingerprint match obtained through the AFIS database and the defendant having a build resembling the victim's description of the perpetrator); People v. Ford, 239 Ill. App. 3d 314 (1992) (convicting for residential burglary based solely on fingerprint evidence); People v**.** Reno, 32 Ill. App. 3d 754 (1975) (convicting for murder based on a thumbprint match and the insignificant fact that both the suspect and the murderer wore tennis shoes); People v**.** Taylor, 204 N.E.2d 734 (Ill. 1965) (convicting for rape and breaking and entering based entirely on a fingerprint match); Retrial 6148/95 Moshe Azaria v. State of Israel, 51(2) P.D. 334 (convicting based solely on a confession, without any independent, significant corroboration); Cr.F.H 4342/97 State of Israel v. Al Abid, 51(1) P.D. 736 (convicting based solely on a confession, without any corroboration).

86. *See supra* note 22 and accompanying text.

87. *See supra* note 24.

we propose, database searches can be expected to generate many more convictions based on a single piece of evidence. This is because suspects are identified through such searches without any additional evidence—at least during the initial stage. Moreover, if the evidence is perceived as strong—such as a DNA or fingerprint match—it is very likely that this single piece of evidence will be mistakenly relied upon, as legal rules still make it possible to do.[88]

Most importantly, even if these are relatively rare cases, we must remember that each one of them entails the wrongful conviction of an individual. Each individual is a world unto himself—an end in himself. We must not divert our gaze from him and abandon ourselves to statistics. If we have succeeded in convincing readers that a single piece of evidence is insufficient to prove guilt beyond a reasonable doubt, it is essential that this find clear expression in law in order to avoid wrongful convictions.

As to the argument regarding additional, "informal" evidence, there is no room here for obfuscation: if the additional evidence is inadmissible (and for that reason is delicately but vaguely referred to as "informal"), we are left with only a single piece of admissible evidence. In this matter, Tribe's warning against the grave harm caused to the presumption of innocence entailed by considering inadmissible evidence has lost none of its validity, even a third of a century after it was made**.**[89]

The second question that readers may be asking themselves is whether two pieces of evidence are sufficient for a conviction? Our answer to whether a single piece of evidence suffices is unequivocal: No! Never! On the other hand, our answer to whether two pieces of evidence suffice cannot be as clear and precise. It is the weight of the evidence, not only the amount, which is important. It is very possible that two pieces of strong evidence will be sufficient while three or more pieces of weak evidence will be insufficient. Only for a single piece of evidence is it possible to reject the conviction by means of a quantitative threshold test. This is because even the strongest evidence cannot, on its own, prove guilt beyond a reasonable doubt. We will try to demonstrate further this in the following sections.

III. CONVICTIONS BASED ON FINGERPRINT EVIDENCE

Throughout the twentieth century, fingerprint evidence universally enjoyed an image of reliability and certainty—both in the courts and society at large—and has served as a basis for convictions of many defendants.[90] Only in recent years has the special status enjoyed by this form of evidence been criti-

88. *Supra* Part II.E.
89. *See* Tribe, *supra* note 40, at 1368–72.
90. Epstein, *supra* note 70, at 605 n.3.

cized for not being based on solid statistical theory and for not being immune from error.[91]

A. The Possibility of Error in Comparing Fingerprints

It is well accepted that there exists a possibility of a random match of a DNA comparison; namely, that all of the loci compared in the test will be identical for several people. Therefore, the result is provided in statistical form, such as: in a population of X million people, there are an average of Y persons with the same genetic profile.[92] However, for evidence based on a fingerprint comparison, the prevailing assumption is that each fingerprint is unique and there is no possibility of a random match.[93] Consequently, the courts, apparently, do not require that data regarding the possibility of a random match for fingerprints be adduced at trial and the prosecution does not present any such data. In effect, no data currently exists regarding such a possibility.[94] Nevertheless, no scientific proof exists that it is impossible for two people to share the same points of comparison in a fingerprint examined by an expert.[95] Forensic experts testifying in court present this evidence as unequivocal, instead of making an effort to investigate and provide data about random match probability. Therefore, this scientific evidence is perceived in court to be stronger than it actually is.[96] Moreover, in a study conducted in 2002, it was revealed that "the probability that a fingerprint with 36 minutiae points will share 12 minutiae points with another arbitrarily chosen fingerprint with 36 minutiae points is 6.10×10^{-8}."[97] Therefore, contrary to popular belief, some statistical theories do note the possibility of a random match when it comes to

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91. *See id.*; David A. Stoney, *Measurement of Fingerprint Individuality*, *in* ADVANCES IN FINGERPRINT TECHNOLOGY 327, 327–88 (Henry C. Lee & Robert E. Gaensslen eds., 2001); Sandy L. Zabell, *Fingerprint Evidence*, 13 J.L. & POL'Y 143, 152–55 (2005); Nathan Benedict, *Fingerprints and the* Daubert *Standard for Admission of Scientific Evidence: Why Fingerprints Fail and a Proposed Remedy*, 46 ARIZ. L. REV. 519, 526–33 (2004); Jennifer L. Mnookin, *Fingerprint Evidence in the Age of DNA Profiling*, 67 BROOK. L. REV. 13, 57–61 (2001).

92. *See* discussion *infra* Part IV.

93. *See supra* notes 56–57; *see also* William C. Thompson & Simon A. Cole, *Psychological Aspects of Forensic Identification Evidence*, *in* EXPERT PSYCHOLOGICAL TESTIMONY FOR THE COURTS 31, 44 (Mark Costanzo et al. eds., 2007).

94. *See* Zabell, *supra* note 91, at 155–56.

95. Sharath Pankanti et al., *On the Individuality of Fingerprints*, 24 IEEE TRANSACTIONS ON PATTERN ANALYSIS & MACHINE INTELLIGENCE 1010, 1010–11 (2002).

96. Saks & Koehler, *supra* note 54, at 893.

97. Pankanti et al., *supra* note 95, at 1010.

> 1) [C]ontrary to the popular belief, fingerprint matching is not infallible and leads to some false associations, 2) while there is an overwhelming amount of discriminatory information present in the fingerprints, the strength of the evidence degrades drastically with noise in the sensed fingerprint images, 3) the performance of the state-of-the-art automatic fingerprint matchers is not even close to the theoretical limit, and 4) because automatic fingerprint verification systems based on minutia use only a part of the discriminatory information present in the fingerprints, it may be desirable to explore additional complementary representations of fingerprints for automatic matching.

Id.

fingerprints, similar to the possibility that exists with DNA comparisons.[98] It is enough for us to say that it is possible—as it has been proven in the Brandon Mayfield incident[99]—for two different people to have fingerprints so similar that examiners are unable to distinguish between them.

At the beginning of the 1990s, two British researchers attempted to examine the sixteen-point standard for comparing fingerprints, practiced in England and Wales.[100] Their findings demonstrated the subjective nature of analyzing fingerprints: different examiners obtain entirely different points and numbers of comparison.[101]

In 1996, the results of proficiency tests (held in 1995) for 156 fingerprint examiners, under the auspices of the International Association for Identification, were published in the United States.[102] The results shocked the forensic community: from among 156 examiners tested, only 68 (44%) were able to both correctly identify the five latent print impressions that were supposed to be identified, and correctly note the two elimination latent prints that were not to be identified.[103] In total, 48 false matches were counted.[104] The combined results of these proficiency tests demonstrate that examiners get erroneous results, on average, in 0.8% of all cases[105]—namely, in almost one out of 100 cases. As seen in Part II, this is a very high and significant error rate. From Table 1, such a high error rate could only support a conviction when the other evidence already establishes guilt to a level of 50% (prior odds = 1). In other words, only when it is clear from other evidence that one of only two people could have committed the offense and we have determined that the fingerprint of one of them matches the fingerprint found at the scene of the crime. Also, there is no other explanation for finding the fingerprint at the crime scene except for the commission of the offense by its owner.

Errors occur, of course, not only in studies, but also in real cases deliberated in the courts. For example, Simon Cole surveyed 22 documented cases occurring in the United States, England, and Scotland, where people were arrested and sometimes even served prison sentences before the error was

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98. Cedric Neumann et al., *Computation of Likelihood Ratios in Fingerprint Identification for Configurations of Three Minutiae*, 51 J. FORENSIC SCI. 1255, 1255 (2006).

99. Sarah Kershaw et al., *Spain and U.S. at Odds on Mistaken Terror Arrest*, N.Y. TIMES, June 5, 2004, at A1, *available at* http://query.nytimes.com/gst/fullpage.html?res=9800EFDB1031F936A35755C0A9629C8B63.

100. Ian W. Evett & Richard L. Williams, *A Review of the Sixteen Points Fingerprint Standard in England and Wales*, 46 J. FORENSIC IDENTIFICATION 49 (1996).

101. *Id.; see* R. v. Buckley, (1999) 143 S.J.L.B. 159 (regarding the number of points of comparison required in England, and other admissibility requirements for this type of evidence).

102. David L. Grieve, *Possession of Truth*, 46 J. FORENSIC IDENTIFICATION 521, 523 (1996).

103. *Id.* at 524.

104. *Id.*

105. Simon A. Cole, *More than Zero: Accounting for Error in Latent Fingerprint Identification*, 95 J. CRIM. L. & CRIMINOLOGY 985, 1034, 1073 (2005). For more information on proficiency tests, see Joseph L. Peterson & Penelope N. Markham, *Crime Laboratory Proficiency Testing Results, 1978–1991, II: Resolving Questions of Common Origin*, 40 J. FORENSIC SCI. 1009 (1995); Lyn Haber & Ralph N. Haber, *Error Rates for Human Fingerprint Examiners*, *in* AUTOMATIC FINGERPRINT RECOGNITION SYSTEMS 339, 349 (Nalini K. Ratha et al. eds., 2003.

detected.[106] Given the considerable difficulty in discovering errors after a conviction, it makes sense that there are many more cases in which the mistake has not been detected and wrongfully convicted persons continue to rot in jail.

Some of the causes for the frequency of laboratory errors are the poor quality of fingerprints taken from the crime scene (as opposed to the good quality of prints calmly scanned by access control systems),[107] automated fingerprint identification systems,[108] substandard or unscientific practices among certain "experts",[109] and pressure exerted on laboratory workers to find a match.[110]

A thousand words on a given theory and a dozen studies regarding a specific phenomenon are sometimes not as convincing as one individual case examined in depth. Therefore, we will now discuss the Brandon Mayfield incident and the report on this affair issued by the U.S. Department of Justice.

B. The Brandon Mayfield Incident

Following the terror attacks in Madrid, on the eve of the 2004 general elections in Spain, the Spanish police found a fingerprint left on a plastic bag linked to the attacks—containing detonators and remnants of explosives.[111] Through Interpol, the Spanish police asked for some assistance from the American FBI.[112] The FBI searched its fingerprint database by means of an automated fingerprint identification system and the search printout contained a list of 20 potential suspects.[113] An analysis of the samples of the candidates by an examiner yielded a match between the fingerprint found at the scene of the attacks and the fingerprint of an attorney from Oregon named Brandon Mayfield.[114] Three senior FBI examiners verified the identification.[115] In an affidavit leading to the issue of an arrest warrant, it was stated that this was a "100 percent positive identification."[116] While Mayfield was being detained, the court appointed an independent fingerprint examiner who checked and verified the original identification by FBI examiners.[117]

After two weeks, during which Attorney Mayfield was held in custody, the Spanish police located another person, named Ouhnane Daoud, whose fingerprints matched those found at the scene of the attacks.[118] It turned out

106. Cole, *supra* note 105, at 1001–16.

107. Pankanti et al., *supra* note 95, at 1017.

108. U.S. DEP'T OF JUSTICE, OFFICE OF THE INSPECTOR GEN., OVERSIGHT & REVIEW DIV., A REVIEW OF THE FBI'S HANDLING OF THE BRANDON MAYFIELD CASE 137 (2006), *available at* http://www.usdoj.gov/oig/special/s0601/final.pdf.

109. Saks & Koehler, *supra* note 54, at 893.

110. *Id.*

111. FBI'S HANDLING OF THE BRANDON MAYFIELD CASE, *supra* note 108, at 29.

112. *Id.* at 29–30.

113. *Id.* at 30.

114. *Id.* at 31.

115. *Id*. at 29–33, 64.

116. *Id.* at 64–65.

117. *Id*. at 80–81.

118. *Id.* at 81–82.

that the "sure" identification of Mayfield by four different examiners was mistaken, and he was released.[119]

In March 2006, a comprehensive report regarding this case was published by the U.S. Department of Justice.[120] According to this report, the main reason for the false identification was a very high similarity between the fingerprints of the unfortunate Mayfield and the fingerprints taken from the scene of the attacks, which, according to the Spanish police, belonged to Ouhnane Daoud.[121] The report explains that, when an automated fingerprint identification system is used, it is possible for there to be a great similarity between fingerprints, since the system scans millions of prints and compares each one to the fingerprint found at the scene of the attacks.[122] The printout yielded by the system contains a list of 20 candidates who, according to the computer, have the most similar fingerprints to those found at the crime scene.[123] Therefore, the examiners were forced to deal with fingerprints very similar to those of Daoud. The report warns that the chance of error in such cases is much higher than when suspects are located through a normal investigation, since the system chooses those fingerprints with the greatest potential to confuse examiners.[124]

Another major cause for the misidentification is what the report refers to as "circular reasoning."[125] In Mayfield's case, after ten true points of comparison were found between the two fingerprint images, the examiners began to look for and found additional characteristics in Mayfield's fingerprints which, in reality, did not exist at all.[126]

According to the report, this was not a normal human error, but rather the result of methodological problems described therein.[127] The report issued recommendations for a series of research projects in the discipline of fingerprint identification, including the determination of objective criteria for declaring a match.[128] In addition, the report recommended a study to test the accuracy of examiner performance in a controlled manner.[129]

The report determined that the second examiner, who was supposed to verify the first examiner's findings, was aware that the first examiner had

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119. *See generally* Robert B. Stacey, *Report on Erroneous Fingerprint Individualization in the Madrid Train Bombing Case*, 54 J. FORENSIC IDENTIFICATION 706 (2004); William C. Thompson & Simon A. Cole, *Lessons From The Brandon Mayfield Case*, 29 CHAMPION, Apr. 2005, at 42; Steven T. Wax & Christopher J. Schatz, *A Multitude of Errors: The Brandon Mayfield Case*, 28 CHAMPION, Sept.–Oct. 2004, at 6; Zabell, *supra* note 91, at 148–51 (all describing and treating the *Mayfield* case but not including the findings of the 2006 U.S. Justice Department report).

120. FBI'S HANDLING OF THE BRANDON MAYFIELD CASE, *supra* note 108.

121. *Id.* at 130.

122. *Id.* at 137.

123. *Id.*

124. *Id.* at 137.

125. *Id.* at 138.

126. *Id.*

127. *Id.* at 198.

128. *Id.* at 196.

129. *Id.*

already identified Mayfield as the owner of the fingerprint taken from the crime scene.[130] The report naturally recommends that, in the future, such information not be given to subsequent examiners.[131] Finally, the report concludes that Attorney Mayfield's background data—the fact that he was a Muslim, that his wife was Egyptian, that he had represented a terrorist in a child-custody hearing, and his association with persons suspected of terrorism—did not, in fact, affect the initial stage during which the match was declared, since this was not yet known to the investigators; but, apparently, these facts did have an impact at a later stage.[132] Indeed, there are other studies demonstrating that the analysis is also influenced by external information that examiners are provided with.[133]

The report discusses further causes of misidentification. We have given only some examples in order to illustrate that the possibility of error is real. Errors in fingerprint analysis are not only possible on the theoretical level, but do actually occur in reality, both in famous cases where they have been detected and—it is reasonable to assume—in many other cases where they remain undiscovered. It is also clear that some fingerprints are so similar to one another that examiners are unable to distinguish between them. Unfortunately, the general rate of error is unknown for fingerprinting.[134]

The accepted, overly optimistic estimate is that the rate of error is low. However, as we have seen, proficiency tests given to examiners indicate an error rate of 0.8%, which is very high and very significant. Moreover, even if examiners were to achieve an error rate tenfold lower—for example, 0.1% (one error in a thousand cases)—as we have already shown in Part II, in the absence of other evidence, it is still impossible, given such an error rate, to prove the defendant's guilt beyond a reasonable doubt.

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130. *Id.* at 175–77.

131. *Id.* at 204.

132. *Id.* at 179. Attorney Mayfield's background data had an influence at the stage in which a "negativo report," questioning the identification, had arrived from the Spanish police. *Id.* Even then, F.B.I examiners continued to claim that they had absolute confidence in the identification. *Id.* One examiner testified, after the fact, that if Mayfield had not had such background data, the identification would have been examined with much greater scrutiny. *Id.*

133. Itiel E. Dror, David Charlton & Ailsa E. Péron, *Contextual Information Renders Experts Vulnerable to Making Erroneous Identifications*, 156 FORENSIC SCI. INT'L 74 (2006).

134. Mnookin, *supra* note 91, at 60.

C. Case Law

American courts have held that a criminal conviction may be based solely on fingerprint evidence.[135] On the one hand, some courts have begun to show skepticism towards fingerprint evidence beginning in the new millennium. Thus, for example, in one case, a judge ruled fingerprint evidence inadmissible, holding that the examiner could not unequivocally determine that there was a match between two fingerprints; however, several months later the same judge reversed his previous decision, affirming the admissibility of the evidence.[136] Other courts have explicitly ruled that errors are possible with fingerprint comparisons. Thus, for example, in the *Quintana* case,[137] it was held that:

> Until there is a nationally adopted certification system—ensuring examiner proficiency—and a nationally adopted minimum standard for matching latent fingerprints to known samples—minimizing the risk of misidentification—courts should ensure that juries are instructed that examiner testimony is informed opinion, but not fact.

In a similar spirit, in the *Crisp* case,[138] it was stated that:

> The government did not offer any record of testing on the reliability of fingerprint identification. Indeed, it appears that there has not been sufficient critical testing to determine the scientific validity of the technique . . . . The government did not introduce evidence of studies or testing that would show that fingerprint identification is based on reliable principles and methods.

On the other hand, fingerprint evidence received unwarranted support, relied upon by several judges in recent years, from the questionable report

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135. *E.g.,* People v. Ford, 606 N.E.2d 690, 693 (Ill. App. Ct. 1992) ("Fingerprint evidence is circumstantial evidence which may serve as the basis for a conviction, and when a conviction is obtained based solely on circumstantial fingerprint evidence, fingerprints must satisfy both physical and temporal proximity criteria. Physical and temporal proximity criteria are satisfied by proving that the fingerprints were found in the immediate proximity of the crime under circumstances which indicate that they could have been made only at the time of the occurrence."); People v. Rhodes, 422 N.E.2d 605, 608 (Ill. 1981) ("In order to sustain a conviction solely on fingerprint evidence, fingerprints corresponding to the fingerprints of the defendant must have been found in the immediate vicinity of the crime under such circumstances as to establish beyond a reasonable doubt that the fingerprints were impressed at the time the crime was committed."); *see also* Cr.A 4471/03 State of Israel v. Krispin, 59(3) P.D. 277, 285 (2004) ("It is a rule of case law that it is enough that the defendant's fingerprint has been found, without a logical explanation on his part, in order to convict him of a crime that was committed at the same location or by means of the object upon which the fingerprint was found.").

136. *See* United States v. Llera Plaza, 188 F. Supp. 2d 549, 565 (E.D. Pa. 2002), *withdrawing* 179 F. Supp. 2d 492 (E.D. Pa. 2002). *See also* Epstein, *supra* note 70; Simon A. Cole, *Grandfathering Evidence: Fingerprint Admissibility Rulings from* Jennings *to* Llera Plaza *and Back Again*, 41 AM. CRIM. L. REV. 1189, 1196–97 (2004); David H. Kaye, *The Nonscience of Fingerprinting:* United States v. Llera-Plaza, 21 QUINNIPIAC L. REV. 1073 (2003); Michael Lynch & Simon A. Cole, *Science and Technology Studies on Trial: Dilemmas of Expertise*, 35 SOC. STUD. SCI. 269 (2005); Jennifer L. Mnookin, *Fingerprints: Not a Gold Standard*, 20 ISSUES IN SCI. & TECH. 47 (2003).

137. State v. Quintana, 103 P.3d 168, 171 (Utah Ct. App. 2004).

138. United States v. Crisp, 324 F.3d 261, 273–74 (4th Cir. 2003) (Michael, J., dissenting).

referred to by the FBI as the "50K study."[139] This "study" was conducted in order to support the prosecution claim that each person's fingerprint is unique and that false positive errors are not made when comparing different fingerprints.[140] Although this "study" was not published in a scientific journal and was not subjected to a peer review—as required by the *Daubert* ruling[141]—judges have still relied on it.[142]

In the 50K study, FBI examiners used a computerized database of 50,000 fingerprints and an automated fingerprint identification system in order to compare each fingerprint against itself and against the other 49,999 fingerprints in the database.[143] The result yielded two and a half billion comparisons ($50{,}000 \times 50{,}000$)[144] This is considered by some courts as evidence that no false positive occurs in comparing different fingerprints.[145]

The main conceptual error in the FBI "study" was in the very fact that the 50,000 fingerprint images were compared *with themselves*. In order for the study to be valid, it is necessary to compare 50,000 images with 50,000 *other* images of the same fingerprints (namely, two different images of each fingerprint). When 50,000 images are compared with themselves, there is no possibility of error. We should remember that the image is stored on the computer as a digital file, which is a collection of digits. When two images are identical, the digits that represent them are identical. In contrast, two different digital images, even if they are of the same fingerprint, will be characterized in the computer's memory by different digits—in which case, an error is very possible. And, in reality, we are comparing two different images, such as the one taken from the scene of the crime and that of the suspect. In light of this serious conceptual mistake, it is no wonder that the FBI "study," which is essentially a self-fulfilling prophecy, has drawn scathing criticism from experts in this field.[146]

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139. Epstein, *supra* note 70, at 629–32; Cole, *supra* note 105, at 1046–48 n.334.

140. United States v. Sanchez–Birruetta, 128 F. App'x. 571, 573 (9th Cir. 2005). ("Meagher's testimony discussed a FBI study in which fingerprint examiners and computers compared 50,000 rolled fingerprints to each other and found no false positive identifications.").

141. Daubert v. Merrel Dow Pharm. Inc., 509 U.S. 579, 593 (1993).

142. *See, e.g.*, United States v. Byron Mitchell, 365 F.3d 215, 239–41 (3d Cir. 2004); *Sanchez–Birruetta*, 128 F. App'x 571.

143. *Byron Mitchell*, 365 F.3d at 225.

144. *Id.* In a second experiment, they compared partial prints. *Id*. at 226.

145. *Sanchez–Birruetta*, 128 F. App'x 571.

146. Christophe Champod & Ian W. Evett, *A Probabilistic Approach to Fingerprint Evidence*, 51 J. FORENSIC IDENT. 101, 112 (2001) ("[W]e are amazed that it was admitted into evidence."); David H. Kaye, *Questioning a Courtroom Proof of the Uniqueness of Fingerprints*, 71 INT'L STAT. REV. 521 (2003) ("[T]his article suggests that the study is neither designed nor executed in a way that can show whether an individual's fingerprint impressions are unique."); Pankanti et al., *supra* note 95, at 1015; James L. Wayman, *When Bad Science Leads to Good Law: The Disturbing Irony of the* Daubert *Hearing in the Case of* U.S. v. Byron, C. Mitchell, BIOMETRICS IN THE HUMAN SERVICES USER GROUP NEWSLETTER (Jan. 2000), *available at* http://vvv.dss.state.ct.us/digital/news17/bhsug17.htm.

Most surprisingly, despite the considerable methodological problems of the FBI's 50K "study," some courts continue to rely on it, concluding that fingerprint evidence is very reliable and that errors are essentially impossible.[147]

Given this state of affairs, in which the scientific basis for proof by means of fingerprint comparison has essentially never been established (that is, the possibility of a random match has never been refuted) and the courts have not been presented with the error rates of experts, it should amaze us that this type of evidence has been awarded such a pivotal role in criminal trials. It is our contention that, even if it is proven that the random match probability is very low (or even zero), and that the error rate is very low (but does exist), it would still be impossible to establish a conviction beyond a reasonable doubt solely on this evidence—as we have already shown.

D. Interim Summary

First of all, we want to stress that we are not proposing to rule out the admissibility of fingerprint evidence. In our opinion, such a far-reaching proposal[148] is misdirected. It is undisputed that this is significant, weighty evidence[149] that the courts must continue to rely on. However, it should not be the sole basis for a conviction.

We have shown that there is a possibility of error with fingerprint evidence. Fingerprints from two different people can be so similar that several experts will mistakenly conclude that they belong to the same person. Errors occur in proficiency tests for laboratories,[150] just as they occur in real cases. The judicial system is just beginning to accept this fact, but it still believes that the error rate is too low to be significant. The important point demonstrated in this article is that even a very low error rate—which, at first glance, appears negligible—turns out to be extremely significant when a conviction is solely based on fingerprint evidence. Counterintuitively, in *most* cases where we use fingerprints as the sole evidence for a conviction, we will be mistaken and we will convict an innocent person. This is a classic example of the fallacy of the

147. *See, e.g.*, *Sanchez–Birruetta*, 128 Fed. App'x. at 573.

148. See, e.g., claims that fingerprint evidence does not meet the criteria of the *Daubert* ruling, in Epstein, *supra* note 70.

149. In recent decades, computerized models in the field of pattern recognition have been developed, and published in scientific journals—models that allow computerized comparisons of fingerprints to be performed. Gonzalez-Rodriguez et al., *supra* note 65, at 132–34. These models provide us with data about the error rate in various categories of test conditions for different systems. *Id*. Hence, computerized fingerprint evidence has an identification capability and even allows an identification error rate to be determined. Indeed, the error in a computerized analysis (which is dependent on the particular system and conditions) is not sufficiently low to enable a single piece of evidence to suffice for a conviction—however, this single piece of evidence can certainly supplement other evidence.

150. For an additional examination of proficiency tests in the discipline of fingerprint analysis, see Simon A. Cole, *The Prevalence and Potential Causes of Wrongful Conviction by Fingerprint Evidence*, 37 GOLDEN GATE U. L. REV. 39, 47–51, 69–85 (2006).

transposed conditional. Therefore, we propose that it be forbidden to convict a person solely on the basis of fingerprint evidence.

IV. CONVICTIONS BASED ON DNA EVIDENCE

The use, in a criminal trial, of scientific evidence comparing two genetic samples is relatively new—beginning in the 1980s.[151] DNA evidence still entails a significant danger of convicting innocent persons, even though it is accepted that the possibility of a random match must be addressed, because of the strong inclination to ignore the tremendous impact of the possibility, even if slim, of a laboratory error in DNA testing. This dangerous tendency is even apparent in the reports issued by the National Research Council's Committee on DNA Forensic Science[152]—and, as we shall see, these reports perpetuate misconceptions to many others, including judges.

A. The Possibility of a Random Match

The assumption in DNA testing is that, with the exception of identical twins, each person's DNA is unique.[153] However, with DNA evidence, not all the molecules in the two samples tested are compared—instead, the comparison is performed for a limited number of loci.[154] Therefore, there is a possibility of a coincidental match between DNA samples that are not from the same source.

The random match probability is the odds that a DNA test will still yield a match even if the sample from the crime scene does not belong to the suspect.[155] At this point, we should pause to remember that this is not the probability the court must determine. The court must determine the inverse conditional probability—that is, the probability that the two samples belong to the defendant and that the defendant is indeed guilty of the crime, given a match. In order to resolve this question, the remaining evidence in the case must be weighed—which may be accomplished by using the logic of Bayes' Theorem (not necessarily in a numerical fashion), or some other acceptable method.

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151. David H. Kaye, *DNA Evidence: Probability, Population Genetics, and the Courts*, 7 HARV. J.L. & TECH. 101, 101 (1993).

152. NRC-I, *supra* note 76, NRC-II, *supra* note 53.

153. For an explanation of the scientific aspect of DNA testing, see, e.g., Kaye , *supra* note 151; FED. JUDICIAL CTR., REFERENCE MANUAL ON SCIENTIFIC EVIDENCE 485–576 (2d ed. 2000); *What Every Law Enforcement Officer Should Know About DNA Evidence*, National Institute of Justice (2004), at: http://www.dna.gov/audiences/investigators/know (last visited Jan. 28, 2007).

154. REFERENCE MANUAL ON SCIENTIFIC EVIDENCE , *supra* note 153, at 493.

155. However, it should be noted that the phenomenon known in literature as "the birthday paradox" also leads to the discovery of more random matches in the population than we would intuitively expect. *See, e.g.,* Thomas S. Nunnikhoven, *A Birthday Problem Solution for Nonuniform Birth Frequencies*, 46 AM. STATISTICIAN 270 (1992). Thus, despite the fact that the probability for a random person to have the same birthday as another random person is 1/365, surprisingly, in a group of only 23 people there is a 50% probability that two people will have the same birthday. This is because we are not comparing the birthday of one random person with the birthdays of several persons, but rather we are comparing the birthdays of all possible pairs.

The possibility of a random match in a DNA comparison is not a particularly significant problem in a criminal trial, since it is well accepted that this factor needs to be considered.[156] However, because there is an awareness of this possibility regarding DNA evidence, and because it is sometimes expressed in astronomical terms—for example, that a random match between the sample from the crime scene and the sample taken from the defendant can only be expected to occur in one out of a billion cases—the danger of convicting an innocent person based on a DNA comparison is considerably greater when the possibility of laboratory error is ignored (as it unfortunately is[157]). We should therefore remember the above example of the HIV diagnosis,[158] where our first intuition was radically altered (from 99.9% to only 9%) when we took into account the possibility of a laboratory error and the data for the risk group of the person tested.[159] Recalling this, we shall now proceed to discuss the possibility of error in a DNA test.

B. The Considerable Impact of the Possibility of a Laboratory Error

When DNA evidence began to be used in court, experts would claim that there was no possibility of error and that the reliability of the test was essentially absolute.[160] As Koehler correctly notes, a distinction should be made between a DNA match and a report of a DNA match; the difference stems from the possibility of error.[161]

As many studies demonstrate, errors occur for a variety of reasons.[162] Thus, for example, cross-contamination and sample mix-ups appear to be chronic and occur even at the best DNA labs.[163] The concern is greater with PCR (Polymerase Chain Reaction) based typing methods.[164] This process entails the duplication of a small amount of DNA, in order to produce a larger amount sufficient for conducting the DNA test. The problem is that even a tiny contamination of the small sample is liable to be amplified into a significant contamination of the enlarged sample, thus biasing the test results. Errors could occur in each testing phase—from the moment the samples are collected

156. *See, e.g.*, State v. Bible, 858 P.2d 1152, 1185 n.18 (Ariz. 1993) ("Any argument that the random match probability constitutes a 'guilt probability' is, of course, incorrect and misleading."); State v. Bloom, 516 N.W.2d 159, 163 (Minn. 1994).

157. People v. Reeves, 109 Cal. Rptr. 2d 728, 753 (Cal. Ct. App. 2001) ("Because appellant has not presented persuasive evidence of an ongoing controversy in the scientific community, we conclude that the NRC's recommendation is generally accepted, and DNA probability calculations need not be modified to account for a laboratory error rate.").

158. *See supra* Part II.A.

159. Indeed, even HIV counselors might make a mistake at this point and assume that the danger of a false positive is low even for a low-risk population. *See* Gerd Gigerenzer, Ulrich Hoffrage & Axel Ebert, *AIDS Counselling for Low-Risk Clients*, 10 AIDS CARE 197, 207 (1998).

160. Thompson et al., *supra* note 57, at 47–48.

161. Jonathan J. Koehler, *On Conveying the Probative Value of DNA Evidence: Frequencies, Likelihood Ratios, and Error Rates*, 67 U. COLO. L. REV. 859, 868–69 (1996).

162. NRC-II, *supra* note 53, at 80–85.

163. Thompson, *Gold Standard*, *supra* note 85, at 11–14.

164. NRC-II, *supra* note 53, at 83, 84.

until the test itself.[165] Moreover, the test entails a subjective interpretation of lines that appear at its conclusion.[166] An incorrect interpretation is liable to yield an erroneous result.[167] Even the most human of errors, like mislabeling samples, could occur. These are just examples of possible errors. Our goal here is not to list all possibilities, but to just note their existence.[168]

The first report of the National Research Council's Committee on DNA Forensic Science, from 1992, stated that:

> Interpretation of DNA typing results depends not only on population genetics, but also on laboratory error. Two samples might show the same DNA pattern for two reasons: two persons have the same genotype at the loci studied, or the laboratory has made an error in sample handling, procedure, or interpretation.[169]

The NRC-I report further stated that *"[l]aboratory errors happen, even in the best laboratories and even when the analyst is certain* that every precaution against error was taken" (emphasis added).[170] Therefore, it was concluded that laboratories should undergo blind proficiency tests—where laboratory personnel believe they are working on a real case and are unaware that they are being tested, and that the results of the proficiency tests should be reported to juries.[171] The Federal Judicial Center's Reference Manual on Scientific Evidence also acknowledges the possibility of a laboratory error in a DNA test.[172]

Reality provides us with numerous examples of convictions for serious offenses, like murder and rape, based on laboratory errors obtained in DNA testing. In the United States, the wrongful convictions of Josiah Sutton,[173] Timothy Durham,[174] and other unfortunate defendants[175] have been well publicized. In 2001, the justice minister of New Zealand announced that his government would pay David Dougherty compensation of approximately $900,000 for his conviction and three-year imprisonment for the rape of a

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165. *Id.* at 87.

166. William C. Thompson et al., *Evaluating Forensic DNA Evidence: Essential Elements of a Competent Defense Review: Part 1*, 27 CHAMPION, Apr. 2003, at 16, 21–24; NRC-II, *supra* note 53, at 84–85.

167. *Id.*

168. For more detailed discussions of the sources of error, see Thompson, *Gold Standard*, *supra* note 85; Thompson, *Evaluating Forensic DNA Evidence*, *supra* note 166; William C. Thompson et al., *Evaluating Forensic DNA Evidence: Essential Elements of a Competent Defense Review: Part 2*, 27 CHAMPION, May 2003, at 24; Stacy L. Stouder et al., *Trace Evidence Scrapings: A Valuable Source of DNA?*, 3 FORENSIC SCI. COMM. 152 (2001); James Herbie DiFonzo, *In Praise of Statutes of Limitations in Sex Offense Cases*, 41 HOUS. L. REV. 1205, 1232–61 (2004).

169. NRC-I, *supra* note 76, at 88–89.

170. *Id.* at 89.

171. *Id.*

172. REFERENCE MANUAL ON SCIENTIFIC EVIDENCE, *supra* note 153, at 520.

173. DiFonzo, *supra* note 168, at 1249–53.

174. SCHECK ET AL., *supra* note 22, at 158–61, 166–71.

175. See, e.g., the cases surveyed in Thompson, *Gold Standard*, *supra* note 85, at 10, 13, 14; Thompson et al., *supra* note 57, at 48.

young girl—a wrongful conviction based on erroneous DNA testing.[176] Another case of error, which fortunately did not reach the courts, also occurred in New Zealand in 2000.[177] An investigation designed to ascertain the source of the error failed to do so with certainty and found only that it apparently arose from contamination in the initial stages of the laboratory work.[178]

Thompson reports numerous errors and problems in the management of DNA laboratories in the United States and other countries, both in confirmation cases and in database searches ("cold hits").[179] He bases his findings on laboratory records and warns of the unexpectedly high frequency of cases in which mislabeling and sample contamination (where genetic material from one sample is somehow transferred to another sample) have been detected.[180] Although these cases of contamination were discovered early at the laboratory, they still worry Thompson, because such phenomena occur regularly even in what are considered to be the best laboratories, and because "the same processes that cause detectable errors in some cases can cause undetectable errors in others."[181] Indeed, "[e]rrors that incriminate a suspect are unlikely to be detected as errors; they are likely to be treated as incriminating evidence."[182] Thompson also discusses the possibility of the falsification of test results by laboratory technicians in an attempt to cover up incidents of contamination, which can be the result of negligence, and can cost a worker his job.[183]

In his 1993 survey,[184] Koehler reports on professional proficiency tests that were not blind. The error rates in these tests were tremendous, varying between 1% and 4%.[185] Another survey, from 1995,[186] revealed an error rate of

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176. New Zealand Government Executive Press Release, July 11, 2001, http://www.executive.govt.nz/speech.cfm?speechralph=35330&SR=0 (last visited Sept. 25, 2007).

177. New Zealand Justice Minister Announcement, Mar. 9, 2000, http://www.executive.govt.nz/Speech.aspx?type=press&rid=30507 (last visited Sept. 25, 2007).

178. *Id.* This announcement also mentioned a report on this topic: SIR THOMAS EICHELBAUM & SIR JOHN SCOTT, REPORT ON DNA ANOMALIES (New Zealand Ministry of Justice) (1999). For a discussion of another case, regarding the murderer Jaidyn Leskie, see Thompson, *Gold Standard*, *supra* note 85, at 13–14.

179. Thompson, *Gold Standard*, *supra* note 85.

180. *Id.*

181. *Id.* at 12.

182. *Id.*

183. Thompson, *Gold Standard*, *supra* note 85. An example of this phenomenon is the case of the biologist Jacqueline M. Blake, who was eventually fired from her job. U.S. Department of Justice, Office of the Inspector General, *The FBI DNA Laboratory: A Review of Protocol and Practice Vulnerabilities, Chapter Four: Jacqueline Blake's Misconduct*, http://www.usdoj.gov/oig/special/0405/index.htm (last visited Sept. 25, 2007). This happened as well in the case of Sarah Blair, from the Orchid–Cellmark Laboratory, and also in the case of the Houston police laboratory, which was closed down because of faulty management. Thompson, *Gold Standard*, *supra* note 85, at 12. *See also* Richard O. Lempert, *After the DNA Wars: A Mopping Up Operation*, 31 ISR. L. REV. 536, 552–53 (1997).

184. Jonathan J. Koehler, *Error and Exaggeration in the Presentation of DNA Evidence*, 34 JURIMETRICS J. 21, 26 (1993).

185. *Id.* at 26; *supra* Part II (regarding the significance of this data) and Table 1.

186. Jonathan J. Koehler et al., *The Random Match Probability in DNA Evidence: Irrelevant and Prejudicial?*, 35 JURIMETRICS J. 201, 206–11 (1995).

1/800 (0.125%). As we have seen, even an error rate of 1/10,000 (0.01%) is very significant for a conviction based on a single piece of evidence.[187]

Koehler, Chia and Lindsey claim—and we agree—that when the probability of a laboratory error is much greater than the probability of a random match, then the probability of the latter is insignificant, and the relevant statistic is the probability of the former.[188] For example, if the random match probability is one in a billion, and the probability of a laboratory error is one in a thousand, then the first statistic—unfortunately, the only statistic presented to the jury, thus blinding them—creates a bias against the defendant. Therefore, it is better not to even report this statistic to the jury, since the much more relevant statistic is the one in a thousand possibility of a laboratory error. Indeed, when other evidence exists against the defendant, this scientific evidence does carry inculpatory significance. However, as we have seen in Part II, when there is no other inculpatory evidence, scientific evidence of this nature is incapable of proving the defendant's guilt—at least not beyond a reasonable doubt.

Another interesting argument in this matter, raised by Lempert, states that if a specific laboratory errs in 10% of its tests, and *all* the matches that it has found are false, then the more relevant statistic for juries is that 100% of the matches found at this laboratory are false.[189] Finally, another claim, raised by Koehler, is that in the absence of statistics regarding the error rate of a given laboratory, the average error rate of *all* laboratories should be taken into account.[190]

C. The Surprising Second Report of the National Research Council[191]

The NRC-I report was issued at the behest of government agencies—headed by the FBI—expecting a report that would enhance the status of DNA evidence in the courts and rebut the claims of defense attorneys challenging

187. Table 1, *supra* Part II.C.

188. Koehler et al., *supra* note 186, at 210–11.

189. Richard O. Lempert, *After the DNA Wars: Skirmishing with NRC II*, 37 JURIMETRICS J. 439, 449 (1997).

190. Koehler, *supra* note 59, at 433. Here we disagree slightly with Koehler. We believe that test results from a laboratory for which the court has no statistical data regarding error rates should be inadmissible as evidence in a criminal trial, inter alia, in light of the *Daubert* ruling (even if this has not been explicitly determined). Alternatively, for the sake of caution, and in order to avoid convicting innocent persons, if the court still decides to accept such "evidence," then it should assume that the error rate in this particular laboratory—whose statistics are "secret"—is not average (that is, it should be ascribed the highest rate of error among laboratories of its type). Regarding the *Daubert* ruling, see *supra* note 49 and the accompanying text. A similar claim has been raised in Barry C. Scheck, *DNA and* Daubert, 15 CARDOZO L. REV. 1959, 1981–85 (1994). In this matter, it should also be remembered that the defense has no access to information kept by the manufacturers of DNA testing kits, which could be relevant in finding the sources of false positives. *See* Jennifer N. Mellon, *Manufacturing Convictions: Why Defendants Are Entitled to the Data Underlying Forensic DNA Kits*, 51 DUKE L.J. 1097 (2001).

191. NRC-II, *supra* note 53.

the reliability and certainty of this type of evidence.[192] The NRC-I report was a big disappointment to these agencies.[193] Therefore, an additional report (NRC-II)[194] was issued, supposedly as an update of the first report that would "deliver the goods."[195] The most significant aspect of the NRC-II report is essentially the case-specific argument:[196] "The question to be decided is not the general error rate for a laboratory or laboratories over time but rather whether the laboratory doing DNA testing in this particular case made a critical error."[197]

The report's position is that, in each case deliberated, the court should examine the manner in which the test was performed ("taking into account the record of the laboratory performing the tests, the extent of redundancy, and the overall quality of the results") and then decide whether an error occurred in that specific case.[198] This means that the court must reach a decision on this issue without relying on the other evidence in the case. According to this approach, therefore, if no other evidence exists against the suspect, and there is no apparent testing error, but the probability of a random match is one in a billion or a trillion, then the defendant will be convicted. In the *Adams* case,[199] a random match probability of one in 200 million was sufficient to convict a defendant against whom there was not only no other inculpatory evidence, but for whom there was even exculpatory evidence.

The position taken by the NRC-II report is amazing given the diverse possibilities for laboratory errors and test results that are potentially biased by laboratory workers or investigators. There are cases in which the source of the laboratory errors cannot be ascertained even in hindsight.[200] It is implausible that courts could do this in advance, when it is still unknown that an error has occurred. Therefore, it is no wonder that many scholars disagree with this approach.[201]

Another explanation, sociological in nature, for the NRC-II report's position regarding laboratory error, is that when a dispute exists in the forensic community, considerations of legal policy are intertwined with scientific considerations.[202] It is unfortunate that, in this matter, legal policy is so biased in favor of the "law and order" and "crime control" approaches, and that the

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192. Lempert, *supra* note 189, at 450–51.

193. *Id.*

194. *Id*.

195. *Id*.

196. *See supra* Part II.D.

197. NRC-II, *supra* note 53, at 85.

198. *Id*. at 87.

199. R. v. Adams, [1996] 2 Cr. App. R. 467; R. v. Adams, [1998] 1 Cr. App. R. 377.

200. *See, e.g.*, *supra* notes 177–78 and accompanying text.

201. *See, e.g.*, Thompson et al., *supra* note 57; Lempert, *supra* note 189, at 446–54; Koehler, *supra* note 161, at 864–68; Koehler, *supra* note 59, at 431–34; Scheck, *supra* note 190.

202. Mike Redmayne, *Expert Evidence and Scientific Disagreement*, 30 U.C. DAVIS L. REV. 1027 (1997). One committee member criticized this article in Margaret A. Berger, *Laboratory Error Seen Through the Lens of Science and Policy*, 30 U.C. DAVIS L. REV. 1081 (1997). Another scholar supported it in William C. Thompson, *A Sociological Perspective on the Science of Forensic DNA Testing*, 30 U.C. DAVIS L. REV. 1113 (1997).

proper weight has not been accorded to the danger that innocent persons may be wrongfully convicted.

The case-specific approach taken by the NRC-II report does not rely on any scientific references for support.[203] The report does not explain why the attitude towards the possibility of an error in DNA testing needs to be any different from the accepted attitude regarding the possibility of an error in other realms of science, such as medical diagnosis,[204] engineering,[205] and other fields related to scientific evidence.[206] In these other fields, there is suitable awareness that the rarer the phenomenon tested the more precise the testing needs to be. In effect, not only has the (supposed) correctness of the committee's position not been proven but, in our opinion, it may even be said that it has been refuted by those same cases—some mentioned above—where it was discovered, only after the fact, that a laboratory error had occurred, and where it was not even possible to discover the source of the error in retrospect.

We do agree with the claim in the NRC-II report that a retest, especially if performed by another laboratory, could reduce the error rate.[207] Such retesting, however, will not reduce the error rate to zero. First of all, it is possible that the same cause of error in the first test will repeat itself in the retest at the second laboratory.[208] Different laboratories have repeated the same errors.[209] The possibilities for the same mistake to be repeated in a different laboratory vary and include, *inter alia*, errors in interpreting the lines obtained in the test and contamination of the sample prior to the retest.[210] In addition, the first laboratory sometimes exhausts all of the sample material, thus precluding the option of a retest.[211]

Nevertheless, since the additional test could prevent some laboratory errors leading to the wrongful convictions of innocent persons, we believe that legislation should be enacted stipulating that—as a condition for relying on the laboratory results of DNA testing for the purposes of a conviction—a retest must be performed by an independent, objective expert. It should be noted and stressed that, because an additional test does not completely eliminate the possibility of error, DNA evidence should not suffice for a conviction.

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203. See NRC-II, *supra* note 53, at 85–87.

204. *See, e.g.,* Meyer & Pauker, *supra* note 74.

205. When an electronic system, such as radar, is supposed to detect a particular signal from among the general noise, the threshold of detection is set while taking into account the rarity of the signal that it is supposed to detect. The rarer the signal the higher the threshold needs to be in order to avoid numerous false alarms. Saks & Risinger, *supra* note 39, at 1052–53.

206. *See, e.g.,* Gonzalez-Rodriguez et al., *supra* note 65, at 128–29.

207. *See* NRC-II, *supra* note 53, at 87.

208. David J. Balding, *Errors and Misunderstandings in the Second NRC Report*, 37 JURIMETRICS J. 469, 475–76 (1997).

209. *See, e.g.,* Koehler, *supra* note 59, at 437; Thompson et al., *supra* note 57, at 48.

210. Thompson et al., *supra* note 57, at 48.

211. This was the common practice in a Houston police laboratory. For a case study of the faulty operation of this laboratory, see DiFonzo, *supra* note 168, at 1242–49.

D. Interim Summary

It is important to emphasize that we are not proposing that DNA evidence be ruled inadmissible in court. It is undisputed that this is significant, weighty evidence that the courts must rely on—but not as the sole evidence for a conviction.

There is a tendency to treat the possibility of a laboratory error in isolation from the other evidence in the case. This is done despite the fact that laboratory errors are unavoidable and it is impossible to determine in court whether they have occurred in a specific case. Even repeating the test in another laboratory does not fully solve this problem. Unfortunately, since 1996, courts both in the United States[212] and other countries[213] have relied on the misleading NRC-II report. Courts refuse to consider the possibility of a laboratory error when they assess the weight of DNA evidence and conclude that this is an entirely different issue that should not be confused with the possibility of a random match (which they have taken into account). Thus, despite the fact that the possibility of a laboratory error (which could be one in a thousand and perhaps even one in a hundred cases) might be much greater than that of a random match, juries are not provided with this statistic and are left only with the dark shadow of a random match possibility (which could be only one in a million, a billion, or even a trillion cases). This means that a possibility of one error in a thousand cases is evaluated independently from the other evidence in the case, which is incompatible with the decision-making theories described in this article. Therefore, when there is only a single piece of DNA evidence, the error by the fact finder in a trial is liable to be immense. As we have seen in Part II, even an average error rate of one in 100,000 cases is very significant.

In our opinion, the possibility of a laboratory error—the occurrence of which has been proven again and again in reality—detracts from the tremendous theoretical power, attributed to DNA evidence, to isolate the suspect from among the hundreds of thousands of other people who could have committed the crime (as expressed in the possibility of a random match).

The problem is that there are no adequate statistics regarding the error rates of various laboratories. In our opinion, the burden to establish these statistics falls on the prosecution. In the absence of data for a specific laboratory, it is possible to conclude that the evidence should be inadmissible. Alternatively, the evidence could be admitted and ascribed the highest known rate of error for tests performed in various laboratories.

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212. *See, e.g.*, People v. Reeves, 109 Cal. Rptr. 2d 728 (Cal. Ct. App. 2001); United States v. Trala, 162 F. Supp. 2d 336, 350 (D. Del., 2001).

213. *See, e.g.*, R. v. Karger, [2001] SASC 64, ¶¶ 664–66 (Supreme Court of South Australia Mar.. 29, 2001), *available at* http://www.austlii.edu.au/cgi-bin/sinodisp/au/cases/sa/SASC/2001/64.html?query=^Karger; R. v. Love [1995], 102 C.C.C. (3d) 393 (Alta. C.A.) (this case is reviewed in Trevor R. McDonald, *Genetic Justice: DNA Evidence and the Criminal Law in Canada*, 26(1) MANITOBA L.J. 1 (1998)).

One way or another, we should not accept a conviction based solely on a DNA test—for, in most cases, there is a very tangible danger that this will be a wrongful conviction. As we have already shown, a conviction solely based on a fingerprint comparison is also unacceptable. Therefore, at this point, we can already state that, until proven otherwise (and, in our opinion, it will never be proven otherwise), a person should not be convicted on the basis of any single piece of scientific evidence. The next argument that we will try to make is that a person should not be convicted on the basis of any single piece of evidence (even nonscientific evidence). In order to do this, we discuss the two major types of nonscientific evidence adduced in criminal trials—confessions and eyewitness testimony.

V. CONVICTIONS BASED ON CONFESSIONS

A. The Danger of False Confessions

At least in the past, courts have tended to view a confession as a trump card—namely, as very strong evidence of guilt and certainly sufficient to sustain a conviction. This approach is based on the notion that a voluntary confession stems from the strongest feelings of guilt.[214] Accordingly, the confession has been crowned the "queen of evidence."[215]

Numerous studies indicate that false confessions are a significant phenomenon. Given the revealing findings of the Innocence Project, this is no longer a matter of mere speculation. There is now proof that many suspects and defendants have been convicted on the basis of false confessions.[216] It should be noted that when genetic testing shows that the DNA found at the crime scene did not come from the defendant, statistical probabilities related to random matching are no longer an issue.[217]

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214. The King v. Warickshall, (1783) 168 Eng. Rep. 234 (K.B.).

215. Significant support for the belief that the confession is the "queen of evidence" is attributed to Andrey Vyshinsky, Prosecutor General of the Soviet Union and the legal mastermind of Stalin's Great Purge during the late 1930's. *See*, HAROLD J. BERMAN, SOVIET CRIMINAL LAW AND PROCEDURE 92 (1966); IDEAS AND FORCES IN SOVIET LEGAL HISTORY: A READER ON THE SOVIET STATE AND LAW 288 (Zigurds L. Zile, ed.,1992); *see also* Stephen C. Thaman, Miranda *in Comparative Law*, 45 ST. LOUIS U. L.J. 581, 581 (2001) (stating that "[h]istorically, confessions of guilt have been the 'best evidence in the whole world'").

216. According to the findings of the Innocence Project, from among the first 210 cases in which genetic testing proved the falsity of confessions, in over a quarter the conviction was based on a confession. *See* http://www.innocenceproject.org (last visited Jan. 14, 2008).

217. *See* the sources cited *supra* note 22; *see also* Achikam Stoler & Yoram Plotsky, *DNA on the Witness Stand*, MEDICINE AND LAW (Jubilee Edition) 143 (2001) [Hebrew] ("if there is a difference in part of the sequence, then it is impossible that the whole sequence would be identical. The answer is absolute and unequivocal, and it is not defined in terms of probability" (*id*. at 146) [translated by the authors]); Lafollette, *supra* note 22, at 1296, n.7 ("The inculpatory use of DNA evidence has been controversial because statistical analysis is used to declare a DNA 'match.' . . . However, '[o]ne aspect of DNA testing, an exclusion, has never been at issue scientifically.' [Barry Scheck, *The Use of DNA Evidence in Death Penalty Cases*, 23 HOFSTRA L. REV. 639, 639–40 (1995)]").

The physical conditions necessary for conducting a DNA test only exist in a small number of cases where the claim of a wrongful conviction has been raised.[218] Accordingly, it may be inferred that there are many more actual cases of wrongful conviction than those where it has been proven by DNA testing.

In their study, Bedau and Radelet have confirmed that a phenomenon of false confessions does exist.[219] Out of the 350 wrongful convictions that they examined, 49 entailed false confessions.[220] Furthermore, in a great number of these cases (17), interrogees made false confessions voluntarily, without any illegitimate pressure exerted on them by police interrogators.[221] These cases demonstrate that it is not enough to address the external factors leading to false confessions (illegitimate pressure exerted by interrogators); it is also necessary to consider the internal factors prompting an individual to make a false confession.

In their noteworthy study, Leo and Ofshe[222] presented findings on sixty cases of false confessions in the United States brought to light following the landmark decision in *Miranda v. Arizona*.[223] The *Miranda* ruling, as it is well known, held that, under the Fifth Amendment of the U.S. Constitution, police are required to inform suspects of their constitutional right not to answer questions (the right to silence), that if they do respond to questions their answers may be used against them in a court of law, and that they have the right to meet with an attorney (private or court-appointed) prior to the interrogation and to have an attorney present during the interrogation itself.[224] A violation of these rights by the police leads to the exclusion of the confession as evidence at trial.[225] Leo and Ofshe have demonstrated that, even following *Miranda*, false confessions and the wrongful convictions based on them continue to be a significant phenomenon in the United States—despite the fact that the police have, on the whole, made the transition from a coercive interrogation to a more sophisticated "psychological" interrogation.[226]

The English Runciman Commission also concluded that wrongful convictions based on false confessions are a significant phenomenon demanding attention.[227] Consequently, it recommended that legislative reform be enacted regarding both the admissibility of a confession in court and the weight that should be accorded to it.[228]

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218. *See* Koehler, *supra* note 161.

219. *See* Bedau & Radelet, *supra* note 20.

220. *Id.* at 57.

221. See *id.* at 56–63.

222. Leo & Ofshe, *supra* note 20.

223. 384 U.S. 436 (1966).

224. *Miranda*, 384 U.S. at 467–68.

225. *Id*. at 468–69. For a detailed analysis of the *Miranda* rules, see CHARLES TILFORD, MCCORMICK ON EVIDENCE 218–26 (John W. Strong ed., 5th ed. 1999).

226. *See* Leo & Ofshe, *supra* note 20.

227. Runciman Commission Report, *supra* note 16, Chapter 4 ("The 'Right of Silence' and Confession Evidence").

228. *Id.*

In Israel, a turning point in addressing the problem of false confessions may be found in a report issued by a commission of experts headed by Justice Eliezer Goldberg.[229] The report concluded that a common reason for suspects to make false confessions is the external pressure exerted on them by interrogators.[230] This is not limited to cruel and abusive pressure designed to break the interrogee's spirit, but also relates to more subtle applications of pressure, such as sleep deprivation. It is particularly acute for suspects who are not habitual criminals and, therefore, not used to conditions of detention and interrogation. Additional factors leading to false confessions are related to the personality of the interrogee himself and the subjective emotional pressure that he experiences.[231]

The Goldberg Commission examined three main risk factors leading to false confessions:[232] (1) the interrogee's personality (including inability to differentiate between fantasy and reality, atonement for past behavior (real or imagined), self-destructive tendencies,[233] emotional or mental handicap, age, and influence of drugs or alcohol); (2) the effect of interrogation or detention on the interrogee (such as the desire of interrogees to put an end to the interrogation, because of the resulting mental exhaustion, and the willingness to confess to a lesser charge for the sake of immediate advantage);[234] and (3) social pressure (such as the desire to cover up for the true culprit).

Studies conducted in recent years have shown that the motivating factors for false confessions are extremely diverse, some even bizarre: suspects have falsely confessed to avoid the burden of a trial (for minor offenses), out of a fear of the death penalty, in order to cover up for friends, as a result of mental illness, and to obtain financial reward for their families from a criminal organization.[235] Some have confessed to prevent their names from appearing in the press or because of the fear that they would be exposed as adulterers.[236] There are those who have confessed in order to get quickly to an exam at the university or an important game of chess, because they were too drunk to

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229. REPORT OF THE COMMISSION FOR CONVICTIONS BASED SOLELY ON CONFESSIONS AND FOR ISSUES REGARDING THE GROUNDS FOR RETRIALS (December, 1994) [Hebrew] [hereinafter Goldberg Commission Report].

230. *Id.* at 8.

231. *Id.* at 8–9.

232. *Id.* at 9–10. For a different classification, which includes four categories, see section 32 of the Runciman Commission Report, *supra* note 16.

233. See Maimonides, *Mishneh Torah* (Code of Jewish Law), Book of Judges, *Hilchot Sanhedrin* (Laws of the Sanhedrin) 18:6 ("The court shall not put a man to death or flog him on his own admission . . . perhaps he was one of those who are in misery, bitter in soul, who long for death . . . perhaps this was the reason that prompted him to confess to a crime he had not committed, in order that he be put to death.").

234. It should be noted that, despite the presumption of innocence, conditions of detention are extremely harsh—sometimes even worse than prison conditions. For a survey of detention conditions in the United States and their incompatibility with the presumption of innocence, see Rinat Kitai-Sangero, *Conditions of Confinement—The Duty to Grant the Greatest Possible Liberty for Pretrial Detainees*, 43 CRIM. L. BULL., Mar.–Apr. 2007, at 4.

235. Goldberg Commission Report, *supra* note 229, at 9–10.

236. Sangero, *supra* note 11, at 2800–01 n.28.

remember what happened, and even as a joke or to impress a girlfriend.[237] In one case, a person confessed, while in prison, to a murder that he did not commit, in order to prove that a wrongful conviction was possible—and he actually succeeded. Reality is often stranger than fiction.[238]

To conclude, in our opinion, not only is the confession *not* the "queen of evidence," but, rather, it is the "*empress of wrongful convictions*."

B. The Danger of Convictions Based on False Confessions

American law addresses the danger of coerced, involuntary confessions in a relatively satisfactory manner. However, as we shall demonstrate, it does not adequately address the danger of false confessions (which might be voluntary) and the wrongful convictions based on such confessions.

1. *Voluntariness, in General, and Miranda Rules, in Particular*

The landmark decision of *Miranda v. Arizona*[239] expounded the central doctrine regarding confessions in American law. This judgment took the approach that, in principle, a custodial interrogation constitutes a violation of the privilege against self-incrimination established by the Fifth Amendment.[240] The Court recognized that "without proper safeguards the process of in-custody interrogation of persons suspected or accused of crime contains inherently compelling pressures which work to undermine the individual's will to resist and to compel him to speak where he would not otherwise do so freely,"[241] stressing that "the modern practice of in-custody interrogation is psychologically rather than physically oriented."[242] The Court further noted that "[u]nless adequate protective devices are employed to dispel the compulsion inherent in custodial surroundings, no statement obtained from the defendant can truly be the product of his free choice."[243]

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237. *Id*.

238. *See* Bedau & Radelet, *supra* note 20, at 63; Runciman Commission Report, *supra* note 16; Goldberg Commission Report, *supra* note 229; Arye Rattner, Convicting the Innocent: When Justice Goes Wrong (Ph.D. Dissertation. Ohio State University, 1983); Rattner, *supra* note 20.

Another major cause of false confessions is a suspect's misguided belief that after having initially made a confession, extracted from him by police interrogators through the use of improper methods, additional confessions are meaningless. Sometimes the suspect is tricked into believing this. *See* Peter Mirfield, *Successive Confessions and the Poisonous Tree*, CRIM. L. REV. 554 (1996). However, see and compare the ruling handed down on this subject in Missouri v. Seibert, 542 U.S. 600 (2004).

239. 384 U.S. 436 (1966); *see also* RONALD N. BOYCE & ROLLIN M. PERKINS, CRIMINAL LAW AND PROCEDURE—CASES AND MATERIALS 218–26 (8th ed. 1999). The *Miranda* ruling was confirmed in Dickerson v. United States, 530 U.S. 428 (2000). For a collection of two dozen articles dealing with the *Miranda* ruling, see THE *MIRANDA* DEBATE—LAW, JUSTICE AND POLICING (Richard A. Leo & George C. Thomas III, eds., 1998).

240. *Miranda*, 384 U.S. at 458, 466–67.

241. *Id.* at 467.

242. *Id.* at 447.

243. *Id*. at 458.

Under *Miranda*, police interrogators are required to advise the suspect of his right to remain silent and his right to consult with an attorney.[244] A confession obtained while infringing these rights is a violation of the Fifth Amendment and, therefore, inadmissible in court.[245]

The problem of involuntary confessions is indeed seriously addressed by the *Miranda* rules. However, as Leo and Ofshe[246] have shown, despite these rules, false confessions remain a significant problem in the United States, and innocent persons are still convicted on the basis of such confessions.[247] Firstly, a large number of interrogees validly waive their *Miranda* rights. Secondly, the use of trickery, and even deceit, by police interrogators, is not prohibited and does not render a confession inadmissible.[248] Finally, as we will show, American law does not seriously address the danger of confessions that, although voluntary, are still false.

2. *The Existing Corroboration Requirement*

American law provides a rule attempting to cope with the fear that a confession—even if voluntary—is false.[249] This rule requires that additional corroborative evidence be adduced at trial in order to convict a person based on a confession. Such rules have been established in many American jurisdictions, in both legislation and case law.[250] However, a thorough examination of the American corroboration requirement indicates that it does not serve its intended purpose.

There are two main objectives to the proposed requirement for "strong corroboration": (1) to eliminate the fear of a false confession (even when voluntary) and (2) to send a message to police investigators that they should not limit themselves to interrogations and attempts to extract confessions, but that they should employ sophisticated investigative techniques in a serious effort to find objective, tangible evidence extrinsic to the suspect.[251] Such evidence may rule out the interrogee as a suspect and perhaps even direct suspicion at another individual.

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244. *Id*. at 444.

245. Furthermore, there are other rules that, in rare cases, may lead to the exclusion of involuntary confessions that have been obtained in violation of the Constitution. MCCORMICK, *supra* note 225, at 226–42.

246. *See* Leo & Ofshe, *supra* note 20; *see also* Laurie Magid, *The* Miranda *Debate: Questions Past, Present and Future—A Review of the* Miranda *Debate: Law, Justice and Policing, Edited by Richard A. Leo and George C. Thomas III*, 36 HOUS. L. REV. 1251 (1999).

247. *See also* Amanda L. Prebble, *Manipulated by* Miranda*: A Critical Analysis of Bright Lines and Voluntary Confessions under* United States v. Dickerson, 68 U. CIN. L. REV. 555, 578–79 (2000); Mandy DeFillipo, *You Have the Right to Better Safeguards: Looking Beyond* Miranda *in the New Millennium*, 34 J. MARSHALL. L. REV. 637, 639–40 (2001).

248. *See* Prebble, *supra* note 247, at 583; *see also* Welsh S. White, *False Confessions and the Constitution: Safeguards Against Untrustworthy Confessions*, 32 HARV. C.R.-C.L.L. REV. 105 (1997); Richard A. Leo, *From Coercion to Deception: The Changing Nature of Police Interrogation in America*, 18 CRIME L. & SOC. CHANGE 35 (1992).

249. *See, e.g.,* the survey in MCCORMICK, *supra* note 225, at 212.

250. *Id.*

251. *Id.* at 215.

The corroboration requirement traditionally formulated by American law requires some evidence other than the confession tending to establish the *corpus delicti*. It does not demand that this additional evidence prove the *corpus delicti* beyond a reasonable doubt—only "slight" corroborative evidence is required.[252]

Corpus delicti is literally defined as "the body of the crime." The American corroboration requirement only pertains to the actual commission of the offense, not to the question of whether or not the defendant was the perpetrator. The prosecution must prove three main elements in a criminal trial: (1) the occurrence of the injury or harm constituting the crime; (2) that this injury or harm was done in a criminal manner; and (3) that the defendant was the person who inflicted the injury or harm.[253] The *corpus delicti* has been defined to include the first and the second elements. Therefore, the corroborative evidence does not need to prove that the defendant was the guilty party.[254]

Indeed, a requirement for evidence that a crime was actually committed—in addition to the confession itself—could disprove some false confessions and prevent wrongful convictions. It would also save the legal system the embarrassment that ensues when a person is convicted and, subsequently, it becomes apparent that no crime was committed at all—such as when someone is convicted of murder and it is later discovered that the "victim" is alive.[255] However, this only represents a small fraction of false confessions and wrongful convictions. In the majority of cases, the police have strong evidence that a crime was indeed committed, and the main question regarding a confession should be whether or not the suspect is the perpetrator—a question that the existing corroboration requirement fails to address.

Whether or not a crime was actually committed is a meaningless question if it is asked regarding someone who was not even involved in the incident. When the wrong person is in custody, the proof that a crime was committed does not say anything about this individual's involvement or guilt.[256]

As with American law, the legal systems of other countries have also attempted to deal with the danger of a coerced, involuntary confession.[257] Unfortunately, in the absence of a requirement for strong corroboration, they do not meaningfully address the danger of false confessions (which may be voluntary) and the wrongful convictions based on such confessions.[258] There-

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252. *Id*. at 214.

253. *Id*.

254. *Id*.

255. *See, e.g.*, SCHECK ET AL., *supra* note 22, at 88.

256. In order to complete the picture, it should also be noted that the U.S. Supreme Court has provided an alternative approach to the corroboration requirement whereby, instead of evidence supporting the *corpus delicti*, it is necessary to present "substantial independent evidence which would tend to establish the trustworthiness of the statement.": Opper v. United States, 348 U.S. 84, 93 (1954). This requirement is even weaker. MCCORMICK, *supra* note 225, at 215–16. Therefore, in our opinion, it is even less satisfactory.

257. Regarding other legal systems, in particular, that of England and Israel, see Sangero, *supra* note 11, at 2806–14.

258. *Id*.

fore, it is still possible for someone to be convicted solely based on a confession.

C. The Need for "Strong Corroboration" to a Confession

Properly defined, "strong corroboration" is independent evidence, derived from a source extrinsic to the evidence that needs to be corroborated, pertaining to a central question on which the trial revolves and tending to implicate the defendant in the commission of the offense.[259] If we return to the above analysis, the corroborative evidence should relate to all three elements that must be proven in a criminal trial: (1) the occurrence of the injury or harm constituting the crime; (2) that the injury or harm was done in a criminal manner; and (3) that the defendant was the person who inflicted the injury or harm.[260] In our opinion, unlike the approach taken by American courts, the emphasis should be placed on the third element. If there is a concern that the defendant has made a false confession, only independent evidence tying him to the commission of the crime—that is, only "strong corroboration"—can remove this fear.

It should be pointed out that, contrary to the mistaken belief of many, research shows that police investigators, prosecutors, judges and juries are incapable of distinguishing between a true confession and a false confession**.** In one interesting study it was revealed that: (1) police investigators are no better at identifying false confessions than students; the only difference is that the police are very sure of themselves—even when mistaken—and that they act under a misguided conception of the suspect's guilt and are therefore biased and inclined to believe false confessions, while tending to reject denials; (2) both police investigators and students are incapable of distinguishing between true confessions and false confessions, so much so that, given an equal number of genuine and false confessions, they would have reached the same outcome by simply flipping a coin.[261]

Supposedly—if they were capable of distinguishing between true and false confessions—we could assume that investigators, prosecutors, judges and juries would screen out the false confessions, and that convictions would be

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259. *See, e.g.,* COLIN TAPPER, CROSS & TAPPER ON EVIDENCE 235–43 (9th ed. 1999); CrimA. State of Israel v. Yehudai, 39(4) P.D. 197 [Hebrew]. For the definition in English law of a requirement for strong corroboration, see DAVID WOLCHOVER & ANTHONY HEATON-ARMSTRONG, ON CONFESSION EVIDENCE 24 (1996): "In English law the term 'corroboration' has a technical meaning. In *Baskerville* [1916] 2 K.B. 658 it was held that in order to be corroborative the evidence must be independent evidence which affects the accused by connecting or tending to connect him with the crime by confirming in some material particular not only the evidence that the crime has been committed but also that the accused committed it." In our opinion, such corroboration should be demanded for confessions.

260. *Supra* note 252.

261. Saul M. Kassin, Christian A. Meissner & Rebecca J. Norwick, *"I'd Know a False Confession if I Saw One": A Comparative Study of College Students and Police Investigators*, 29 LAW & HUM. BEHAV. 211 (2005). And see the references to additional studies with similar findings, *id.* at 212, 222. *See also* Leo & Ofshe, *supra* note 20, at 482 (in 73% of the cases in which defendants were tried on the basis of a false confession, they were convicted).

based solely on genuine confessions. However, as this is not the case, we should not convict an individual on the basis of a confession alone, and we should demand independent, strong corroboration, linking the defendant to the crime.

The main argument against a requirement for strong corroboration is that there is sometimes no corroborating evidence at all, in which case a guilty person might be acquitted at trial. In a previous paper, one of the authors of this article has demonstrated that this is not a serious argument and that it would be rare for a guilty person to be acquitted because of a lack of "strong corroboration" to a confession.[262]

In modern criminal law, we must limit convictions to those cases in which guilt is proven beyond a reasonable doubt.[263] The very fact that it is impossible to find any tangible evidence whatsoever to prove that someone has committed a crime—even though he has confessed and, therefore, could supposedly point investigators in the direction of additional evidence (especially if they would ask the right questions)—raises a reasonable doubt demanding an acquittal.

A requirement for strong corroboration would achieve two very important objectives—it would help to verify the credibility of the confession and it would send a message to law enforcement officials that they must conduct a proper investigation.

D. Applying the Proposed General Theory to Confessions

When the only evidence supporting a person's guilt is his own confession, and there is no other evidence against him, we should ask ourselves the following question: if the police had interrogated all citizens under the same conditions in which the suspect was interrogated (for example, while being held in custody) how many would have confessed to the same crime? We have no statistical answer, but research indicates that many more than just one person would confess.[264] So, how do we know that the specific person who confessed is the real culprit, and that this is not one of the many others who would also have confessed if they had been interrogated in the same manner?

Studies prove that a phenomenon of false confessions does exist: many interrogees confess to crimes that they have not committed.[265] It is reasonable to assume that the many cases where false confessions have come to light represent only the tip of the iceberg.[266] What is the significance of this fact? Although we have no proven statistics regarding false confessions, we wish to demonstrate that this information is very important. Given the studies mentioned above, let us assume that one (or more) out of every ten confessions is

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262. Sangero, *supra* note 11, at 2820–21.

263. Coffin v. United States, 156 U.S. 432, 453, 460–63 (1895).

264. *See supra* notes 216, 219, 222, 227, 229, 238.

265. *Id*.

266. GISLI H. GUDJONSSON, THE PSYCHOLOGY OF INTERROGATIONS AND CONFESSIONS 174–88 (2003).

false. Do the courts know how to identify these false confessions? As we have seen, research demonstrates that the answer is no.[267]

We shall illustrate this problem with the help of a numerical example. Assume that a crime has been committed and that the person who was interrogated—not because there was any evidence linking him to this specific crime, but merely because he was already in police custody for the investigation of an entirely different offense—has confessed to the crime. In his confession, the interrogee has not provided any information not already known by the interrogators or the public, and the police have not found any additional evidence tying him to the crime. Assume that the person who has confessed lives in a city of one million adults, every one of whom is as likely as the confessor to have committed the crime (remember that no other evidence, apart from the confession, ties this person to the crime). Assume that we have confirmed statistics that one out of every ten confessions is false, and that there is a 50% probability that a court will erroneously believe a false confession (this is a conservative, optimistic assumption—the aforesaid research supports a much more pessimistic estimate). If everyone were interrogated, we would likely get 100,000 false confessions, 50,000 of which a court would be expected to believe. This example shows that if the chances that the person in custody was the culprit were one in a million, in the absence of other evidence linking the suspect to the crime and prior to the confession, then following the confession the chances that the right person is in custody are a bit higher, but still slim—only one in 50,000. A conviction, in such a case, is taking the fallacy of the transposed conditional to extreme proportions, and the error by the fact finder in a trial is liable to be immense. If we move our story to a town of 10,000 adults, then still, all that we would achieve with a confession lacking corroboration would be to go from a ratio of 1:10,000 to a ratio of 1:500. Even in a remote village of only 100 adults, instead of a ratio of 1:100, we would get a ratio of 1:5 (20%)—that is, guilt has not even been proven by a balance of probabilities, and certainly not beyond a reasonable doubt.

Similar to the mistaken case-specific argument applied to DNA evidence—whereby the court is assumed capable of examining the manner of operation of the particular laboratory in the case before it and of determining whether or not an error has occurred—it is also possible to claim (mistakenly, in our opinion) that the court is able to reach a correct decision regarding the confession's truth after examining the circumstances under which the confession was obtained. As stated, and as studies already demonstrate, it has been proven that, in reality, the courts do not possess such an amazing ability.[268]

The belief that most confessions are genuine is based on certain assumptions regarding a guilty person's motivation for confessing to a crime—a motivation that an innocent person does not have. One of these assumptions is that, given the existence of other evidence against him, a guilty person understands that he has nothing to lose. This assumption is completely unfounded

267. *See* Leo & Ofshe, *supra* note 20; *see also* GUDJONSSON, *supra* note 266, at 177.
268. *See supra* notes 261, 267.

regarding the special type of case that this article deals with. When there is no other evidence against a suspect then, in most cases, his confession is irrational and should therefore be treated with skepticism and not relied on solely for a conviction.

In an interesting analysis of confessions obtained in the investigation of acts of terrorism, through a different use of Bayes' Theorem, the information engineering expert Matthews has shown that, in certain cases, not only does a confession not indicate guilt, but that it could even point to innocence.[269] Matthews bases his conclusions on studies of confessions—such as Gudjonsson's famous study.[270] He demonstrates that, since terrorists are trained to withstand the pressures of an intense interrogation, the underlying assumption justifying the use of a confession as evidence for a conviction—whereby the probability that an innocent person will confess must be less than the probability that a guilty person will confess under the same conditions—does not apply to confessions obtained in the investigation of acts of terror.[271] Under such circumstances, not only is the confession not an indication of guilt, but it is actually an indication of innocence. This analysis not only explains unfortunate cases like the Birmingham Six[272] and the Guildford Four[273], but, in our opinion, also demonstrates that if a confession does not even indicate guilt in some cases, then certainly the weight of the confession must be carefully examined in all cases and it should not be ascribed greater weight than it deserves. This examination must be conducted in light of the other evidence in the case.

An understanding and internalization of the possibility of a false confession and wrongful conviction must lead not only to a careful examination of additional evidence—evidence pointing to guilt as well as evidence pointing to innocence—but must lead, in our opinion, to the conclusion that, in the absence of any other significant evidence, it is best to not even begin an intensive interrogation designed to extract a confession. As we have already seen, the inherently coercive nature of a custodial interrogation is liable to elicit a false confession. It is interesting to note that even in the Middle Ages, when attempts were made to extract confessions from interrogees through torture, there was an awareness that a confession, on its own, did not carry great weight. Therefore, probable cause was required in order to conduct an interrogation by means of torture, and there was even a rule excluding confessions obtained in this manner without probable cause.[274]

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269. Robert A.J. Matthews**,** *The Interrogator's Fallacy*, 31 BULL. INST. MATH. APPL. 3, 4 (1995).

270. GUDJONSSON, *supra* note 266, at 173.

271. Matthews, *supra* note 269, at 4.

272. *Supra* note 14.

273. *Supra* note 15.

274. JOHN H. LANGBEIN, PROSECUTING CRIME IN THE RENAISSANCE—ENGLAND, GERMANY, FRANCE 179–88 (1974).

As we demonstrated above in the example of the HIV diagnosis, where, if the test result is "positive" for someone from a low-risk group, the chances of a testing error are very high; when there is no other significant evidence indicating a suspect's guilt (apart from a confession), there is a high probability that the confession is false and the person should not be convicted solely on its basis. In most cases where we convict a person solely on the basis of a confession we will be mistaken[275] and a very concrete danger of wrongful conviction exists. As we have seen, reality and research indeed prove that, in a considerable number of cases where wrongful convictions have been based on false confessions, there was no other significant inculpatory evidence apart from the confession.

VI. CONVICTIONS BASED ON EYEWITNESS TESTIMONY

Given the scope of our previous examination of DNA, fingerprint, and confession evidence, we will only discuss the main characteristics of eyewitness testimony before applying the proposed general theory to it. We will also show that this brief discussion of eyewitness testimony is possible because, in effect, it is undisputed that there is a significant rate of mistaken eyewitness identifications.

A. Studies Regarding Mistaken Identification

Despite the lofty status of eyewitness testimony in criminal law—in many legal systems, eyewitness identification is enough to establish that a particular person is the perpetrator of a given offense, without a need for any additional evidence[276]—in the professional literature covering this field it is undisputed that a mistaken identification by an eyewitness is far from uncommon.[277] Indeed, many scholars believe that this is the most common factor in the conviction of innocent persons. For example, Rattner has shown that mistaken identifications were the main cause of 52% of the wrongful convictions he examined.[278] A similar rate of error has been found in the study by Bedau and

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275. It should be clarified that we are not claiming that most confessions are false confessions. We are only focusing on those same cases where the confession stands alone and there is no other evidence whatsoever linking the accused to the crime.

276. *See, e.g.,* MCCORMICK, *supra* note 225, at 722; the leading English case in R v. Turnbull and others, [1977] Q.B. 224, (CA Crim. Div.) (according to which it is enough for the judge to warn the jury about the danger of relying on eyewitness testimony as the sole evidence); CROSS & TAPPER, *supra* note 259, at 234–35, 670–87; IAN H. DENNIS, THE LAW OF EVIDENCE 203 (1999); the leading Israeli case in Cr.A. 347/88 Ivan (John) Demanjuk v. State of Israel, 47(4) P.D. 221, 392, 429 [Hebrew]; *see also* DENNIS at 196–228.

277. *See, e.g.,* Margery Malkin Koosed, *The Proposed Innocence Protection Act Won't—Unless It Also Curbs Mistaken Identifications*, 63 OHIO ST. L. J. 263 (2002); Gabriel W. Gorenstein & Phoebe Ellsworth, *Effect of Choosing an Incorrect Photograph on a Later Identification by an Eyewitness*, 65 J. APPLIED PSYCHOL. 616 (1980); BRIAN L. CUTLER & STEVEN D. PENROD, MISTAKEN IDENTIFICATION—THE EYEWITNESS, PSYCHOLOGY AND THE LAW (1995).

278. Rattner, *supra* note 20, at 289.

Radelet,[279] and even higher rate—75%—within the context of the Innocence Project.[280] Additionally, an English commission examining this subject stated in its report that "[w]e regard mistaken identification as by far the greatest cause of actual or possible wrong convictions."[281]

The studies show that, despite what most people would think—including judges—there is no connection between the accuracy of the identification and the quality of the description given by the eyewitness.[282] Moreover, and counterintuitively, there is no relation between the degree of certainty of the witness making the identification, which reflects social and environmental factors and variables as well as the personality and traits of the witness,[283] and the correctness of the identification.[284]

Many studies in the field of cognitive psychology have shown that human memory is prone to fallacy and bias and, therefore, cannot be trusted, especially when it comes to remembering faces.[285] Researchers commonly divide the process of remembering faces into three stages,[286] each of which is a source of mistaken identifications. The first stage is acquisition, in which the witness perceives the incident and acquires the information. At this stage, the witness's eyes are exposed to a wealth of visual detail and the witness's ears are exposed to a wealth of auditory effects, but attention is only focused on some of these details. In frightening or traumatic incidents or in brief events (characteristic of criminal acts), the witness is only capable of taking in a small portion of the occurrence. Consequently, an imperfect and incomplete, or distorted, picture is created in the witness's mind.[287]

The second stage is that of retention—the period of time from the occurrence of the event until the moment when the witness is asked to re-create what he saw and heard.[288] The third and final stage is that of retrieval, where the witness recalls the information that he has acquired and stored in his mem-

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279. Bedau & Radelet, *supra* note 20, at 60 (out of the 350 miscarriages of justice uncovered by the study, 193 (55%) were caused by the mistakes of witnesses).

280. SCHECK ET AL., *supra* note 22, at 73, 263 (52 instances out of 62 cases); Innocence Project Home Page, http://www.innocenceproject.org (last visited January 29, 2008) ("more than 75%"). The last rate is updated, relating to about 200 cases.

281. CRIMINAL LAW REVISION COMM'N, ELEVENTH REPORT OF THE CRIMINAL LAW REVISION COMMISSION para. 196 (1972); *see also* PATRICK DEVLIN, REPORT TO THE SECRETARY OF STATE FOR THE HOME DEPARTMENT OF THE DEPARTMENTAL COMMITTEE ON EVIDENCE OF IDENTIFICATION IN CRIMINAL CASES para 8.1 (1976); DENNIS, *supra* note 276, at 197–202.

282. *E.g.*, Melissa Pigott, John Brigham & Robert Bothwell, *A Field Study of the Relationship Between Quality of Eyewitnesses' Description and Identification Accuracy*, 17 J. POLICE SCI. & ADMIN. 84 (1990).

283. *See, e.g.,* Evan Brown, Kenneth Deffenbacher & William Sturgill, *Memory for Faces and the Circumstances of Encounter*, 62 J. APPLIED PSYCHOL. 311 (1977).

284. Gary L. Wells et al., *Eyewitness Identification Procedures: Recommendations for Lineups and Photospreads*, 22 LAW & HUM. BEHAV. 603, 622–27 (1998); ELIZABETH F. LOFTUS, EYEWITNESS TESTIMONY, 100–01 (1979).

285. *E.g.,* Robert Buckhout, *Eyewitness Testimony*, SCIENTIFIC AMERICAN, Dec. 1974, at 23.

286. *E.g.,* LOFTUS, *supra* note 284, at 20–110.

287. *E.g.*, Steven I. Friedland, *On Common Sense and the Evaluation of Witness Credibility*, 40 CASE W. RES. L. REV. 165, 181 (1989/1990). See also LOFTUS, *supra* note 284, at 20–51.

288. See, e.g., LOFTUS, *supra* note 284, at 52–87.

ory, and relates it to others.[289] The re-creation is not only dependent on the type of information or the image acquired during the original event but also on the witness's subsequent experience during the retention stage and the circumstances prevailing at the time when he is asked to recollect what he has seen and heard.[290] As already stated, research shows that in each one of these three stages there is a reasonable possibility of distortion that may lead to error.[291] Some causes of distortion are individual variables and circumstance-dependent, such as the personal abilities of the witness, the length of time that the event was viewed, the amount of pressure that the witness was under during the event (sometimes the witness is the victim, sometimes he fears violence), cultural and social variables, etc.; and some are systemic variables, such as the nature of the police investigation, the type of questions, the manner in which the lineup is conducted, the number of lineup members and their selection, the instructions and hints given during the lineup, the behavior of the persons in the lineup, etc.[292] The possibilities for error increase considerably when a suspect is picked out of a photo array instead of an actual lineup,[293] while the "identification" of a suspect from an album of police suspects is extremely problematic.[294]

Up to this point, we have discussed the issue of mistaken identification. A decision to convict a person on the basis of eyewitness testimony must, of course, take into account not only the reasonable possibility of a mistaken identification, but also the possibility of false testimony.

B. Applying the Proposed General Theory to Eyewitness Testimony

Given our previous application of the general theory proposed in this article to confessions, it seems that our task is easier when applying the same model to eyewitness testimony.

First of all, when the only evidence supporting a person's guilt is the fact that he has been identified by an eyewitness, and there is no other evidence against him, we must ask ourselves the following question: if instead of the members of a normal lineup (usually eight to twelve persons) we had allowed the witness to take a close look at a thousand people in a lineup, how many would look to him like the person that he saw at the scene of the crime? And

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289. *Id.*

290. *E.g., id.* at 88–109.

291. *E.g.,* Friedland, *supra* note 287, at 178–80.

292. *See, e.g.*, GARY L. WELLS, EYEWITNESS IDENTIFICATION 13–25 (1988).

293. *See, e.g.*, R.C.L. Lindsay & Gary L. Wells, *Improving Eyewitness Identifications from Lineups: Simultaneous Versus Sequential Lineup Presentation*, 70 J. APPLIED PSYCHOL. 556 (1985) (showing that, in a lineup with live members, studies indicate that a sequential identification procedure is preferable to a simultaneous lineup procedure).

294. *See* Gary L. Wells & R.C.L. Lindsay, *Methodological Notes on the Accuracy-Confidence Relation in Eyewitness Identification*, 70 J. APPLIED. PSYCHOL. 413, 414 (1985) (arguing that the selection of a photo from an album, when there is no suspect to begin with, should not be ascribed any evidentiary weight, because this is "fishing": any choice of a photo is considered a correct answer).

what if he were allowed to take a look at a hundred thousand people? Or even every citizen in the country?

As we have already seen, research proves that mistaken identification is widespread: many eyewitnesses erroneously identify an innocent person as the perpetrator. This is due, at least in part, to the limitations of human memory. It is possible that an eyewitness will identify the suspect as the person who committed the crime and even express great confidence in the identification, demonstrating an ability to describe the offender in detail (prior to the identification), and, yet, the identification is still mistaken. It is reasonable to assume that the numerous cases of mistaken identifications that have been uncovered are only a drop in the bucket compared to the cases that have remained undetected. Based on the aforesaid studies[295]—and since we do not have exact figures, but wish to demonstrate how important such data is—let us assume that at least one (or more) out of every ten cases of eyewitness identification is mistaken. Are the courts capable of detecting these mistaken identifications?

As we have seen, research[296] shows that, counterintuitively—even for judges—there is no connection between the degree of confidence expressed by the identifying witness and the correctness of the identification, and there is no connection between the quality of the description provided by the eyewitness and the level of accuracy of the subsequent identification. Accordingly, we may conclude that police investigators, prosecutors, judges, and juries are incapable of determining whether a given identification of a suspect by a given eyewitness is correct or mistaken. Here too—based on the studies discussed above—we would assume that the error rate of the courts, when they examine mistaken identification testimony, is at least ten percent (and probably much more). Thus, for eyewitness testimony as well, if we were to illustrate this point in a numerical example, we would get a similar result as that obtained when we discussed the matter of confessions.

An understanding and internalization of the possibility of a mistaken eyewitness identification and the possibility of a wrongful conviction based on such identification should not only lead to a careful examination of additional evidence—evidence indicating guilt as well as evidence indicating innocence—but also to the enactment of a legal rule whereby, a defendant should not be convicted solely on the basis of eyewitness testimony, that is, in the absence of any other significant evidence of guilt. In most cases where a person is convicted solely on the basis of eyewitness testimony an error will be made.[297] Reality and research indeed prove that in a significant number of cases of wrongful conviction based on eyewitness testimony, there was no other significant evidence that tied the suspect to the crime. Therefore, a requirement for "strong corroboration" to eyewitness testimony should be estab-

295. *Supra* notes 278–86.

296. *Supra* notes 282–85.

297. We are not saying that most eyewitness testimony is mistaken. We are only focusing on those cases where eyewitness testimony stands on its own and in the absence of any other evidence tying the defendant to the crime.

lished in legislation as an essential condition for a conviction based on such evidence.

VII. EPILOGUE: A CALL FOR LEGISLATIVE REFORM—ENACTING A RULE PROHIBITING CONVICTIONS BASED ON ANY SINGLE PIECE OF EVIDENCE

In this article, we have encountered the two types of scientific evidence considered the most reliable and the two types of nonscientific evidence most frequently used in criminal trials. We have show that the reasonable doubt standard requires convictions to be based on more than a DNA match, a fingerprint match, a confession, or the testimony of an eyewitness as the sole evidence. From this, the important general conclusion follows naturally that *no* single piece of evidence should suffice for a conviction.

Based on our analysis, and in order to significantly reduce the danger of convicting the innocent, we call on lawmakers to enact a rule prohibiting convictions on the basis of *any* single piece of evidence, as well as an unequivocal requirement for "strong corroboration" to the main evidence in a case: independent and significant additional evidence indicating that the defendant is the perpetrator. If this is not done, then we (as a society) continue to take the considerable risk that innocent persons will be convicted. Until it is done, our consciences should torment us.