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The Individualization Fallacy in Forensic Science Evidence

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Abstract

Forensic scientists across a broad array of sub-specialties have long maintained that they can link an unknown mark (e.g., a partial fingerprint or tireprint) to a unique source. Yet no scientific basis exists for this assertion, which is sustained largely by faulty probabilistic intuition that equates infrequency with uniqueness. This article traces the origins of the individualization claim and explicates the various failed lines of evidence and argument offered in its support. We conclude with suggestions for how to improve the scientific basis of the forensic identification sciences.

Introduction

Forensic scientists across a broad array of sub-specialties have long maintained that they can link an unknown mark (e.g., a partial fingerprint or tireprint) to a unique source. Popular television programs such as CSI and Forensic Files reinforce this idea in the collective public imagination by offering confident pronouncements from supposed scientists about whose hair was recovered from the knife or which gun fired the murderous bullet. But can forensic science really make such pinpoint determinations? Can forensic scientists be sure that a particular hammer, to the exclusion of all other hammers in the world, produced the imprints observed on a victim's body? In fact, the concept of individualization, which lies at the core of numerous forensic science subfields, exists only in a metaphysical or rhetorical sense. There is no scientific basis for such individualization claims.

In his recent book on DNA typing, David Balding explains what he terms "the uniqueness fallacy".[1] The fallacy is committed by attorneys, judges and experts in cases involving DNA evidence when they assume that a set of genetic markers that is expected to occur less than once per five billion people (a denominator that roughly equals the earth's population) must be unique. An illustration is provided by the following argument offered in the O.J. Simpson murder trial:

> [L]adies and gentlemen, his blood on the rear gate with that match, that makes him one in 57 billion people that could have left that blood, I mean there is what,

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[1] DAVID J. BALDING, WEIGHT-OF-EVIDENCE FOR FORENSIC DNA PROFILES (2005).

> five million [sic] people on the planet, that means you would have to go through 57 billion people to find the DNA profile that matches Mr. Simpson's. There is only five billion people on the planet. Ladies and gentlemen, that is an identification, okay, that proves it is his blood. Nobody else's on the planet; no one.[2]

Balding refers to a British case in which the appellate judge made a similar assumption: "… I should think there are not more than 27 million males in the United Kingdom, which means that it is unique".[3] Likewise, a forensic science textbook states: "... Balthazaard has mathematically determined that the probability of two individuals having the same fingerprints is one out of 1 x 10^{60}.... This probability is so small as to exclude the possibility of any two individuals having the same fingerprints."[4] In yet another example of the same faulty logic, Inman and Rudin argue that objects of forensic interest are unique by analogy to the asserted uniqueness of snowflakes, arguing that the number of ways that water molecules can be arranged into a typical snowflake "is so astronomically larger than the number of snowflakes that have ever existed that it is unreasonable to believe that any one arrangement has occurred more than once. When a characteristic (or characteristics) of an item can be described in such a fashion, it is believed to be unique, with no duplicate on earth. It has then been individualized."[5]

Although markers that rarely occur *might* be unique, it is a fallacy to infer uniqueness from profile frequencies simply because they are smaller than the number of available objects. A simple analogy clarifies this point: Imagine a machine that prints lottery tickets with numbers 00 through 99. This machine can print 100 different tickets. Suppose that each of 10 customers purchases one ticket and that the machine generates ticket numbers at random, with replacement. The total number of unique tickets that could be sold (100) exceeds the population of customers (10) by a factor of ten. And yet there is no law of mathematics or nature that prevents two (or more) customers from being issued different tickets bearing the same number. Indeed, the probability of that happening is nearly 40%.[6]

Some people might be surprised by the rather high chance of finding matching lottery tickets in this example. Ironically, such a reaction is itself unsurprising. Empirical research demonstrates that people commit an array of errors when describing and interpreting

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[2] *People v. Simpson*, Transcript (Superior Court, Los Angeles County, Closing Argument by Ms. Clark), 1995 WL 672671 (September 26, 1995).

[3] *R. v. Adams*, 1 Cr.App.R 369 (1997).

[4] RICHARD SAFERSTEIN, CRIMINALISTICS: AN INTRODUCTION TO FORENSIC SCIENCE (9th ed. 2007), at 73.

[5] KEITH INMAN AND NORA RUDIN, AN INTRODUCTION TO FORENSIC DNA ANALYSIS (1997), at 4.

[6] The probability of at least two people sharing a winning lottery ticket in our example is $1-(\frac{100x99x98x...x91}{100^{10}})=37.2\%$. This computation is similar to that used to solve the famous "birthday problem," in which the probability that two people in a small gathering would have the same birth date is found to be far greater than human intuition would suggest. *See* P. Diaconis and Frederick Mosteller, *Methods For Studying Coincidences*, 84 J. AMER. STAT. ASS'N 853 (1989).

probabilistic evidence, such as DNA random match probabilities.[7] Probabilistic reasoning is hard, and assigning an appropriate weight to unfamiliar and extreme probabilistic events such as those that occur 0.1% or 0.001% of the time is particularly challenging. Certainly, a criminalist's work and a factfinder's task would be simplified if they could assume that physical evidence that reportedly matched a potential source meant that a unique and absolute identification of the source of the evidence had been achieved. Unfortunately, that is not possible on current knowledge. And that is the central point of this article. The concept of "individualization," which lies at the core of numerous forensic science subfields, exists only in a metaphysical or rhetorical sense. It has no scientific validity, and is sustained largely by the faulty logic that equates infrequency with uniqueness. We discuss the implications of this fallacy and offer suggestions for how the science and practice of criminalistics might proceed in its absence.

I. Reliance on the Notion of Individualization

The "individualization fallacy," as we term it, is a more fundamental and more pervasive cousin of Balding's uniqueness fallacy. Criminalists seek to individualize crime scene evidence to its unique source and frequently claim to have achieved individualization in specific instances. Individualization has been defined as "[t]he process of placing an object in a category which consist of a single, solitary unit. Individualization implies uniqueness….".[8] Individualization refers to "absolute specificity and absolute identification".[9] Though occasionally criminalists are more conservative, for nearly a century they have clearly and repeatedly characterized individualization as fundamental to what they do. "Criminalistics is the science of individualization."[10] "Individualization is unique to forensic science."[11] "The concept of individualization is clearly central to the consideration of physical evidence.... Our belief that uniqueness is both attainable and existent is central to our work as forensic scientists."[12] A forensic science textbook states: "The major members of the pattern group are fingerprints, questioned documents, tool mark, and firearms evidence, and other patterns such as footwear and

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[7] *See, e.g.*, Valerie P. Hans et al., *Science in The Jury Box: Do Jurors Understand MtDNA Evidence?* Paper Presented at the 1st Annual Conference on Empirical Legal Studies (June 30, 2006), available at SSRN: http://ssrn.com/abstract=913442; Jonathan J. Koehler, *Error And Exaggeration in The Presentation of DNA Evidence*, 34 JURIMETRICS J. 21 (1993); Jonathan J. Koehler and L. Macchi, *Thinking About Low-Probability Events: An Exemplar Cuing Theory,* 15 PSYCHOLOGICAL SCI. 540 (2004).

[8] John Thornton and Joseph Peterson, *The General Assumptions and Rationale of Forensic Identification*, *in* David Faigman, David H. Kaye, Michael J. Saks, and Joseph Sanders (eds.) 4 MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY (2005-2006 ed., 2005), at 8.

[9] David A. Stoney, *What Made Us Ever Think We Could Individualize Using Statistics?,* 31 J. FORENSIC SCI. SOC'Y 197, 197 (1991).

[10] J.W. Osterburg, *The Evaluation of Physical Evidence in Criminalistics: Subjective or Objective Process?,* 60 J. CRIM. LAW & CRIMINOLOGY 97, 97 (1969).

[11] PETER R. DE FOREST, RICHARD E. GAENSSLEN, AND HENRY C. LEE, FORENSIC SCIENCE (1983), at 7.

[12] KEITH INMAN AND NORAH RUDIN, PRINCIPLES AND PRACTICE OF CRIMINALISTICS (2000), at 54 and 123.

tire impressions. This kind of evidence consists of patterns that might be called individualization patterns. Under favorable circumstances, individualization-pattern evidence can be attributed to a unique source."[13]

To practicing forensic scientists, individualization is more than an abstraction or an idealization; it is the state of their art. For example, a firearms examiner testifying in a federal court claimed to be able to identify the unknown weapon "to the exclusion of every other firearm in the world."[14] Similar claims are made by examiners of other kinds of toolmarks,[15] as well as of fingerprints,[16] bitemarks,[17] handwriting,[18] shoeprints,[19] tiremarks,[20] and other objects of forensic interest. Even practitioners from one area that clearly recognizes its inability to individualize sometimes (or frequently) offer testimony that borders on individualization. For example, a microscopic hair comparison expert testified that when questioned and known hairs are consistent, "the [questioned] hairs either did originate from that [known] source, or there could be or might be another individual in the world somewhere that might have the same microscopic characteristics."[21]

Elsewhere,[22] we have used the phrase “discernable uniqueness” to capture the presumption of criminalists that object uniqueness is not merely a hypothetical construct but is instead a conclusion that is frequently attainable in practice. The assumption of discernible uniqueness endows criminalistics with important practical benefits. It enables criminalists to assert strong, definitive conclusions in casework. At the same time, it relieves criminalistics of the rigors of developing measures of object attributes and collecting population data on the frequencies of variations in those attributes. It also exempts the various subfields from determining the proper statistical model for estimating random match probabilities, calculating those probabilities in actual cases, and explaining to judges and juries the extent to which different objects could share a common set of observable characteristics. In short, without the assumption of discernible uniqueness, far more scientific work would be necessary and criminalists would need to offer more tempered opinions in court.

II. Origins and Evolution of the Notion of Individualization

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[13] H.J. Stuart and John J. Nordby (eds.), FORENSIC SCIENCE: AN INTRODUCTION TO SCIENTIFIC AND INVESTIGATIVE TECHNIQUES (2nd ed., 2005), at 341.
[14] *United States v. Green*, 405 F.Supp.2d 104 (D.Mass. 2005).
[15] *Fletcher v. Lane*, 446 F.Supp. 729 (S.D.Ill., 1978).
[16] International Association for Identification, *Resolution VII*, 29 IDENT. NEWS 1 (1979).
[17] *People v. Milone*, 43 Ill. App. 3d, 385, 356 N.E.2d 1350 (2d Dist. 1976).
[18] ALBERT OSBORN, QUESTIONED DOCUMENTS (2d ed., 1929).
[19] WILLIAM J. BODZIAK, FOOTWEAR IMPRESSION EVIDENCE (1995).
[20] William J. Bodziak, *Forensic Tire Impression and Tire Track Evidence*, *in* H.J. Stuart and John J. Nordby (eds.), FORENSIC SCIENCE: AN INTRODUCTION TO SCIENTIFIC AND INVESTIGATIVE TECHNIQUES (2nd ed., 2005).
[21] *Williamson v. Reynolds*, 904 F.Supp. 1529 (1995).
[22] Michael J. Saks and Jonathan J. Koehler, *The Coming Paradigm Shift In Forensic Identification Science*, 892 SCIENCE 892 (2005).

Gottfried Wilhelm Leibniz (1646-1716) developed the ontological principle of the identity of indiscernibles ("Leibniz's Law"). This metaphysical principle states that if there is no way to tell two entities apart then they are one and the same entity. Although philosophers disputed the principle and offered counterexamples,[23] echoes of Leibniz's law appear in arguments for individualization.

The first potentially scientific notion of uniqueness originated with Lambert Adolphe Jacques Quételet (1796-1874), a Belgian statistician and sociologist best known as the father of descriptive social statistics. Quételet hypothesized that "nature never repeats".[24] He based that notion on the product rule, a fundamental tool of probability theory which yields the joint probability of independent events by multiplying together their separate probabilities. Objects with many attributes, each of which can take on numerous different values, and where each attribute is uncorrelated with every other attribute, would have long odds against the complete repetition of their patterns.

Alphonse Bertillon (1853-1914) learned of Quételet's theory from his father and grandfather, those gentlemen being serious students of statistics, anthropology, medicine, and demography. From his position as a records clerk with the Paris police, Bertillon overcame the resistance of his superiors and used Quételet's hypothesis to develop the first system of forensic identification, termed anthropometry, or *bertillonage*.[25] Bertillon measured eleven different physical features of each prisoner and assembled the prisoner profiles into special files reflecting their classifications. If the prisoners were properly measured (a difficult challenge that Bertillon worked hard to meet), and if Quételet were correct, then Bertillon would be able to identify prisoners who had been arrested before and who were using aliases on re-arrest (to avoid longer sentences for being recidivists).

Early proponents of each forensic identification subfield followed the lead of Quételet and Bertillon, explicitly invoking the product rule to argue that no two of this or that type of object could be mistaken one for another. Balthazard[26] thus argued for the uniqueness of fingerprints, Osborn[27] for handwriting, Goddard[28] for firearms, May[29] for toolmarks, and so on. No efforts were made to test the assumed independence of attributes, nor were any explicit computations made based on actual observations, nor were empirical data of any sort obtained and offered in support the theory. Just speculative arguments or thought experiments.

Sir Francis Galton was an interesting exception. A major early contributor to the study of

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[23] M. Black, *The Identity of Indiscernibles*, 61 MIND 153 (1952).
[24] JORGEN THORWALD, THE CENTURY OF THE DETECTIVE (1965).
[25] *Id*. and SIMON COLE, SUSPECT IDENTITIES: A HISTORY OF FINGERPRINTING AND CRIMINAL IDENTIFICATION (2001).
[26] M.V. Balthazard, *No Two Finger Prints Alike*, 105 SCI. AMER. 160 (1911).
[27] *Supra* note 18.
[28] Calvin H. Goddard, *Scientific Identification of Firearms and Bullets*, 8 J. AMER. INST. CRIM. LAW & CRIMINOLOGY 254 (1926).
[29] Luke May, *The Identification of Knives, Tools and Instruments a Positive Science*, 1 AMER. J. POLICE SCI. 246 (1930).

fingerprints, Galton remains one of the few students of any of these techniques to attempt to collect empirical data on these fundamental issues and to subject the data to meaningful probabilistic analysis. He was never entirely convinced of the ability of fingerprints to individualize, and never even believed that the field to which he made such important contributions was scientifically superior to anthropometry.[30] This seeming irony will not seem at all ironic to conventional scientists, who know that those who perform empirical tests tend to be more sober about the phenomenon under study than those who merely theorize.

III. Unproved and Perhaps Unprovable

Even without supportive data, various arguments were offered on behalf of the individualization hypothesis. None are scientifically compelling. Some arguments rely on the metaphysical notion that because no two objects can be the same object, they will inevitably manifest observable differences. Some rely on appeals to venerated authority (dead members of our field said it was so), contemporary authority (living members of our field say it is so), wishful thinking (because object variability has been observed, there will always be discernable differences between any two different objects or fragments of them), or the personal experience of practitioners (as if by doing casework on pairs of objects the nature of the entire population and relationships within that population are revealed).[31] These approaches amount to nothing more than faith and intuition.

The only remotely rigorous argument offered to support the hypothesis of individualization derives from the Multiplicative Rule of Probability (i.e., the product rule), suggested for use by Quételet and relied upon by those who founded the various subfields of criminalistics. According to this Rule, the probability that each of a series of independent events will occur is given by the product of their unconditional probabilities. Attempts to use the product rule to support individualization run into several problems. First, proper application of this rule requires a set of reliable frequency estimates for the relevant set of forensic characteristics. Second, the characteristics must be independent of each other. Third, even if the first two problems were overcome, application of the product rule falls short of establishing unique individualization. The product of probabilities greater than zero always yields a value greater than zero. The probabilistic approach, therefore, always leads to the conclusion that a source other than the suspected individual or object might exist.[32]

Alarmed by the prospect of courts following newly rigorous judicial[33] and statutory[34] requirements for the admission of expert evidence, forensic scientists recently have undertaken studies intended to prove that no two sets of markings left by distinct objects can be indistinguishably alike. That such studies were not undertaken until this late date in the history of

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[30] Cole, *supra* note 25.

[31] Sandy A. Zabell, *Fingerprint Evidence*, 13 J. LAW & POLICY 143 (2005).

[32] *See, e.g.*, H. CUMMINS AND C. MIDLO, FINGER PRINTS, PALMS AND SOLES: AN INTRODUCTION TO DERMATOGLYPHICS (1943) and *supra* note 9.

[33] *Daubert v. Merrill Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993); *Kumho Tire Co., Ltd. v. Carmichael*, 526 U.S. 137 (1999).

[34] FEDERAL RULES OF EVIDENCE, Rule 702 (as revised in 1999).

these disciplines is itself remarkable. How could the practice have been allowed to get so far ahead of the science? Why could it be concluded, a century after fingerprint experts began testifying in courts, that "the suggestion that recorded fingerprints are unique has never been rigorously checked"?[35] The few such studies that now exist were launched with the problematic goal of trying "to prove" empirically what for so long had been asserted on faith, rather than being undertaken as neutral inquiries. Given the pressures and motivations that precipitated them, it may not be surprising that even when these studies fell short of proving what they set out to prove, they would be proclaimed to have met their goals.[36]

For example, the first noteworthy study aimed at proving the uniqueness of fingerprints was conducted by Lockheed Martin at the request of the FBI in 1999. This study was conducted *during* the first case in which the admissibility of fingerprint identification testimony was challenged under *Daubert*. In that study, each of 50,000 file prints was compared to itself and to the others in the file using AFIS. Its authors concluded that it is virtually impossible for any two fingerprints to be indistinguishably alike.[37] But in a detailed critique of the study published in a statistics journal, Kaye identified substantial errors in the study's design and analysis that cast serious doubt on the study's conclusions. According to Kaye, this study – which he notes was "unpublished and prepared expressly for litigation" – provides "a lesson about probabilities generated for use in litigation: If such a probability seems too good to be true, it probably is."[38]

In the handwriting area, Srihari et al. conducted a study "for the purpose of establishing the individuality of handwriting." The authors noted that such an inquiry had never been undertaken but was now necessary because of reliability concerns raised by the courts.[39] Even though the design of this study – a relatively small sample of writers and large samples of writing – favored distinguishing each writer from every other writer in the sample, the analysis fell short of its goal. Even had the study succeeded within its own sample, it would not have answered the crucial question of whether every writer in the population is distinct from every other writer. (The study has been critiqued in some detail.[40])

The claim of unique individuality cannot be proven with samples, especially samples that are a tiny proportion of the relevant population. As Balding has pointed out: "It is impossible to prove any human characteristic to be distinct in each individual without checking every individual, which has not been done."[41] Anything less results in probability statements rather than conclusions of "absolute specificity and absolute identification."

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[35] *Supra* note 1; *see also supra* note 31; David H. Kaye, *Questioning a Courtroom Proof of the Uniqueness of Fingerprints*, 71 INT'L STAT. REV. 521 (2003); David A. Stoney, *Measurement of Fingerprint Individuality*, *in* Henry C. Lee and Robert E. Gaensslen (eds.), ADVANCES IN FINGERPRINT TECHNOLOGY (2nd ed., 2001).

[36] D. Michael Risinger and Michael J. Saks, *A House With No Foundation,* 20 ISSUES IN SCI. & TECH. 35 (Fall 2003).

[37] Lockheed Martin Co., *50K vs. 50K Fingerprint Comparison Test* (unpublished study) (1999).

[38] Kaye, *supra* note 35, at 528. *See also* Zabel, *supra* note 31, and Stoney, *supra* note 35.

[39] S.N. Srihari et al., *Individuality of Handwriting*, 47 J. FORENSIC SCI. 856 (2002).

[40] Michael J. Saks, *Commentary on "Individuality of Handwriting,"* 48 J. FORENSIC SCI. 916 (2003).

[41] *Supra* note 1, at 54.

With no coherent theory to support the individualization hypothesis and few studies that even attempt to test the hypothesis, proponents have been casting about looking for other evidence that might arguably support a claim of discernible uniqueness.[42] Some have seized upon data from studies of monozygotic twins which found that the twins in those studies had discernibly different fingerprints.[43] If identical twins do not have identical fingerprints, proceeds the logic, then surely everyone else has distinguishable prints. Though appealing at first, reflection suggests that the uniqueness hypothesis would have found greater support if identical twins actually *did* have identical fingerprints. If that were so, then one could argue that if the phenotype of fingerprints is isomorphic with the genotype, then whatever diversity exists in fingerprint genotypes will be reflected in fingerprint phenotypes. But if unspecified random and systematic[44] events are interposed along the pathway from genotype to phenotype, then the need for a rigorous scientific approach that takes into account the probability of duplication becomes more, not less, necessary.[45]

Another line of argument offered in support of the object individualization hypothesis is that in examining many pairs of objects in their casework, examiners have not yet come upon two sets of markings produced by different sources that are indistinguishable from each other. This observational argument has at least three shortcomings. First, as Karl Popper famously explained, it is logically impossible to prove a hypothesis by accumulating positive instances.[46] The hypothesis, "all swans are white," remains unproven even after a large number of sightings of white swans because the sighting of a single black swan would disprove the hypothesis. Similarly, the truth of the hypothesis that no two objects are indistinguishably alike cannot be proven from an accumulation of observations in which different object sources produce distinctive markings.

The second weakness is that no systematic, concerted efforts have been made by criminalists across disciplines to find different objects that produce identical markings. In casework, forensic examiners compare questioned marks to those of the suspect and, sometimes, to other known persons in the case. Even a very large number of pairwise, case-by-case comparisons made by individual examiners would not provide a satisfactory method for testing the object uniqueness claim. To illustrate, suppose that exactly 100 pairs of firearms out of an estimated 100,000 guns in a Texas town share indistinguishable gun barrel markings. If each of 100 firearms experts examined 10 pairs of guns from the town's gun population every day for 10

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[42] The reader is reminded that the phrase "discernible uniqueness" is merely a shorthand way to describe the criminalists' presumption that conclusions about object uniqueness are not only theoretically possible but attainable in practice.

[43] *United States v. Mitchell*, 365 F3d 215 (2004).

[44] William J. Babler, *Prenatal Development of Dermatoglyphic Patterns: Associations with Epidermal Ridge, Volar Pad, and Bone Morphology*, 11 COLLEGIUM ANTROPOLOGICUM 297 (1987).

[45] Handwriting examiners have also argued that differences in writing between identical twins support the conclusion that handwriting is unique. The role of twin studies in this context is perplexing because the theory of the source of handwriting individuality emphasizes learning, not genetics.

[46] KARL R. POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY (1959).

years (n=3,650,000 gun pairs), there is about a 93% chance that none of the indistinguishable pairs will have come under examination. That is, despite 100 x 10 = 1,000 "collective years" of forensic science experience, the failure to find even a single pair of guns with indistinguishable markings would offer little basis for drawing conclusions about whether gun barrel markings, even in this one town, are indeed unique. Examiners rarely search a large database for multiple possible matches. Indeed, very few subfields even have such databases. Conducting a serious search for them, and failing to find any, would have markedly strengthened the observational argument. But under the available search conditions, falsification of the individualization hypothesis has been unlikely, and so the lack of falsification proves very little. As the size of a comparison database becomes larger, the object uniqueness hypothesis is subjected to an increasingly tough empirical test. If, under these circumstances, scientists still do not find indistinguishably similar matches produced by different objects, then object uniqueness becomes a more credible theory.

A third weakness is that indistinguishable markings produced by different objects have already been found in a number of forensic areas. Consider, for example, an analysis of signatures taken from a voter registration database which revealed numerous signatures that were indistinguishably alike ("… many of these signatures lacked individuality and looked alike…."[47]). In the fingerprint area, cases have been documented in which the fingerprints of one person were identified as belonging to someone else.[48] Similarly, there have been many false positive identifications of bitemarks.[49]

In sum, no sound and rigorous evidence supports the assumption of unique individualization. Moreover, the assumption is so heroic and the research that would be required to test it seriously would be so massive, that one must doubt whether any empirical study or set of studies could ever be conducted that would provide solid support for it.

IV. Old News

Ironically, at the same time that criminalistics continues to depend on the theory of individualization and the assumption that it is attainable in practice, thoughtful and informed forensic and other scientists have long recognized the lack of evidence for that core belief. In the 1940s, a team of biomedical researchers tried mightily to develop support for individualization in fingerprints, but ultimately concluded that "it is impossible to offer decisive proof that no two fingerprints bear identical patterns."[50] Nearly half a century later, Stoney published an article entitled, "What Made us Ever Think we Could Individualize Using Statistics?"[51] Elsewhere, Stoney has observed: "The criteria for absolute identification in fingerprint work are subjective

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[47] John Harris, *How Much Do People Write Alike: A Study of Signatures*, 48 J. CRIM. LAW & CRIMINOLOGY 647, 647 (1958).
[48] Simon A. Cole, *The Prevalence and Potential Causes of Wrongful Conviction by Fingerprint Evidence*, 37 GOLDEN GATE UNIV. L. REV. 39 (2006).
[49] C. Michael Bowers, *Problem-Based Analysis of Bitemark Misidentifications: The Role of DNA*, 159 FORENSIC SCI. INT'L S104 (May, 2006).
[50] *Supra* note 32, at 154.
[51] *Supra* note 9.

and ill-defined. They are the product of probabilistic intuitions widely shared among fingerprint examiners, not of scientific research. Outside of the fingerprint profession this is generally unappreciated."[52] Similarly, Thornton and Peterson[53] observed: "[T]hough individualization is clearly the goal toward which forensic science strives, it can be achieved only in a probabilistic sense, of reducing uncertainty to the smallest possible amount.... (at 7) Behind every opinion rendered by a forensic scientist there is a statistical basis. We may not know what that basis is, and we may have no feasible means of developing an understanding of that basis, but it is futile to deny that one exists" (at 22). In the firearms and toolmark area, Biasotti, Murdock & Moran have noted that "existing research was insufficient to validate the quantitative objective criteria necessary to conclude that a working surface is unique."[54] Inman & Rudin allow that examiners in various areas of criminalistics do not yet have the science to back them up, so they are merely "making the leap" to individualization.[55]

Why, then, do many criminalists ascribe greater powers to their fields than the research evidence supports? Part of the problem may be that most practitioners are not well schooled in the probabilistic nature of scientific claims. Or perhaps practitioners simply are not aware of the dearth of scientific support for their discipline's core assumptions. For example, evidence of dental uniqueness is limited to "a small number of journal articles which are less than persuasive in their efforts to prove uniqueness scientifically,"[56] yet "91% [of forensic dentists] support dental uniqueness and 78% believe that uniqueness transfers faithfully to human skin)."[57] Or perhaps the adversarial nature of the environment in which most forensic scientists must operate induces them to exaggerate the probative value of the evidence about which they are testifying. Whatever the explanation, the obvious question that arises is: What can be done to remedy the contradiction between knowledge and practice?

V. What to Do

Knowledgeable forensic scientists have for quite some time recognized that criminalists' belief in individualization is based on anecdote, intuition and speculation rather than on a scientific foundation. Consequently, individualizations in casework rely on a "leap of faith." To remedy this shortcoming, Inman and Rudin have called on the forensic science community "to produce a body of empirical work that can support that pragmatic leap of faith to a conclusion of

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[52] David Stoney, *Fingerprint Identification, in* David L. Faigman, David H. Kaye, Michael J. Saks, and Joseph Sanders (eds.), MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY (2005-2006 ed., 2005), at 262.

[53] *Supra* note 8.

[54] Alfred Biasotti, John Murdock, and Bruce Moran, *Firearms and Toolmark Identification*, *in* David L. Faigman, David H. Kaye, Michael J. Saks, Joseph Sanders, and Edward K. Cheng, MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY (2006-2007 ed., 2006), at 565.

[55] *Supra* note 12.

[56] C. Michael Bowers, *Identification from Bitemarks*, *in* David L. Faigman, David H. Kaye, Michael J. Saks, and Joseph Sanders, MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY (2005-2006 ed., 2005), at 466.

[57] *Id*. at 474.

a single common source."[58] But this puts the cart before the horse. Scientists and serious practitioners customarily refrain from making inferential leaps unjustified by data. They confine their statements to what is known and supportable, not to what they take on faith.

While waiting for the necessary knowledge base to develop, what can forensic scientists do to contribute to a factfinder's understanding of the evidence in a case without exaggerating or distorting that contribution? Moreover, what can forensic and other scientists do to build the necessary scientific foundation?

A. *The Present*

For the present, when criminalists cannot distinguish a questioned pattern from a known pattern (i.e., when they judge a questioned and a known pattern to be indistinguishable, consistent, or to "match"), they should report that finding with appropriate clarity and restraint. For example, they could explain that a conclusion that two patterns are consistent (or a match) does not require a conclusion that the patterns share a common source. Once they have explained this point, criminalists should resist the urge to draw a source conclusion – or any other inference – that is not supported by sound theory and hard data. (Judicial thinking can be found that approximately parallels this restraint.[59])

Examiners could explain that, in finding that two patterns match, they have placed the suspect object or person in a pool of one or more objects that match the evidentiary marks. The strength of the likelihood that the known object or person shares a common source with the questioned object or person depends upon the size of the pool. No scientific justification exists for assuming that the size of the pool is 1. And, for most areas of criminalistics (other than DNA typing and, potentially, fingerprinting), there are no empirically grounded estimates of how large such pools might be. Experts should not substitute their intuition or judgment in an effort to fill these knowledge gaps. The speculation of an examiner about the size of those pools is not scientific evidence. It is, simply, speculation.

Nevertheless, if a court does encourage or permit an examiner to venture a guess about the size of the matching pool, the guess ought to reflect something akin to confidence intervals in statistics.[60] The interval should be set wide enough to have a high probability of including the actual number that might be in the pool. As the necessary research proceeds, those confidence intervals can narrow appropriately. But, no data now exist, and are unlikely to come into being in the foreseeable future, that could permit forensic scientists to offer an identification "to the exclusion of all others in the world" (or any similar formulation). Such testimony is speculative and improper, both scientifically and legally.

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[58] *Supra* note 12.

[59] *See*, *United States v. Hines*, 55 F. Supp. 2d 62 (D. Mass. 1999); *United States v. Llera-Plaza I*, 2002 WL 27305 (2002).

[60] *See, generally*, David H. Kaye and David A. Freedman, Reference Guide on Statistics, in REFERENCE MANUAL ON SCIENTIFIC EVIDENCE, (2d, ed., 2000); David H. Kaye and David A. Freedman, *Statistical Proof*, *in* David L. Faigman, David H. Kaye, Michael J. Saks, Joseph Sanders, and Edward K. Cheng, MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY (2006-2007 ed., 2006).

B. *The Future*

For the future, traditional forms of forensic identification should begin to emulate the general model used in DNA typing. Whether or not geneticists believe in the biological uniqueness of individuals, they also know that DNA tests examine only a fraction of the genome. Even if two DNA samples match on a dozen or more alleles, geneticists know that the samples might not share a common source because differences might exist between the samples on untested alleles. They also know that their data reflect samples of people, not genetic censuses of the human population.[61] The solution to this problem in DNA typing has been a frank reliance on probability: The population (and subpopulation) frequencies of the observed genetic attributes are estimated through sampling; the independence of those attributes is verified; and the product rule is applied to the individual frequencies in order to determine the joint probability of the occurrence of that set of attributes in the population. This latter estimate is then reported to factfinders to help them assess the probative value of the DNA evidence.[62]

Similar procedures can, in principle, be employed for other materials of forensic interest: fingerprints, handwriting, bitemarks, toolmarks, and so on. One of the central challenges will be developing valid and reliable measures of the images of interest – of friction ridges, of toolmark striations, of bitemarks, of writing. A second challenge will be developing databases that identify the frequency with which various images appear. In some areas (e.g., toolmarks, firearms and shoeprints), the challenge of producing sound probability estimates may be especially difficult because the materials themselves change over time and with use.

Conclusion

This article challenges conventional wisdom about the capabilities of the forensic identification sciences. Forensic scientists are not able to link a fingerprint, a hair, a handwriting sample, a tiremark, a toolmark, or any other evidentiary forensic item to its unique source, though they assert such ability every day in American courts. The issue is not the sincerity of the beliefs of workaday forensic scientists. The issue is whether any scientific evidence exists that can support those beliefs. There is no basis in theory or data for the core contention that every distinct object leaves its own unique set of markers that can be identified by a skilled forensic scientist. Their claims exaggerate the state of their science. This sort of exaggeration, combined with public credulity is the classical reason that common law evidence doctrine required a heightened threshold for admission of expert testimony. Under Fed. R. Evid. 702 as interpreted by *Daubert* and *Kumho Tire*, such testimony would properly be a prime target for exclusion. But, short of exclusion, the legal community would do well to understand the individualization fallacy, take steps to encourage reforms designed to place a scientific foundation beneath forensic identification, and place appropriate limits on what such expert witnesses are and are not

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[61] *Supra* note 1.

[62] Although the DNA typing model has much to offer the traditional forensic sciences, offering source identifications at trial for sufficiently low probabilities (*see* Bruce Budowle et al., *Source Attributions of a Forensic DNA Profile*, 2(3) FORENSIC SCI. COMMUNICATIONS (2000) (online journal)) would not be an implication of the science but an evasion of it in the service of advocacy.

permitted to assert. Forensic identification scientists can help themselves immediately by forswearing exaggerated, definitive conclusions in favor of humbler, scientifically justifiable, probabilistic conclusions.

Afterword

This article has focused on the inferences that can or cannot be drawn from a conclusion that two patterns match. One might think of this as the second of the two major steps in forensic identification. The first step – knowing when two patterns are so alike that they can properly be said to match – raises scientific issues of its own.[63] Let us briefly consider the related challenges of that first step.

The risk that a called match might be in error affects the ultimate inferences that can be drawn about the evidence in a case. This risk, which is separate from the risk associated with drawing an inference from an accurately called match, has been the subject of far too little research. As a result, existing standards and procedures do not provide sufficient protection from erroneous match calls.

Indeed, few if any criminalistics subfields have any objective standards for making the decision as to whether or not two patterns match. This determination is left to the judgment of each examiner. For example, Stoney[64] had this to say about fingerprint examination standards:

> How much correspondence between two fingerprints is sufficient to conclude that they [are the same pattern]....? An adequate answer... is not currently available. The best answer at present... is that this is up to the individual expert fingerprint examiner to determine, based on that examiner's training, skill, and experience. Thus, we have an ill-defined, flexible, and explicitly subjective criterion for establishing fingerprint identification....
> Any unbiased, intelligent assessment of fingerprint identification practices today reveals that there are, in reality, no standards.

The lack of objective standards helps explain the disturbing findings from the small body of research on pattern matching by forensic scientists that has been conducted to date. In some tests, examiners disagreed with one another about whether various images matched.[65] In other

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[63] From an evidentiary value perspective, the two steps that we identify might be referred to as "reliability" and "diagnosticity," respectively. *See* DAVID A. SCHUM, EVIDENTIAL FOUNDATIONS OF PROBABILISTIC REASONING (1994). The first step involves the reliability of the evidence because it concerns the value of the expert's testimony for establishing that the questioned and the known samples do, in fact, share characteristics. The second step involves the diagnosticity of the evidence because it concerns the value of the match conclusion for drawing an inference that the questioned and known samples share a common source.

[64] *Supra* note 35, at 329-30.

[65] *See, e.g.*, *supra* note 8; Collaborative Testing Service, Forensic Testing Program (various fields, various years); J. Sita, Brian Found, and Doug Rogers, *Forensic Handwriting Examiners' Expertise For Signature Comparison*, 47 J. FORENSIC SCI. 1117 (2002).

tests, examiners who agreed that two patterns matched disagreed (sometimes dramatically) on what about them constituted the match.[66] Examiners differ not only in their ability to perceive pattern similarity and differences, but also in their thresholds for calling matches.[67]

Other research shows that the match judgments of experienced criminalists are influenced by extraneous information. A study by Dror et al.[68] showed that four out of five fingerprint experts who had previously identified two prints as a match later reached different conclusions about those same prints when they were led to believe that others had declared those prints to be from different sources. In a follow-up study,[69] six fingerprint experts were provided with eight pairs of prints that they had previously judged. The study found that introduction of contextual information induced four of the six experts to make at least one different match judgment than they had made previously. Sometimes pairs that were judged to be exclusions were subsequently judged to be matches, and sometimes pairs that were judged to be matches were subsequently judged to be exclusions.[70] Surprisingly, experts made some inconsistent decisions even in the control condition where contextual information was not introduced (which reflects random rather than systematic error). These results suggest that criminalists should employ the same kind of blind examination procedures in casework that are widely used in other fields.[71] Such procedures would protect initial judgments from the contextual influences that contribute to errors.[72]

As Dror and Charlton[73] point out, "[h]ow rare and under what conditions errors occur at a practical level is still unclear at this stage." One major reason for this knowledge gap is the dearth of high quality proficiency tests across the various disciplines. Good proficiency tests are closed (i.e., the analyst is blind to the fact that the test materials are not part of ordinary case work), external (i.e., administered by a disinterested party), and use realistic case samples. Unfortunately, tests that include all three ingredients are virtually non-existent. On the one hand, results from the proficiency tests that have been conducted sometimes reveal discouragingly high error rates. On the other hand, because the tests are open, relatively easy, *and lack the biasing contextual information that is available in much real casework*, performance on proficiency tests likely is better than performance in actual casework.[74] Although forensic science leaders have,

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[66] Ian W. Evett and R.L. Williams, *A Review of the Sixteen Points Fingerprint Standard in England and Wales*, 46 J. FORENSIC IDENT. 49 (1996).
[67] Victoria Phillips, Michael Saks, and Joseph Peterson, *Signal Detection Theory and Decision-Making in Forensic Science*, 46 J. FORENSIC SCI. 294 (2001).
[68] Itiel E. Dror, David Charlton, and Ailsa E. Peron, *Contextual Information Renders Experts Vulnerable to Making Erroneous Identifications*, 156 FORENSIC SCI. INT'L 74 (2006).
[69] Itiel E. Dror and David Charlton, *Why Experts Make Errors*, 56 J. FORENSIC IDENT. 600 (2006).
[70] Surprisingly, experts made some inconsistent decisions even in the control condition where contextual information was not introduced – which reflects random rather than systematic error.
[71] D. Michael Risinger, Michael J. Saks, Robert Rosenthal & William C. Thompson, *The* Daubert/Kumho *Implications of Observer Effects in Forensic Science: Hidden Problems of Expectation and Suggestion*, 90 U. CAL. L. REV. 1 (2002).
[72] Robert B. Stacey, *Report on the Erroneous Fingerprint Individualization in the Madrid Train Bombing Case*, 54 J. FORENSIC IDENT. 706 (2004).
[73] *Supra* note 68.
[74] *Supra* note 22.

on occasion, declared errors to be so frequent as to be "unacceptable,"[75] the fact that errors occur with some regularity signals that a reported match between a pair of markings probably has less probative value than conventional claims suggest.

[75] David L. Grieve, *Possession of Truth*, 46 J. FORENSIC IDENT. 521, 524 (1996).