SUPERIOR COURT OF THE DISTRICT OF COLUMBIA
Criminal Division — Felony Branch

UNITED STATES,	:	**Case No. 2018 CF1 004356**
v.	:	**Hon. Robert D. Okun**
ROBERT GREEN.	:	

BRIEF OF *AMICI CURIAE* CRIMINAL LAW SCHOLARS, SCIENTISTS, STATISTICIANS, AND THE INNOCENCE PROJECT, INC. IN SUPPORT OF DEFENDANT ROBERT GREEN

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STATEMENT OF INTEREST OF AMICI CURIAE[1]

The *amici* are law professors, scientists, and statisticians at some of America's leading universities who have devoted a substantial part of their teaching, work, research and/or writing to criminal law and procedure, including issues pertaining to the accuracy and reliability of evidence and equity in criminal outcomes. Their work has been published by major university presses and in leading scientific and law journals. The professors, scientists, and statistician *amici* are listed on Appendix A hereto.

INTRODUCTION

By ensuring that only valid, reliable expert testimony is admitted into evidence or relied upon to secure convictions, courts play a crucial role in the prevention of the injustice of wrongful convictions. To protect the integrity of both individual judicial proceedings and the broader justice system, courts must exclude unproven and unreliable forensic testimony at criminal trials. At bottom, "[t]he fair administration of justice requires that science is accurately and effectively communicated to the fact finders" in judicial proceedings. Itiel E. Dror & Nicholas Scurich, *(Mis)use of Scientific Measurements in Forensic Science*, 2 Forensic Sci. Int'l: Synergy 333, 333 (2020).

Firearm and toolmark ("FA/TM") examiners purport to "match" spent ammunition to *one particular firearm*—not a type of firearm, make of firearm, or model of firearm—by visually comparing spent ammunition recovered from a crime scene with spent ammunition from a test fire from the firearm suspected to have been used in the crime. FA/TM evidence is premised on

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1 Both parties have consented to the filing of this *amici* brief. No counsel for a party authored this brief in whole or in part, and no party or its counsel made a monetary contribution intended to fund the preparation or submission of this brief. No persons other than *amici*, their members, or their counsel made a monetary contribution to this brief's preparation or submission.

the *unproven assumption* that each firearm leaves unique, individualized markings on spent ammunition. Though routinely admitted by courts for decades, the scientific community at large has now sounded the alarm that the "fair administration of justice" is severely threatened by the admission of FA/TM evidence. In particular, the current scientific consensus is that FA/TM evidence lacks scientific support from well-designed, empirical studies.[2] The overwhelming majority of studies purporting to demonstrate the validity and reliability of FA/TM evidence, in fact, have been poorly designed, having been "developed by insular communities of nonscientist practitioners"—members of the AFTE, i.e., practicing FA/TM examiners rather than scientists—"who did not incorporate effective statistical methods." William A. Tobin, H. David Sheets & Clifford Spiegelman, *Absence of Statistical and Scientific Ethos: The Common Denominator in Deficient Forensic Practices*, at 1, 4 Statistics & Pub. Pol'y (2017), https://www.tandfonline.com/doi/pdf/10.1080/2330443X.2016.1270175.

The myriad flaws in the design of existing FA/TM studies render their conclusions statistically—and scientifically—unreliable. Poorly designed studies result in narrowly applicable data from which proponents of FA/TM analysis draw overbroad and improper inferences. Among other things, while interested proponents of FA/TM analysis assert that it has an error rate of "1%," *e.g.*, FBI Laboratory Response to the Declaration Regarding Firearms and Toolmark Error Rates, *People v. Winfield*, No. 15 CR14066-01 (Cook Cnty. Cir. Ct. May 3, 2022), at 3 ("FBI Lab Response"), the scientific community has overwhelmingly concluded that, because of the design of existing studies, (i) this number is woefully underinclusive and (ii)

[2] The *amici* will not address here the serious flaws in the entirely subjective methodology employed by FA/TM examiners propounded by their trade group, the Association of Firearm and Toolmark Examiners ("AFTE"). *Amici* understand that Mr. Green has extensively briefed that issue. (*See* Motion to Exclude Expert Testimony in Firearms Identification and Memorandum of Points and Authorities In Support Thereof, Nov. 2, 2021.)

existing studies have not actually or appropriately shown a "known or potential rate of error." *Daubert v. Merrell Dow Pharms., Inc.*, 509 U.S. 579, 593-94 (1993). The import of a "known or potential rate of error" is obvious: "[k]nowing the error rates in a particular forensic domain is a vital measurement needed to ascertain the weight of the evidence. The appropriate weight of the evidence cannot be known without some sense of the rates at which the technique errs." Dror & Scurich at 333 (citation omitted); *see also* Thomas D. Albright, *How to Make Better Forensic Decisions*, Proc. Nat'l Acad. of Sci., at 7 (Sept. 2022), https://doi.org/10.1073/pnas.2206567119 (noting that the trier of fact "truly needs to know" the "examiner's decision, together with an estimate of the probability that the decision is correct."). Of the few more appropriately designed studies, the most recent—a collaboration between the FBI and the Ames Laboratory—demonstrates that examiners are unable to repeat their conclusions between 21% and 70% of the time. (Ames II, *infra* Section I.B.2.)

Though some proponents of FA/TM evidence have attempted to cover over these consistent flaws by employing the idea of "convergent validity"—that is, the idea that, when taken as a whole, a group of flawed studies can tend to demonstrate reliability—this semantic dodge cannot change the fact that the vast majority of FA/TM studies suffer from *common* flaws and, as such, their conclusions do not become any more forceful in the aggregate.

Moreover, despite this astounding absence of demonstrated validity, FA/TM evidence is often presented to juries in broad categorical strokes. Testifying examiners report their conclusions by declaring a definite identification (i.e., the crime scene ammunition came from the suspected firearm), definite exclusion (i.e., the crime scene ammunition did not come from the suspected firearm), or inconclusive (i.e., the examiner cannot state one way or another). Such confident, definitive statements, combined with the uncertainty of how often the FA/TM methodology actually results in errors, can easily cause jurors to be misled—or, at a minimum, confused—about the import and weight of FA/TM evidence.

To prevent future wrongful convictions—and unfair proceedings—based on now-discredited FA/TM evidence, *amici* respectfully urge this Court to take the opportunity presented by this case to explicitly hold that FA/TM evidence is inadmissible in criminal courts in the District of Columbia because it is not scientifically validated, is inherently unreliable, and does not meet the well-established standards set forth in Federal Rule of Evidence 702 and *Daubert*. In the alternative, if the Court is unwilling to hold that FA/TM evidence is inadmissible, *amici* respectfully urge the Court to hold that, at most, FA/TM examiners may opine that a firearm "cannot be excluded" as the source of the ammunition at issue.

ARGUMENT

I. THE SCIENTIFIC COMMUNITY HAS REJECTED THE NOTION THAT FA/TM IS RELIABLE OR SCIENTIFICALLY VALIDATED

District of Columbia courts have "allowed the admission of expert testimony concerning ballistics comparison matching techniques" for "decades." *Gardner v. United States*, 140 A.3d 1172, 1183 (D.C. 2016) (citing *Laney v. United States*, 294 F. 412, 416 (D.C. Cir. 1923)). "Beginning around 2008, however, questions about pattern matching generally, and bullet pattern matching specifically, surfaced in the scientific community." *Id.*.

Beyond raising mere "questions," however, the broader scientific community has re-assessed and forcefully discredited FA/TM because it has not yet been demonstrated to be scientifically valid.

A. Four Reports By Committees Of Experts From The Scientific Community Have Concluded That FA/TM Is Not Scientifically Valid

Beginning in 2008 and continuing through 2017, three separate panels of distinguished independent experts from the broader scientific and academic community (not limited to

FA/TM)—convened by National Academy of Sciences ("NAS") and the President's Council of Advisors on Science and Technology ("PCAST")—authored four separate reports raising serious concerns about the scientific validity and reliability of FA/TM evidence (as well as other "pattern-matching" fields).[3] Importantly, the committees authoring these reports consisted of independent scientists and professors with expertise in physics, chemistry, biology, materials science, engineering, biostatistics, statistics, scientific methodology and study design, and medicine, as well as judges and lawyers—rather than toolmark examiners, whose financial and professional stake in the continued embrace of their discipline is apparent. Each of those national scientific committees heard testimony from forensic scientists, reviewed nearly every available journal article and study involving toolmark examination, and read every article or study submitted by members of the forensic community.[4] As such, these bodies were uniquely qualified to determine whether this field is based on valid, reliable scientific principles or methodologies.

In the end, the conclusions of these committees were uniform and devastating: the "fundamental assumptions" underlying toolmark examination, including the claimed uniqueness

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[3] *See generally*, National Research Council, *Ballistic Imaging*, National Academies Press (2008), https://doi.org/10.17226/12162 ("Ballistic Imaging"); National Research Council, Committee on Identifying the Needs of the Forensic Sciences Community, *Strengthening Forensic Science in the United States: A Path Forward* (Aug. 2009), https://www.ojp.gov/pdffiles1/nij/grants/228091.pdf ("NAS Report"); President's Council of Advisors on Science and Technology, *Forensic Science in Criminal Courts: Ensuring Validity of Feature-Comparison Methods* (Sept. 2016), https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf ("PCAST Report"); President's Council of Advisors on Science and Technology, *An Addendum to the PCAST Report on Forensic Science in Criminal Courts* (2017), https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensics_addendum_finalv2.pdf ("PCAST Addendum").

[4] *See, e.g.*, PCAST Report at 2, 155-160; NAS Report at xx, 2-3; Ballistic Imaging at xiii–xvi; PCAST Addendum.

of all striae, have not been proven; the theory of toolmark identification—i.e., "individualization" or matching any particular tool to a particular mark—is "not a scientific theory"; the method is subjective; and there is insufficient empirical evidence establishing either the scientific validity of the field or even estimating the reliability of toolmark examinations.[5] In short, the committees concluded that FA/TM examination consists of applying a subjective methodology to an unvalidated assumption, and it lacks the studies necessary to demonstrate that it produces reproducible, repeatable, and valid results.

B. Since The Ballistic Imaging, NAS, And PCAST Reports, The Scientific Community Has Continued To Cast Doubt Upon FA/TM

Since publication of the Ballistic Imaging, NAS, and PCAST Reports, the scientific community has elaborated upon and amplified the criticisms of FA/TM evidence. A litany of publications by authors spanning multiple disciplines have continued to call FA/TM into question, including but not limited to:

- David L. Faigman, Nicholas Scurich, & Thomas D. Albright, *The Field of Firearms Forensics Is Flawed*, Sci. Am. (May 25, 2022), https://www.scientificamerican.com/article/the-field-of-firearms-forensics-is-flawed/;

- Itiel E. Dror & Nicholas Scurich, *(Mis)use of Scientific Measurements in Forensic Science*, 2 Forensic Sci. Int'l: Synergy 333 (2020);

- William A. Tobin, H. David Sheets & Clifford Spiegelman, *Absence of Statistical and Scientific Ethos: The Common Denominator in Deficient Forensic Practices*, 4 Statistics & Pub. Pol'y (2017), https://www.tandfonline.com/doi/pdf/10.1080/2330443X.2016.1270175;

- Thomas D. Albright, *How to Make Better Forensic Decisions*, Proc. Nat'l Acad. of Sci., at 7 (Sept. 2022), https://doi.org/10.1073/pnas.2206567119;

- Alan H. Dorfman & Richard Valliant, *Inconclusives, Errors, and Error Rates in Forensic Firearms Analysis: Three Statistical Perspectives*, at 5, 5 Forensic Sci. Int'l: Synergy (June 8, 2022); and

[5] *See* Ballistic Imaging at 3; NAS Report at 154; PCAST Report at 47, 60, 104, 111, 113.

- Heike Hoffman, Alicia Carriquiry & Susan Vanderplas, *Treatment of Inconclusives in the AFTE Range of Conclusions*, 19 Law, Prob., and Risk 317 (2020).

1. Existing FA/TM Studies Almost *All* Suffer From Serious Design Flaws Which Prevent Them From Validating FA/TM As A Discipline

For a scientific method to be valid, it must be: (i) repeatable, i.e., in the context of FA/TM evidence, the examiner reaches the same conclusion when presented with the same evidence; (ii) reproducible, i.e., different examiners reach the same conclusion when presented with the same evidence; and (iii) accurate, i.e., the conclusion is correct. Validation studies are intended to understand the range of conditions under which the method works as required, how well it performs, and to identify conditions under which it is likely to fail.

A high quality study design is needed to achieve these goals. Existing FA/TM studies, however, overwhelmingly suffer from design flaws preventing them from reaching these aims and contributing toward the validation of FA/TM. The scientific community, including leading experts in study design, human cognition, statistics, and other scientific disciplines, have noted the myriad design flaws in existing FA/TM literature to include:

Fundamental Study Design. Two fundamental flaws in the design of nearly all FA/TM studies render them incapable of providing meaningful, generalized results applicable to FA/TM evidence as a whole—even when considered in the aggregate:

First, existing FA/TM studies have largely used closed rather than open sets. In a closed-set study there is a "match" for every test sample in a set. PCAST Report at 108-09. As such, a closed-set study is easier than one in which a test sample might have no "match," because in a closed set the examiner can merely look for the closest match in the set. Moreover, a closed set allows an examiner to come to correct conclusions simply by process of elimination, akin to a Sudoku puzzle. Indeed, an examiner in a closed set study will be able to come to at least some conclusions without having to perform any analysis. *Id.*; *see also United States v. Adams*, 444 F. Supp. 3d 1248, 1264-65 (D. Or. 2020) (error rates in tests using "partly closed sets" were "'nearly 100-fold higher' than from the closed-set tests" (quoting *United States v. Shipp*, 422 F. Supp. 3d 762, 777-78 (E.D.N.Y. 2019); citing PCAST Report at 109)). For example, in one study, participants were asked to evaluate spent ammunition and match it to 10 potential barrels; as a result, *random guesses* have a 1-in-10 chance of being correct. Clifford Spiegelman & William A. Tobin, *Analysis of Experiments in Forensic Firearms/Toolmarks Practice Offered as Support for Low Rates of Practice Error and Claims of Inferential Certainty*, 12 Law, Probability & Risk 115, 127 (2013). Error rates in a closed set study would not correlate with casework error rates, since in casework, of course, there is by definition no guarantee that any of the evidence in fact "matches" the test samples.

Second, existing FA/TM studies do not generally report the drop-out rate for participants. Research has found that if less than 5% of participants drop out, "there is little threat to the statistical validity of the study, but if more than 20% of participants drop out, the study's validity is severely compromised." (Ex. 1 at 4.) It is simply not known what the effect of participant drop-out is on existing FA/TM studies—it could be minimal, or could be significant.

Participant Sampling. In order for studies to be generalizable to FA/TM on the whole, the participants must be a representative sample from the population at issue—in the case of FA/TM, all qualified examiners in the U.S. (*Id.* at 5; *see also* Alan H. Dorfman & Richard Valliant, *Inconclusives, Errors, and Error Rates in Forensic Firearms Analysis: Three Statistical Perspectives*, at 5, 5 Forensic Sci. Int'l: Synergy (June 8, 2022).) Existing FA/TM studies, however, have not randomly selected participants from the population, but have instead relied upon self-selected volunteers. (Ex. 1 at 6.) This leads to inherent biases in the study population;

for example, experienced examiners who may have lower error rates than the population of examiners on the whole may be more likely to volunteer "out of a sense of duty to the discipline." (*Id.*) Without a representative sample of participants, a study can speak only to the error rate of those participants, not to the discipline as a whole.

Material Sampling. Like participant sampling, well-designed studies should also have a representative sample of the ammunition and firearms that an examiner could encounter in a real-world setting. Existing FA/TM studies largely concern a single type of firearm and/or a single type of ammunition. (*Id.*) In many cases, existing studies examine firearms of the same make and model manufactured closely in time. (*Id.*; *see also* Spiegelman & Tobin at 124 (noting that in one study oft-cited to courts by proponents of FA/TM, only three types of weapons were used, "two with sample size 1"), 127 (noting that in another oft-cited study, "one type of weapon" and "possibly two types of ammunition" were used).) In other cases, the studies concern only firearm makes and models that are known to mark well. (Ex. 1 at 6-7.) Existing FA/TM studies are thus not representative of the discipline on the whole, and findings and error rates may not generalize well to FA/TM on the whole.

Missing Data and Non-Responsive Bias. In addition to those dropping out, participants commonly fail to complete the full study, creating two potential sources of missing data. (*Id.* at 7-8; *see* Dorfman & Valliant, *Inconclusives* at 5.) Missing data can create several potential biases—particularly if the participants that are the source of missing data are "systematically different" from those who do complete the study. (Ex. 1 at 7.) FA/TM studies have not reported their rates of missing data, and it is thus impossible to assess the magnitude of its effect on the error rates reported by those studies.

Type of Marks and Study Difficulty. Marks by firearms can differ significantly based upon the make and model of firearm and the ammunition used. Some firearms leave breechface markings, i.e., markings on the flat end of the cartridge where the breechface of the firearm makes contact with the cartridge to force it out of the barrel; others leave marks on the sides of the cartridge or bullet. It is "not reasonable" to assume that error rates examining one type of marking can be applied to other types of markings. (*Id.* at 8.) Similarly, by design, studies are of varying levels of difficulty; error rates discerned in studies of differing levels of difficulty cannot be compared or generalized for the obvious reasons. (*Id.* at 8-9.)

Inconclusives. Finally, and critically, FA/TM studies are fundamentally flawed in how they treat inconclusive results. Where an examiner cannot identify a match or definitively rule out a match, AFTE's theory of identification permits the examiner to report results as "inconclusive." Dorfman & Valliant, *Inconclusives* at 1. However, existing FA/TM error rate studies were designed such that test items are prescreened and removed from the study if they appear to be inconclusive in nature, and, as such, in these studies *no* answer of inconclusive should be deemed "correct." Dror & Scurich at 336. However, most FA/TM studies count an answer of "inconclusive" as a correct answer. Thus, test takers are effectively allowed to skip difficult questions—which are, by definition, more likely to yield wrong answers—by simply answering "inconclusive."[6] This method of scoring unquestionably "misrepresents the reality of evidence in casework" and inherently, artificially depresses the true error rate. *Id.* at 334, 336 ("A priori presuming that inconclusive decisions can never be an error is problematic. If some

[6] In Ames I (defined below), more than 20% of test takers labeled every single different-source cartridge case comparison (the type of comparison that can produce false positives) as inconclusive. David P. Baldwin et al., Ames Laboratory, USDOE, Technical Report #IS-5207, *A Study of False-Positive and False-Negative Error Rates in Cartridge Case Comparisons* 16 (2014), https://www.ojp.gov/pdffiles1/nij/249874.pdf.

examiners conclude an identification (or exclusion) whereas other examiners conclude as inconclusive, then at least some of the examiners are mistaken. . . [I]t is obvious [everyone] cannot be correct when examiners reach different conclusions on identical comparisons."). Other studies simply exclude inconclusives from their analysis altogether, which also artificially deflates potential error rates and renders reported error rates uninformative. Dorfman & Valliant, *Inconclusives* at 3; Albright at 5. At the extreme, these systems would allow an examiner to answer "inconclusive" on every test question and nevertheless receive a perfect score.

* * *

In sum, the "'validation studies'" that exist concerning FA/TM "typically result from," among other things "statistical . . . deficiencies in the design and conduct of the experiments, and frequently lead to unjustified inferential extrapolation to universal" application to FA/TM. Spiegelman & Tobin at 115. In other words, "[t]he various 'validation studies' may be skilled experiments as forensic proficiency tests for specific examiners (test respondents) in controlled circumstances, but *the same studies as currently exist are inappropriate for extrapolation to universal assumption or otherwise representative of rates of error for the field of*" FA/TM evidence. *Id.* (*See also* Ex. 1 at 10; Ex. 2 at 34.) As a result, existing studies have "conclusions [that] far exceed statistically sound inferences from the experimental evidence." Spiegelman & Tobin at 130; *see also id.* at 118 ("Because most of the studies reviewed by the authors stray to varying degrees from the true scientific method, they frequently contain another characteristic of 'pathological science': wishful data interpretation."). Leading statisticians (and the scientific community on the whole) have therefore reached one inescapable conclusion: multiple *well-designed* studies are still badly needed to demonstrate the general scientific validity and reliability of FA/TM evidence.

2. The Only Arguably Well-Designed FA/TM Studies Demonstrate Alarming Error Rates

Proponents of FA/TM evidence have asserted that it is impossible or impractical to conduct studies establishing a discipline-wide error rate in support of the validity of FA/TM and that criticism of existing studies and FA/TM evidence is thus overblown. Not so. While it may be complex to establish a discipline-wide known or potential rate of error using well-designed empirical studies, Spiegelman & Tobin at 130-31, such difficulty should not prevent the FA/TM and scientific communities from attempting to do so—life and liberty are at stake.[7]

Contrary to its proponents' assertions, it *is* possible to design FA/TM studies with proper study design. Three existing studies have been arguably well-designed, testing multiple types of firearms and substrates. The results of these studies, however, do not support the validity of FA/TM evidence. They instead demonstrate why more well-designed studies are necessary. In particular, these studies demonstrated alarming error rates in FA/TM evidence—rather than establish or in any way support its validity.

Two studies undertaken by the Ames Laboratory, a Department of Energy national laboratory affiliated with Iowa State University, showed astounding error rates in FA/TM examinations.

In the first study ("Ames I"), researchers identified a positive error rate between 1 in 66 and 1 in 46, i.e., examiners made a false positive or inconclusive identification as frequently as every 1 in 46 examinations—a far cry from the near certainty testifying firearms examiners portray in their testimony. *See* Baldwin et al., *supra* n.6.

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[7] Nor should courts permit proponents of FA/TM evidence to simply dispense with *Daubert*'s requirement that the "known or potential rate of error" be established as a threshold issue for reliability and, thus, admissibility.

The results of the second Ames study ("Ames II") are even more troubling. Participants concluded that the results of comparisons were inconclusive 50% of the time with respect to bullets and 40% of the time with respect to cartridge casings—a significant portion of the results. Dorfman & Valliant, *Inconclusives* at 6. The authors of Ames II reported inconclusives as "neutral non-errors," which allowed them to report error rates of less than 0.8%. *Id.* at 2. If inconclusives are regarded as potential errors—and logically, they are (*see* pp. 10-11, *supra*)—the potential error rate rises to more than ***66%***. *Id.*

Aside from the alarming potential error rate, Ames II highlighted the utter subjectivity and inability of FA/TM to demonstrate the repeatability of its methodology. With respect to bullets, examiners were unable to repeat *their own conclusions* 21% of the time for known matches and 35.3% of known non-matches; they were unable to repeat the conclusions of *other* examiners 32.2% of the time for known matches and nearly 70% of the time for known non-matches. Stanley J. Bajic et al., Ames Laboratory-US DOE, Technical Report No. ISTR-5220, *Report: Validation Study of the Accuracy, Repeatability, and Reproducibility of Firearms Comparison* (Oct. 7, 2020). The results as to cartridge casings were equally appalling: examiners disagreed with their own conclusions 24.4% of the time for known matches and 37.8% of the time for known non-matches, and disagreed with other examiners 36.4% of the time for known matches and 59.7% of the time for known non-matches. *Id.* In total, "examiners examining the same material twice, disagree[d] with themselves between 20 and 40% of the time." Dorfman & Valliant, *Inconclusives* at 6; *see also* Alan H. Dorfman & Richard Valliant, *A Re-analysis of Repeatability and Reproducibility in the Ames-USDOE-FBI Study*, Stats. & Pub. Pol'y (2022), https://doi.org/10.1080/2330443X.2022.2120137 (Ames II showed "rather weak Repeatability and Reproducibility").

For different reasons, the third arguably well-designed study likewise cannot and does not support the validity or reliability of FA/TM analysis. That study was a small, open-set study of .40 caliber cartridge cases. Mark A. Keisler et al., *Isolated Pairs Research Study*, 50 AFTE J. 56 (2018). A single, limited study of one type of spent ammunition, alone, cannot validate the entire field, however. Further, that study is not without a significant design flaw: like many FA/TM studies, the author counted inconclusives as correct answers. *Id.* If the inconclusives were counted as errors or potential errors, the error rate rises to nearly 20%.

C. Convergent Validity Does Not Salvage The Failure Of Existing FA/TM Studies To Demonstrate That The Field Is Reliable Or Scientifically Valid

Proponents of FA/TM nonetheless posit that existing studies are sufficiently sound to support the scientific validity and reliability of FA/TM evidence and, by extension, the introduction of FA/TM evidence in legal proceedings. They argue, among other things, that the concept of convergent validity can be applied to FA/TM literature. (Ex. 3 at 22.)

Convergent validity[8] is "the possibility that various publications, each with distinct limitations when considered by itself, can reinforce each other and collectively support conclusions that would not be warranted on the basis of a single article." William Thompson et al., *Latent Fingerprint Examination*, Forensic Science Assessments: A Quality and Gap Analysis, American Association for Advancement of Science (2017) at 94 ("AAAS Report"). In other words, proponents of FA/TM evidence assert that even if existing studies are flawed (*see* Part I.A, *supra*), taken together, they suffice to establish the validity of FA/TM evidence by "drawing a broader picture of how different examiners in various experimental settings, based on data drawn from multiple relevant studies." (Ex. 3 at 22; *see also id.* at 7 ("Moreover, multiple

[8] Many research methodology experts would use the term "triangulation" to refer to what is described in this subsection.

studies, though each with specific limitations, together can complement each other.").) Among other things, proponents of FA/TM evidence note that the consistent findings of approximate 1% error rates in the FA/TM literature support the notion that the error rate is, in fact, around this level. FBI Lab Response at 3.

Convergent validity, however, is not properly applied to existing studies on FA/TM evidence. Convergent validity could, arguably, provide support for the validity and reliability of FA/TM evidence ***if*** the literature consisted of well-designed studies that, together, analyze FA/TM over a representative sample of examiners, firearms, ammunitions, and conditions. It does not. Rather, existing studies nearly universally suffer from the same design flaws. As a result, no matter how many there are, these studies cannot support one another: instead of filling in the gaps resulting from the limitations or flaws of each other, existing FA/TM studies *accentuate* and widen those same gaps.

Indeed, the lead author of the publication FA/TM proponents often cite for the proposition that convergent validity can and should apply to FA/TM—the AAAS Report, which focused on fingerprint analysis—has *explicitly rejected* its application to existing studies. In particular, Professor William C. Thompson—one of the *amici* on this submission—has noted that the AAAS Report was ***not*** "intended to suggest or imply that forensic science techniques can be considered valid in the absence of direct empirical tests of their accuracy or on the basis of studies that PCAST considered flawed and inadequate." (Ex. 4 at 3.) Rather, as Professor Thompson noted,

> The AAAS report was designed to provide a comprehensive review of the scientific literature on fingerprint evidence. Consistent with that goal, it discussed the convergence of findings across multiple studies of latent print examiners, including a number of studies that PCAST noted as having design flaws or other limitations that prevented them from being appropriate empirical tests for establishing foundational validity. The AAAS report also noted these flaws and limitations; it

> did not suggest that these studies were appropriate tests of the accuracy of latent print examination under conditions appropriate to use in practice. It found, however, that many of these studies were nevertheless worthy of consideration *for other purposes*, particularly for identifying factors that might affect the validity of latent fingerprint examination as applied (such as the quality of the latent print; training of examiners, etc.).

(*Id.* (emphasis added).)

At bottom, while proponents of FA/TM evidence may wish to invoke "convergent validity" to prop it up, it simply cannot do so. Absent any well-founded and generalizable conclusions from these studies, the body of evidence concerning FA/TM rests on the tiny number of well-designed FA/TM studies—which undermine the validity and reliability of FA/TM, rather than establishing it. (*See* pp. 12-14, *supra*.)

II. THE COURT SHOULD PRECLUDE CONCLUSIONS THAT IMPLY A STATISTICAL BASIS

Among the chorus of critics of FA/TM are statisticians who have found that, in their present form, studies in many common pattern matching forensic disciplines such as FA/TM and fingerprint comparison, have reported statistically inappropriate conclusions. *E.g.*, American Statistical Association, *Position on Statistical Statements for Forensic Evidence*, at 2 (Jan. 2, 2019), https://www.amstat.org/asa/files/pdfs/POL-ForensicScience.pdf ("ASA Report"); Spiegelman & Tobin at 115. Opining that two pieces of ammunition were fired from the same gun, for example, "requires knowledge of how common or rare the association is, based on empirical data linked to the case at hand." ASA Report at 2. No such probability data currently exists, meaning the weight of FA/TM examiners' observations is undetermined. The uncertainty surrounding FA/TM is compounded by the lack of empirical data appropriately establishing a *realistic* potential or actual rate of error. (*See* pp. 4-14*, supra*.) *See also* Karen Kafadar, *The Critical Role of Statistics in Demonstrating the Reliability of Expert Evidence*, 46 Fordham L. Rev. 1617, 1620 (2018) ("Scientific validity and reliability require that a method has been subjected to empirical testing . . . that provides valid estimates of how often the method reaches an incorrect conclusion." (quoting PCAST Report at 143).) Statisticians attribute the paucity of such data to the poor design of existing FA/TM studies. (*E.g.*, Ex. 1 at 10.)

Despite these failings, FA/TM evidence is often presented in broad—and seriously misleading—categorical strokes: there is a definite identification (i.e., a "match"), a definite exclusion, or the results are inconclusive. Dorfman & Valliant, *Inconclusives* at 1. Such statements inherently imply certainty—or at least a very high probability—where there is none. *See* ASA Report at 2; Albright at 9 (examiner statements "foster an illusion of certainty"). As described above, there is *no basis* in existing data to suggest that a FA/TM examiner's conclusion can be made with any degree of probability or certainty: there are no established error rates or empirical data demonstrating the relative frequencies of various characteristics observed on spent ammunition.

While District of Columbia courts have made important strides in curtailing the false sense of certainty portrayed when FA/TM examiners declare a ballistic "match," this Court should advance the interests of justice further and hold that FA/TM evidence is inadmissible because it is unreliable. At a minimum, the Court should hold that FA/TM evidence may not be presented in such a way that implies a statistical or probabilistic basis for a conclusion where there is none. At most, FA/TM evidence should go no farther than what the data actually tend to support: testimony that a particular firearm "cannot be excluded" as the source of the ammunition in question.

A. District Of Columbia Courts Have Taken Some Steps To Limit Baseless Statistical Conclusions In FA/TM Evidence

Given the ever-growing scientific criticism of FA/TM evidence (*see* Part I, *supra*), District of Columbia courts have been at the forefront of a nascent nationwide shift toward limiting the admissibility of FA/TM evidence. While they have yet to entirely exclude FA/TM evidence—though this Court should—District of Columbia courts have curtailed *how* FA/TM examiners may present their conclusions to the jury.

In particular, a number of District of Columbia courts have considered the critiques of FA/TM evidence and concluded that the sweeping categorical statements often used by FA/TM witnesses are *not* supported by science. In *United States v. Tibbs*, 2016-CF1-19431, 2019 WL 4359486 (D.C. Super. Ct. Sept. 5, 2019), for example, after a multi-day evidentiary hearing and hundreds of pages of briefing, expert affidavits, and other evidence, Judge Edelman held that the government's FA/TM examiner

> may testify that based on his examination, the recovered firearm *cannot be excluded as the source of the cartridge casing found* on the scene of the alleged shooting. . . . Any statements by the expert involving more certainty regarding the relationship between a casing and a firearm would stray into territory not presently supported by reliable principles and methods.

Id. at *23. Among other things, Judge Edelman recognized that "threshold design issues" with existing FA/TM studies "surely impact the validity of these studies' conclusions and limit their utility to some extent." *Id.* at *14.

Likewise, in *Williams v. United States*, 210 A.3d 734 (D.C. 2019), the Court of Appeals found that the trial court committed plain error when it allowed a FA/TM examiner's testimony that the ammunition in question "had all been fired from the same gun," and "fired from" the specific gun recovered in connection with the case. *Id.* at 738. The court unequivocally noted that "the empirical foundation does not currently exist to permit these examiners to opine with certainty that a specific bullet can be matched to a specific gun," and that "these conclusions are simply unreliable." *Id.* at 742; *see also Gardner*, 140 A.3d at 1184 ("[W]e now hold that the trial court erred by allowing Mr. Watkins to give an unqualified opinion about the source of the bullet that killed Mr. Kamara. We further hold that in this jurisdiction a firearms and toolmark expert may not give an unqualified opinion, or testify with absolute or 100% certainty, that based on ballistics pattern comparison matching a fatal shot was fired from one firearm, to the exclusion of all other firearms.").

B. FA/TM Examiners Should Be Precluded From Using Ambiguous Language That Implies Any Statistical Or Objective Basis For Their Conclusions

Without the ability to testify categorically—that a particular piece of ammunition came from a particular firearm—the government and proponents of FA/TM techniques have continued to advocate for FA/TM evidence and push courts to allow FA/TM testimony to go beyond the "cannot be excluded" language in *Tibbs*. Recently, in *United States v. Sutton*, 2018 CF1 009709 (D.C. Super. Ct. May 9, 2022) (Ex. 5), the court held that the government's FA/TM examiner could not state "without any qualifications or limitations that the ammunition at issue was fired from the same firearm," but allowed the examiner to opine "that the ammunition at issue *is consistent with* being fired from the same firearm." *Id.* at 5 (emphasis added). This limitation is insufficient, and this Court should take this opportunity to hold that, at most, FA/TM examiners may opine that a firearm "cannot be excluded" as the source of the crime scene ammunition.

1. Language Other Than "Cannot Be Excluded" Inappropriately Connotes A Statistical Basis For The FA/TM Examiners' Conclusion

On the surface, "is consistent with being fired" from the suspect firearm may seem to address the serious concerns with examiners' categorical but statistically unsound statements of a "match." But conclusions like "consistent with" are both misleading to jurors for at least three reasons and insufficient to prevent confusion and overemphasis by jurors of FA/TM evidence.

First, "is consistent with being fired" from the suspect firearm is inherently ambiguous: different people may understand it differently. Some people may understand "is consistent with" to connote that the ammunition at issue definitely came from the same source as the test ammunition. Others may understand it to mean that the two pieces of ammunition are indistinguishable. Yet others may understand it to mean that the two pieces of ammunition have some similarities—to varying extents. As the American Statistical Association noted, "[t]o evaluate the weight of any set of observations made on questioned and control samples," jurors need to be able "to relate the probability of making these observations if the samples came from the same source to the probability of making these observations if the questioned sample came from another" potential source. ASA Report, *supra*, at 2. Language like "is consistent with" gives jurors no ability to make that evaluation. In an agreement between the Federal Bureau of Investigation, the Innocence Project and the National Association of Criminal Defense Lawyers concerning hair comparison, the Bureau conceded that the conclusion that a hair was "consistent with coming from" a suspect was ambiguous. *See* Federal Bureau of Investigation, Innocence Project & National Association of Criminal Defense Lawyers, *Microscopic Hair Comparison Analysis Agreement* (Nov. 9, 2012), https://www.mtacdl.org/attachments/CPE/Nelson/FBI_Limits_of_Science__%20Microscopic_Hair_Comparison.pdf ("FBI Hair Report").

Second, "is consistent with" fails to acknowledge that the conclusion is subjective and heavily reliant on the "personal impressions" of the FA/TM examiner. *Id.* Even if cross-examined and asked to justify their level of certainty, FA/TM examiners will likely cite their years of experience and their professional judgment. But "although training and experience are important in applying valid techniques, practitioners' subjective opinions are not sufficient for establishing the uncertainty in measurements or inferences." *Id.* This is particularly problematic because jurors are persuaded by, for example, clinicians who testify as "experts," even when their testimony is based solely on personal experience and has no support by reliable scientific studies. *See* Daniel A. Krauss & Bruce D. Sales, *The Effects of Clinical and Scientific Expert*

Testimony in Capital Sentencing, 7 Psych., Pub. Pol'y & Law 267, 272 (2001). This is because jurors generally presume that "scientific" evidence presented to them via "expert" testimony has been thoroughly vetted and screened by the court before its presentation. *See* N.J. Schweitzer & Michael J. Saks, *The Gatekeeper Effect: The Impact of Judges' Admissibility Decisions on the Persuasiveness of Expert Testimony*, 15 Psych., Pub. Pol'y & Law 1, 4 (2009).

Third, conclusions like "is consistent with" connote a statistical basis for the conclusion. The phrase "is consistent with" inherently suggests that the FA/TM examiner has an understanding of how common certain markings are, how rare other markings are, etc.: he or she could not render such an opinion and make such a comparison without information about the relative frequencies of the characteristics at issue. No such relative frequency data has been established for FA/TM evidence; compounding this problem, examiners often lack a sufficient understanding of statistics, statistical models, and the statistical issues inherent in the evaluation of forensic evidence. Kafadar at 1634-35.

2. Language Going Beyond "Cannot Be Excluded" Is Confusing To Juries And Does Not Sufficiently Protect Against The Overstatement Of The Probative Value Of FA/TM Evidence

A recent study highlights the power FA/TM conclusions connoting a degree of statistical certainty, i.e., anything other than "cannot be excluded," is confusing to jurors and fails to adequately protect against the overstatement of the probative value of FA/TM evidence.

Mock jurors presented with seven different potential conclusions by a FA/TM examiner, including one incorporating the "is consistent with" language espoused in *Sutton* and one that is merely inconclusive, were significantly more likely to convict on the basis of the FA/TM evidence alone under any one of the six non-inconclusive conclusions than under the inconclusive conclusions. Brandon L. Garrett, Nicholas Scurich & William E. Crozier, *Mock Jurors' Evaluation of Firearm Examiner Testimony*, 44 Law & Hum. Behav. 412, 415-16

(2020). Similarly, participants were also significantly more likely to convict under any of the conclusions (other than inconclusive) than under the *Tibbs* "cannot be excluded" condition. *Id.* at 416. Notably, when presented with the conclusion that ammunition "is consistent with" coming from a particular firearm, participants were 1.8 times more likely to convict than when presented with the conclusion that the firearm "cannot be excluded" as the source of the ammunition. *Id.* There was little practical change in results when participants were shown cross-examination of the FA/TM examiner. *Id.* at 419-22; *see also* Lora M. Levett & Margaret Bull Kovera, *The Effectiveness of Opposing Expert Witnesses for Educating Jurors about Unreliable Expert Evidence*, 32 Law & Hum. Behav. 363 (2008) (even when cross-examination is well-constructed and exposes considerable flaws, it has little to no effect on juries).

At bottom, other than *Tibbs*' "cannot be excluded" language, "adopting types of modified conclusion language . . . did not affect guilty verdicts [and] many judicial and prosecution-driven interventions to limit conclusion language for firearms testimony are not likely to be effective." Garrett, Scurich & Crozier at 422.

Indeed, because of the problems with language like "is consistent with" and other phrases tested in the above-referenced study, the FBI has conceded in another pattern-matching forensic discipline lacking in empirical studies, hair comparison, that the only "appropriate" conclusion by hair examiners concerning an association between known and questioned hair is "that a contributor of a known sample could be included in a pool of people of unknown size, as a *possible source* of the hair evidence (without in any way giving probabilities, as an opinion to the likelihood or rareness of the positive association, or the size of the class)." FBI Hair Report at 1 (emphasis added).

3. FA/TM Examiners, If Permitted To Testify, Should Not Be Permitted To Connote A Statistical Basis For Their Conclusions And Should Expressly Acknowledge No Such Basis Exists

The American Statistical Association recommends that where possible, forensic witnesses in comparative disciplines couching their conclusions with some level of statistical certainty—or implying such certainty—should include in their testimony explanations of the features compared, the process used to determine the level of similarity/dissimilarity, relative frequencies of the features compared, relative frequencies of combinations of features compared, quantitative statements of confidence, and the sensitivity of the methodology. *See* ASA Report at 4-5. Such information has not been developed *at all* with respect to FA/TM evidence, and such important contextual information thus cannot be presented to juries. (*See* Part I, *supra*.) *Cf.* ASA Report at 5 ("Currently, not all forensic disciplines can support statistical statements."). Accordingly, the American Statistical Association recommends that "the absence of models and empirical evidence be acknowledged both in testimony and in written reports" by FA/TM examiners when presenting their conclusions. *Id.* (emphasis added). The American Statistical Association also recommends, if the examiner "has no information on sources of error in measurements and inferences, or has no validation data" (as is the case with FA/TM), "that this fact be stated." *Id.* at 4.

If FA/TM examiners are permitted to make statements connoting a statistical basis like "is consistent with" —which this Court should not permit them to do—they should first be required to present information that "permits a valid statistical statement regarding the probative value of comparisons or computations (e.g., how rare is an observed positive association when two items arise from the same source and when they arise from different sources?)." ASA Report, *supra*, at 3. This information includes: "(1) a defined relevant database describing characteristics, images, observed data, or experimental results; (2) a statistical model that describes the process that gives rise to the data; and (3) information on variability and errors in measurements or in statistics or inferences derived from measurements." *Id.*

If, therefore, the Court were inclined to follow the holding in *Sutton* and permit the government's FA/TM examiner to opine that the ammunition at issue in this case is "consistent with" the suspect firearm, the Court should, consistent with the American Statistical Association's recommendations above, require such testimony to be accompanied by statements acknowledging that the examiner has no statistical basis to do so because of the limitations of FA/TM evidence.

CONCLUSION

For the foregoing reasons, *amici* respectfully urge the Court to exclude firearms identification testimony because it lacks scientific validation and is inherently unreliable. At a minimum, the Court should follow the holding in *Tibbs*, limiting any such firearms identification testimony to the opinion that a suspect firearm *cannot be excluded* as the source of ammunition.

Dated: September 29, 2022

Respectfully submitted,

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APPENDIX

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EXHIBIT 1

Firearms and Toolmark Error Rates

Susan Vanderplas, Kori Khan, Heike Hofmann, Alicia Carriquiry

Statement

We declare under penalty of perjury and pursuant to the laws of the state of Illinois that the following is true and accurate to the best of my knowledge.

Alicia Carriquiry

Heike Hofmann

Kori Khan

Susan Vanderplas (Jan 3, 2022 15:38 CST)

Susan Vanderplas

1 Qualifications

1.1 Alicia Carriquiry

I, Alicia Carriquiry, hold a Bachelor of Science in Agricultural Engineering from the Universidad de la República del Uruguay, a Master of Science in Animal Genetics from the University of Illinois at Urbana-Champaign, a Master of Science in Statistics from Iowa State University, and a PhD in Statistics and Animal Science from Iowa State University.

I am a Distinguished Professor of Liberal Arts and Sciences at Iowa State University, which is the highest rank that a professor can achieve. I am also the inaugural President's Chair in Statistics. Between 2000 and 2004, I was Associate Provost at Iowa State University, and was Director of Graduate Studies in the Department of Statistics at Iowa State University between 2004 and 2014.

Since 2015, I have been the Director of the Center for Statistics and Applications in Forensic Evidence (CSAFE), a National Institute of Standards and Technology (NIST) Center of Excellence. The Center is a consortium of universities that includes the University of California Irvine, Carnegie Mellon University, the University of Virginia, Duke University, the West Virginia University, Iowa State University, the University of Nebraska Lincoln, the University of Pennsylvania, and Swarthmore College.

I am the only statistician in the history of Iowa State University to be elected to the National Academies. I became a member of the National Academy of Medicine in 2016 thanks to my applied work in statistics, that includes the design and analysis of studies and surveys. I am a member of the Advisory Board for the Division of Behavioral and Social Sciences and Education (DBASSE), of the Report Review Committee, and of the Committee on Applied and Theoretical Statistics at the National Academies of Science, Engineering and Medicine. I am also a member of the Intelligence Science and Technology Experts Group (ISTEG), a group of members of the National Academies that is available to the US intelligence agencies when questions about science and technology arise.

I was elected Fellow of the American Association for the Advancement of Science (AAAS) in 2016, and an Associate Member of the American Academy of Forensic Science (AAFS) in 2019. Since 2018, I have been a Technical Advisor for the Association of Firearms and Toolmark Examiners (AFTE). I am an elected Fellow of almost all major professional statistical organizations: the American Statistical Association, the Institute of Mathematical Statistics, the International Statistical Institute, and the International Society for Bayesian Analysis.

I have published over 140 peer-reviewed manuscripts in the scientific literature and have co-edited several books. I have directed the doctoral research work of 20 students in statistics and related areas, and have been invited to speak at national and international conferences, and at other venues hundreds of times. I have received competitive research funds from the National Science Foundation, the National Institutes of Health, the National Institute of Standards and Technology, the Office of Naval Research, the United States Department of Agriculture, the Federal Bureau of Investigations, and several other federal, state, and private organizations, totaling well over $50M during my professional career.

1.2 Heike Hofmann

I, Heike Hofmann, am a tenured full professor in Statistics at Iowa State University and the professor in charge of the data science program. I have been a faculty member of the Center for Statistics and Applications in Forensic Evidence (CSAFE) since 2015. CSAFE is supported by a cooperative agreement with the National Institute of Standards and Technology (NIST). In my role as CSAFE faculty I have been a key contributor for the work that received the ASA SPAIG (Statistical Partnerships Among Academe, Industry & Government) award in 2018.

I am an elected member of the International Statistical Institute and an elected fellow of the American Statistical Association (ASA). I have been named a Technical Advisor to the Association of Firearms and Toolmark Examiners. I serve as a member of the ASA committee on forensic statistics.

I have published extensively in peer reviewed, scientific journals. My publications cover several areas including computationally intensive methodology for automatic matching of pattern and image evidence, error rate analyses and development of open-source software for reproducible, accessible comparison of firearm evidence. I maintain the `bulletxtrctr` and `x3ptools` R packages, which have been released to the community to facilitate analysis of bullets and 3D scans respectively.

1.3 Kori Khan

I, Kori Khan, hold a Bachelor of Science in Public Health in Biostatistics from the Gillings School of Global Public Health at the University of North Carolina at Chapel Hill, a Juris Doctorate from the Moritz College of Law School at the Ohio State University, a Masters of Science in Statistics from the Ohio State University, and a Ph.D in Statistics from the Ohio State University.

I am an Assistant Professor in Statistics at Iowa State University. My areas of expertise include the analysis of dependent data, which can include repeated observations of individuals in experiments. I frequently serve as a referee for the top journals of statistics and applied statistics, including the American Statistics Associations' flagship journal.

I have in the past and continue to provide consultations regarding the design and analysis of complex data collection efforts and experimental design for studies focused on human subjects for researchers at organizations including the Moritz College of Law at the Ohio State University, Weill Cornell Medicine, and the Institute for Population Research at the Ohio State University.

I currently serve as sub-committee member on the Organization of Scientific Area Committees (OSAC) for Forensic Science Forensic Nursing and the Statistics Task Group. I have, in the past, served as a member of a Scientific & Technical Review Panel for the same organization.

I have personally reviewed the experimental designs, reporting of the obtained data, and statistical methodologies of the 10 studies referenced in Appendix B.

1.4 Susan Vanderplas

I, Susan Vanderplas, hold a Bachelor of Science in Applied Mathematical Sciences and Psychology from Texas A&M University, a Masters of Science in Statistics from Iowa State University, and a Ph.D. in Statistics from Iowa State University.

I am an Assistant Professor in Statistics at University of Nebraska Lincoln. My areas of expertise include data visualization, perception, and communication of statistical information, as well as machine learning algorithms for statistical analysis of forensic pattern evidence, including firearms and footwear.

Between 2018 and 2020 I served as a research assistant professor at the Center for Statistics and Applications in Forensics (CSAFE) at Iowa State University — CSAFE is a collaboration among several university scholars conducting research on how to collect more accurate forensic evidence and more reliably convey that forensic evidence in court. CSAFE is supported by a cooperative agreement with the National Institute of Standards and Technology (NIST)—a federal agency whose mission is to advance measurement science, standards, and technology.

I am the author or co-author of more than a dozen peer-reviewed scientific papers. Publications most relevant here are published in the Handbook of Forensic Science, Law, Probability and Risk, and Forensic Science International. These papers cover machine learning methods for automatic matching of forensic pattern evidence, error rates in forensic studies, and the treatment of inconclusive results in firearm studies. In addition to my own publications, I have served or been asked to serve as a reviewer for Forensic Science International, the Harvard Data Science Review, Forensic Sciences Research, The American Statistician, Journal of the American Statistical Association, Science & Justice, and the Journal of Computational and Graphical Statistics. I also serve on the editorial board of the R Journal and the Journal of Computational and Graphical Statistics.

I am the primary investigator (PI) of a research and development grant on the acquisition and identification of footwear class characteristics funded by the National Institute of Justice. I am also PI on the CSAFE sub-award at UNL, which covers research in firearms, footwear, and human factors. I am also a co-PI on grants from the National Science Foundation and the United States Department of Agriculture.

2 Introduction - Firearm and Toolmark Error Rates

There are an impressive array of existing studies of the "validity" of firearms and toolmark comparisons [Keisler, M. A., Hartman, S., and Kil, A. (2018); Lightstone (2010); Riva et al. (2017); Bunch and Murphy (2003); Brian Mayland and Tucker (2012); Duez et al. (2018); Pauw-Vugts et al. (2013); Neel and Wells (2007); Hamby et al. (2019); Gouwe, Hamby, and Norris (2008); Giroux (2009); Stroman (2014); Lyons (2009); Mattijssen et al. (2020); Smith, Smith, and Snipes (2016)] across different firearms, ammunition types, types of marks made, and even across different countries with different protocols for training and firearms and toolmark examination. As statisticians, however, we have significant qualms with the state of error rate studies in firearms and toolmark examination. Many studies are poorly designed, with problems ranging from a complete inability to characterize the full error rate (Hamby et al. 2019; Gouwe, Hamby, and Norris 2008; Giroux 2009; Thomas G. Fadul, Jr et al. 2013; Lyons 2009) to the acknowledged inability of examiners to follow the instructions set out by the researchers (Baldwin et al. 2014). Furthermore, all of the studies we are aware of which are applicable to the state of firearms and toolmark examination as practiced in the United States at this time suffer from sampling and non-response bias that renders them unreliable for the purposes of establishing the science of firearms and toolmark examination as a reliable discipline.

Here, we will lay out some of the fundamental problems with the state of firearms and toolmark examination error rate studies. We approach these problems both as statisticians who have experience in the design of scientific experiments and as researchers in statistical applications to forensic evidence. We have worked extensively with forensic examiners, metrologists, and other subject-matter experts, and we have an understanding of both the process of firearms and toolmark examination and the statistical underpinnings of estimation of error rates. Before we begin assessing the current state of error rate studies, however, it is useful to establish the characteristics necessary to have a reliable study.

3 Study Design

A statistical estimate is only as reliable as the data used to generate that estimate. In the case of black-box studies, this data originates from the examiners who participate in the study. In order for statistical estimates to be unbiased, the participants selected from the population to participate in the study (the sample) must be representative. The best way to ensure that a sample is representative is to randomly select this set of participants from the population.

Practically speaking, it is relatively rare that all participants selected for a study complete the study. Scientific ethics requires that research using human participants be undertaken with the participants' consent, and that consent can be withdrawn at any time. As a result, it is common for studies to have some level of drop-out rate. In these situations, the risk to the statistical validity of the study is that participants who drop out of the study vary systematically relative to those who remain in the study. One general guideline is that if less than 5% of the participants drop out, there is little threat to the statistical validity of the study, but if more than 20% of the participants drop out, the study's validity is severely compromised (Schulz and Grimes 2002). It is extremely important that when reporting study results, authors clearly state the level of participant drop out and assess whether there is any evidence of bias in the participants who remain relative to the participants who dropped out.

Another important factor in study design is that studies should be designed in such a way as to directly evaluate the desired conclusions and/or produce the desired numerical estimates. If a study is intended to assess the false positive error rate of firearms and toolmark evaluation, then examiners need to have the opportunity to make a false positive error. While this seems straightforward, many common firearms and toolmark black-box study designs do not allow for estimation of the number of different-source comparisons, which ensures that it is not possible to calculate the overall error rate, the correct decision rate, or the true negative rate (the specificity). This problem is detailed at length in Hofmann, Vanderplas, and Carriquiry

(2021) as well as in President's Council of Advisors on Science and Technology (2016) and National Research Council (U.S.) (2009). A well designed black-box study should have a defined number of pairwise comparisons, where each comparison is completed by the examiner with no possibility of eliminating comparisons based on the structure of the test set. In practice, this means that black-box studies should be open set studies (no guarantee that an unknown item matches any provided knowns in the set) and should involve the comparison of one standard (known sample) and one or more unknown samples at a time.

Executing a well-designed study is not an easy task, but it is important that during the study experimenters not provide participants with additional information. This means that experimenters must take care to provide different examiners with test samples which are not shared between examiners in the same lab, and which may have different numbers of same-source and different-source samples. This prevents information from "leaking" from examiner to examiner within a relatively small community. In addition, experimenters should observe strict protocols when communicating with participants to avoid sharing information about the task beyond what is specified in the instructions.

Finally, it is important that experimenters provide the community with all relevant information when reporting study results. It is difficult (and sometimes, impossible) to reconstruct the full set of aggregated answers when the only data reported in a study is the error rate. Experimenters should provide data at the individual level if it is possible to do so without identifying participants, and if this is not possible, data should be provided at the lowest level of aggregation which maintains participant anonymity.

4 Participant Sampling Problems

One of the primary concerns with error rates provided by "well-designed" studies is that even well designed, well-executed studies cannot compensate for sampling bias in the participant pool. That is, no matter how well the experiment is laid out, if the participants are not a representative sample from the population (in this case, all qualified firearms examiners in the United States), the results of the study do not generalize to that population. This principle is taught in even basic undergraduate statistics courses; it is fundamental to our discipline. One of the easiest ways to ensure that a sample is representative is to randomly select participants from the population; a more labor-intensive option is to conduct a full census of the population at a certain time.

Fundamentally, because almost all current black-box studies use volunteers, we can conclusively state that the participants in these studies are likely to meaningfully differ from those who did not volunteer to participate. Some of these differences are likely not related to the error rates estimated by the studies, but there are many potential lurking covariates that would meaningfully affect the error rates estimated by the studies. For instance, it is possible that experienced examiners are more likely to volunteer to participate in these studies out of a sense of duty to the discipline: these examiners might have lower error rates due to their experience, which would lead to an estimated error rate that is lower than the error rate of the general population of all firearms examiners (including those who are inexperienced). In fact, in studies which differentiate between trainee and qualified examiners, we find a higher error rate among trainees(Duez et al. 2018).

Not all potential biases are this direct: it is possible that examiners who have time to volunteer to participate in studies would tend to have lower case loads. Thus, these examiners would be over-represented in the study-wide estimate of the error rate, in that they account for fewer cases than the examiners who do not have time to participate in a voluntary study. Thus, the estimated error rate from the study would not be representative of the error rate of all examiners. There are many variables which might be expected to increase likelihood of volunteering for a study and also change the expected error rate: education, experience, confidence, amount of time available for study participation.

An additional source of participant recruitment bias is that many studies recruit via the AFTE membership forums (Thomas G. Fadul, Jr et al. 2013; Keisler, M. A., Hartman, S., and Kil, A. 2018; Chumbley et al. 2021), which lead to an over-representation of AFTE members and certified examiners (and in particular, those who spend time on the membership boards). There is not a list of examiners who are allowed to testify in court which could be used for sampling for such a study, but we might expect that people who are active in AFTE are more invested in the discipline, may have more training, and may thus have a lower error rate.

Without a random sample of all qualified examiners, there is no way to generalize the results of a biased sample to the whole population; any study only speaks for the error rate of the participants of that study. Random selection of participants mitigates these potential biases by ensuring that any differences in the sample of selected participants are the product of random assortment - while any single experiment might have a random sample of participants who are not fully representative of the population, each experiment's different samples will produce overall unbiased results. This is why it is not only important that study participants be randomly sampled from the population, but also that there are multiple studies.

Unfortunately, sampling bias is one of the hardest biases to work around. Because we cannot determine how the volunteer examiners might differ from the whole population of examiners, we cannot say that it is likely that the error rate is higher or lower than what is reported from the flawed studies. While in some areas it is necessary to work with volunteer populations (for instance, clinical trials take place on volunteers), this requires that statisticians can reasonably expect that there are no differences between the volunteer and non-volunteer populations, which is a claim that is more easily made in medicine than in forensics.[1]

This bias affects all studies conducted in the United States to date. Currently, there is no way to randomly sample all qualified examiners and compel them to participate. This problem is less pervasive in Europe, where lab certification and validation studies are conducted to assess this type of error rate and certification is conditioned upon participation.

5 Material Sampling Problems

As scientists, we want to derive knowledge that is generalizable to the population. The population includes all decisions made from a combination of one or more firearms of interest, and the ammunition that interacts with those firearms. This combination of characteristics is then evaluated by an examiner. We have previously addressed the fact that we need a random sample of examiners in order to generalize to the whole population of firearms examiners. However, we also need a representative set of ammunition/firearm combinations used in black-box studies in order to validate the discipline as a whole.

Many black-box studies are performed on a single type of firearm and a single type of ammunition. In some cases, these firearms are consecutively manufactured, which allows firearms examiners to prove that they can distinguish individual firearms on the basis of fine details, even when these firearms are manufactured closely in time. However, this does reduce the generalizability of the conclusions from these small studies: by examining only firearms of the same make and model manufactured closely in time, we lose the ability to make broad, sweeping claims about the discipline as a whole. In some cases, studies explicitly document that small manufacturing companies with limited operations (and thus generalizability to the wider population) were selected because it was more convenient to obtain consecutively manufactured components (Lyons 2009).

We need black box studies that examine large numbers of firearms as well as those that examine minute differences. We are not currently aware of any study of a large number of firearms of even one specific model, though we are aware of some data which has been collected but not published examining 600 Berettas confiscated by the LAPD. We cannot generalize error rates from small consecutively manufactured firearm studies to the entire population of firearms examinations, and as a result, we do not know how to assess the error rate of the discipline as a whole on the basis of these studies.

Researchers are well aware of these limitations and typically characterize their findings in a much more limited fashion than some professional expert witnesses. Riva et al. (2017) suggest their study is limited in scope and conclusions: "Finally, even if the results obtained in this study illustrate the impact of subclass characteristics for a given make and model of firearm, they cannot be easily transposed to all firearms at this stage. We remain conscious of the limitation of the sample used here. It is known that the quality and the quantity of these features will vary as a function of the type of firearms and the manufacturing process." This makes it

[1] In medicine, it is reasonable to think that someone's willingness to participate in research is not related to their biological response to cancer treatment, as one is psychological and the other is physiological. Forensic examiners, on the other hand, are trained as scientists - the effectiveness of their training is related to their willingness to participate in the scientific process, and they have a stake in the outcome of the experiment in that if the experiment shows that toolmark examination is not reliable, they are out of a job.

extremely difficult for researchers to provide a general estimate of the error rate of firearms and toolmark comparisons, as the discipline is so broad and the data under examination are affected by so many different factors: type of tool or firearm, ammunition, manufacturing process, material interactions, and so on.

We know that not all firearms and ammunition mark equally well - Glocks are renown for being difficult to compare bullets, but for having easy cartridge comparisons. In addition, some ammunition marks better than other ammunition. While it is possible to characterize the error rates of certain studies (subject to the sampling and non-response biases noted earlier), studies are generally conducted with well-marking tools or firearms. Baldwin et al. (2014) did not examine the samples for issues before sending them to examiners for evaluation; due to the design of the study the researchers estimated that 2-3% of known samples were judged to be inappropriate for comparison due to not marking well. If studies are done on ammunition that is generally known to mark well, then we should expect that this non-marking issue is more likely to show up in casework than in studies - that is, currently existing studies are not representative, and error rates from these studies may not generalize well to firearms and ammunition with different properties.

6 Missing Data and Non-response Bias

In addition to the fundamental problems with volunteer-only participation in black-box studies, there are additional statistical issues which plague most black-box studies: even participants who volunteer for the study may not return the full set of answers (or any answers). That is, most studies have a drop-out rate where participants who initially volunteered for the study did not complete the full study. In statistics, this sort of missing data is more problematic if it is "missing not-at-random" - that is, if the participants who do not return full sets of answers are systematically different from those who do return full sets of answers. Some studies deal with this issue in ways that would not be considered statistically valid: Lyons (2009) contacted someone who returned an incomplete answer sheet to prompt them to complete the questions and provide more satisfactory answers. In other studies, such as Chumbley et al. (2021), the issue is acknowledged but not mitigated or even assessed for its' impact on the error rate estimates reported[2].

An example of a situation in which non response or missing not-at-random bias is common is in telephone surveys. We know that people who are more likely to answer a phone call from an unknown number are different from those who do not answer phone calls from unknown numbers; we also know that those people who continue on the phone call to answer all of the poll questions are more likely to be engaged in their communities and have a higher sense of civic responsibility. These biases can sometimes be corrected for statistically when they are a well-studied quantity (as in political polling), but even the models which allow for pollsters to adjust their estimates to account for these biases are sometimes wrong, leading to systematically biased polls. The same set of problems arise when we ignore non-response bias or missing-not-at-random data in black-box studies, but we do not have sufficient data to adjust the estimates based on the issues, because black-box studies in forensics are not nearly as well studied as political polling. The scientific community also do not have the ability to start studying these issues because the authors of black box studies almost never make the data publicly available. This last point is particularly concerning given that the broader scientific community recognizes that publicly available data is necessary to ensure studies are reaching valid statistical conclusions (Wicherts, Bakker, and Molenaar (2011),Stodden (2015))

What is concerning is that most studies do not even indicate levels of non-response bias. This issue is seldom mentioned when describing the conduct of the study, so there is no way for us to assess the magnitude of the problem given the current conventions for reporting non-response bias. One option to bound the problem is to estimate the error rate with an assumed drop-out rate in order to determine just how bad the issue would be if the participants who dropped out had completely incorrect responses. Note that this requires two assumptions: one, that the drop out rate is a certain percentage - in this case, 20%, and two, that the participants who dropped out would have been completely wrong on every comparison. Keisler, M. A., Hartman, S., and Kil, A. (2018) has one of the lowest error rates and highest number of comparisons of any study reported (2520 comparisons, 0% error counting inconclusives as correct). With a 20% non-response

[2]"Slightly more cartridge case (10,110) than bullet (10,020) comparison are reported because some examiners returned partially-completed test packets that had results for all the cartridge case sets but not all the bullet sets." (Chumbley et al. (2021), page 8)

rate (which is conservative relative to rates reported in the literature), the overall error rate in the population (counting inconclusives as correct) could be as high as 16.56% if all non-responses made completely incorrect decisions. While this is unlikely, it does provide an upper bound of the order of magnitude of the possible bias that participant drop-out might have on estimated error rates.

This missing data may occur at the participant level (drop out bias) or at the question level (item non-response bias), but the likely reasons for non response in either form include insufficient time to commit to completing the study or finding the study more difficult than expected and not wanting to return the wrong answers. In either case, this is a potential source of bias for the estimated error rates - if the individual is not sure of the answers or does not have enough time to dedicate to the study, it is likely that estimated error rates with complete data would be higher than estimated error rates with incomplete data. That is, given what we know about why people drop out of black-box studies, we would expect that studies with non response bias under-estimate the error rate.

7 Types of Marks and Study Difficulty

It is common to talk of error rates for firearms and toolmark examination as a whole. While it is certainly true that there are some similarities across different comparison types (toolmarks and land-engraved areas both involve comparisons of striae), there are many different types of marks used for firearms and toolmark examination, and it would not be reasonable to assume they all have the same error rates. For example, striations on land engraved areas usually involve comparison of a number of different lands, most of which must match for the overall comparison to be deemed an identification - there is some redundancy in this comparison, whereas the comparison of a single scrape from a screwdriver involves only one set of striae. Even though the two comparisons are objectively similar in that the examiner is visually comparing striae, we would not expect them to have similar error rates because there is an internal check on incidental matches when bullets are compared that does not exist with screwdriver engraving comparisons.

Expert witnesses[3] have previously testified about high error rates in a closed-set study [Brian Mayland and Tucker (2012)] and low error rates in an open-set study (Keisler, M. A., Hartman, S., and Kil, A. 2018). What is particularly remarkable about this portion of the testimony is that Brian Mayland and Tucker (2012) examined obturation marks, while Keisler, M. A., Hartman, S., and Kil, A. (2018) examined breech face impressions. These two types of marks are entirely different in character, and thus the error rates should never be directly compared. Of the studies we have cited on firearms and toolmark examination, some examine bullet striae (Hamby et al. 2019; Pauw-Vugts et al. 2013), extractors (Lyons 2009), cartridge cases (Baldwin et al. 2014; Chapnick et al. 2021; Pauw-Vugts et al. 2013; Bunch and Murphy 2003; Duez et al. 2018; Keisler, M. A., Hartman, S., and Kil, A. 2018), aperture marks (Mattijssen et al. 2020), obturation marks (Brian Mayland and Tucker 2012), and tool marks (Giroux 2009). It is not reasonable to assume that the error rates in these different disciplines (with different amounts of information available to the examiners) would be similar; after all, studies which provide examiners with the full cartridge case instead of a sub-region of the case (such as the aperture shear or obturation marks) give examiners more information on which to make a decision, which should lower the error rate significantly.

Before we make direct comparisons between error rates in studies, we should also consider other factors beyond the type of comparison made which might make a difference in the reported error rate. Some open set studies include comparisons from marks with similar class characteristics as knowns in the set (Mattijssen et al. 2020; Pauw-Vugts et al. 2013), while others include comparisons with items that do not share class characteristics (this allows for examiners to eliminate based only on class characteristics, as some labs do not allow for elimination based only on individual characteristics) (Bunch and Murphy 2003). Thus, the level of difficulty of comparisons varies considerably between studies. In addition, the proportion of same source comparisons and different source comparisons varies considerably between studies: Baldwin et al. (2014) has about 1/3 same-source comparisons and 2/3 different-source comparisons, while Duez et al. (2018) has 3/4 same-source comparisons and 1/4 different-source comparisons. Obviously, the proportion of same-source and different-source comparisons may influence the precision with which any study can estimate certain error

[3] Todd Weller, California v Auimatagi, February 2021

rates.

The difficulty level across different studies is not necessarily comparable: in studies of European examiners, the goal is typically to differentiate different labs and procedures in skill and effectiveness, so the evaluations may be more difficult in order to separate good examiners and labs from those who are uniquely skilled; in these studies (Pauw-Vugts et al. 2013; Mattijssen et al. 2020), comparisons are typically harder and error rates much higher than in studies conducted in the US, where the study goal is typically to validate the process of firearms and toolmark evaluation.

8 Inconclusives

In fact, the firearms examination community is very aware of the fact that sometimes samples are difficult to match to each other. This issue is so pervasive that the AFTE theory of identification allows for a middle category between identification and elimination: inconclusive. Actually, more accurately, the AFTE theory of identification allows for 3 different levels of inconclusive on the continuum between identification and elimination. Under the AFTE theory of identification, all of the hard decisions are automatically correct because firearms and toolmark examiners don't have to make a decision between elimination and identification. The treatment of inconclusives under the AFTE theory of identification is controversial and has recently seen significant scrutiny from the scientific community (Dror and Scurich 2020; Dror and Langenburg 2019; Biedermann et al. 2019)[4].

Scientifically, an inconclusive result has to be automatically incorrect: a comparison is either from a same-source or a different-source. AFTE rules allow inconclusives to be counted as both identifications and eliminations, and therefore artificially decrease error rates. If we focus on a correct source decisions only, the percentage of correct decisions can be as low as 49%, leaving at least 51% of the decisions as errors (correct source identification rate taken from bullet comparisons in Pauw-Vugts et al. (2013)). This is statistically worse than random chance - that is, examiners would perform about as well if they were flipping a coin to make the decision!

Furthermore, when we examine which comparisons are more likely to result in an inconclusive decision, we find that the overwhelming majority of inconclusive decisions in black-box studies were made on different-source comparisons. This suggests that examiners are more willing to make an identification, and less willing to make an elimination when there is some doubt about the strength of the match. Black box studies conducted outside of the US legal system and forensic training system suggest that this bias is not as strong: Mattijssen et al. (2020), which was conducted on primarily European and UK examiners, did not reveal nearly as strong of a bias towards inconclusive decisions for different-source comparisons (though the scales used differ by jurisdiction). This bias is only obvious when we look at the positive and negative predictive values, as discussed in Hofmann, Vanderplas, and Carriquiry (2021).

The bias towards identification at the expense of elimination is in some cases encoded within the lab evaluation rules. In some laboratories, including at the FBI, examiners are not allowed to make an elimination based on individual characteristics. This is one reason why studies involving the FBI firearms lab often do not report sensitivity, specificity, or the correct source decision rate directly: when inconclusives are considered, the correct source decision rate looks abysmal: 52.22% in Bunch and Murphy (2003) and 37.5% in Giroux (2009).

9 Summary

We have outlined several problems with the state of error rate studies on firearm and toolmark examination. Fundamentally, we do not know what the error rate is for these types of comparisons. This is a failure of the scientific study of toolmarks, rather than the examiners themselves, but until this is corrected with multiple studies that meet the criteria described in Section 3, we cannot support the use of this evidence in criminal proceedings.

[4] CTS used to treat inconclusives as errors, but in 1998 changed to treating inconclusives as correct decisions. The error rates dropped from 12% (firearms) and 26% (toolmarks) to approximately 1.4% and 4% respectively. UNITED STATES OF AMERICA, v. Joseph MINERD, Defendant., 2002 WL 32995663 (W.D.Pa.)

If inconclusives are errors, even if these errors are not necessarily attributable to the examiners' skill level, then examiners make the correct decision in black-box tests of screwdriver and bullet evaluations at rates that are worse than if they used coin flips to determine their answers (37.5% and 49.68%, respectively). Correct source decision rates for many studies mentioned in this assessment are provided in Appendix A. Even if inconclusives are considered correct decisions, as recommended by the Association of Firearms and Toolmark Examiners, however, there are still other problems with this evidence.

The error rates on different types of toolmarks are substantially different, and there are not multiple studies that even allow the estimation of the necessary error and accuracy rates (false positive rate, false negative rate, and correct source decision rate) for most types of evidence. Multiple studies are necessary because any set of participants and required comparisons may be non-representative in some way. Science thrives on replication of studies in slightly different conditions over a period of time; firearms and toolmark examination is no exception. In only one discipline (cartridge case evaluation) are there more than two studies which are designed in such a way that the full set of error rates are estimable. In these studies, overall error rates (counting inconclusives as correct decisions) are between 0% and 8.21%. While these error rates are relatively low, the studies these error rates are based on still have fundamental flaws that suggest that the true error rates in casework may be significantly higher.

One of the major issues with the studies that do exist is that they are plagued by non-response bias. In many disciplines, non-response biases of greater than 20% are sufficient to invalidate study results, and rates greater than 5% are sufficient cause for concern. Most studies in this discipline do not report non-response rates. Few studies report sufficient details to begin to estimate the non-response rates, as seen for the studies reviewed in Appendix B. For these studies, where sufficient details were reported, drop-out rates are up to 35% and item non-response are up to 17%. That most studies do not report drop-out rates is statistical malpractice; failure to report or address this information when reported is particularly egregious in studies that have practicing statisticians as authors. While it is theoretically possible that examiners who drop out of studies or leave missing items are similar to examiners who complete the studies (leading to an unchanged error rate), it is significantly more likely that if these examiners had completed the study, the error rate would have been higher. In the worst case scenario, the actual error rate could be as high as the sum of the dropout rate and the reported error rate. We stress again that there is no possibility of assessing the true impact of non-response bias in these studies when the authors do not make their data available to other researchers: as was the case in every study reviewed in Appendix A.

Even when non-response bias is ignored, there are further issues with the state of error rate studies in firearm and toolmark examination: studies do not cover a wide enough range of firearms and ammunition to generalize to the discipline as a whole. We know that not all firearm and ammunition combinations mark equally well, but studies are conducted using firearms and ammunition that are known to mark. As a result, there is a potential difference between the firearms and ammunition used in studies and those evaluated as part of casework that impacts our ability to generalize error rates from studies to a specific combination of ammunition and firearm in a particular case. Similarly, the firearms examiners who participate in studies are likely to be fundamentally different from the full population of firearms examiners. This, too, means that we cannot generalize error rates from studies conducted on volunteers the entire set of qualified firearms examiners. What we can say with confidence is that the sampling issues with firearms examination studies are problematic and cast doubt on the ability to generalize error rates from these studies to the wider population of all examiners.

As a result of these compounding issues, it is our opinion as statisticians and researchers in forensic science that error rates established from studies with sampling flaws, methodological flaws, non-response and attrition bias, and inconclusive results are not sufficiently sound to be used in criminal proceedings.

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A Table of Reported Correct Source Decision Rates

Some Abbreviations:

- SS: Same Source comparisons
- DS: Different Source comparisons
- LEA: Land Engraved Area

Table 1: Correct source decision rates for many commonly-cited studies, along with number of evaluations and type of mark evaluated in the study.

Type of Mark	Study	# Evaluations	Correct Source Decision Rate
Obturation	Brian Mayland and Tucker (2012)	192 SS, ? DS	Not calculable
Extractor	Lyons (2009)	178 SS, ? DS	Not calculable
Aperture Shear	Mattijssen et al. (2020)	2947 SS, 1673 DS	0.6816
Screwdriver	Giroux (2009)	29 SS, 51 DS	0.3750
Bullet LEA	Hamby et al. (2019)	10455 SS, ? DS	Not calculable
Bullet LEA	Pauw-Vugts et al. (2013)	188 SS, 124 DS	0.4968
Bullet LEA	Smith, Smith, and Snipes (2016)	219 SS, 621 DS	0.8024
Cartridge Cases	Stroman (2014)	75 SS, ? DS	Not calculable
Cartridge Cases	Bunch and Murphy (2003)	70 SS, 290 DS	0.5222
Cartridge Cases	Pauw-Vugts et al. (2013)	127 SS, 189 DS	0.6867
Cartridge Cases	Chapnick et al. (2021)	491 SS, 693 DS	0.7508
Cartridge Cases	Baldwin et al. (2014)	1090 SS, 2180 DS	0.7633
Cartridge Cases	Keisler, M. A., Hartman, S., and Kil, A. (2018)	1512 SS, 1008 DS	0.9179
Cartridge Cases	Smith, Smith, and Snipes (2016)	199 SS, 437 DS	0.9324
Cartridge Cases	Duez et al. (2018)	336 SS, 112 DS	0.9375

Studies that have an unknown number of different source comparisons cannot be analyzed to produce a correct source decision rate because the total number of comparisons performed (and the number of correct eliminations) cannot be computed. These studies are usually closed-set designs, which have been cited as problematic in President's Council of Advisors on Science and Technology (2016). Totals from Smith, Smith, and Snipes (2016) are recreated using reported marginal totals and internal counts; the study results are internally inconsistent, so the approach with the least obfuscation and adjustment was taken for simplicity. The discrepancy in Smith, Smith, and Snipes (2016) also stems from the study design's inability to determine how many comparisons were conducted, but it is at least designed in a way that allows for the calculation of the minimal number of necessary comparisons.

B Table of Participant Sampling, Data Availability, Drop-out Rates, and Item Non-Response Rates

Drop-out Rate: Proportion of examiners who agreed to participate in the study and were not included in the final analysis. "Unreported"" indicates the authors did not provide sufficient information to calculate this number.
Item Non-Response Rate: This is a conservative measure. We are calculating the proportion of items missing only for participants who are included in the final analysis. Note this is a lower bound for the item non-response as it does not account for the items not responded to by participants who dropped out. "Unreported" indicates the authors did not provide sufficient information to calculate this number.

Table 2: Participant sampling types, data availability, drop-out rates, and item non-response rates. Only studies for which one of drop-out rates and item non-response rates are specified are included. This table focuses on data used to calculate accuracy of examiners conclusions.

Study	Volunteer Participants	Data Publicly Available	Drop-out Rate	Item Non-Response Rate
Lyons (2009)	Yes	No	Unreported	0%
B Mayland and Tucker (2012)	Yes	Partially[5]	Unreported	0%
Thomas G. Fadul, Jr et al. (2013)	Yes	No	23%[6]	0%
Stroman (2014)	Yes	No	17%	Unreported
Baldwin et al. (2014)	Yes	No	23%	0.06%
Smith, Smith, and Snipes (2016)	Yes	No	34%	Unreported
Keisler, M. A., Hartman, S., and Kil, A. (2018)	Yes	No	Unreported	0%
Chapnick et al. (2021)	Yes	No	$\geq$ 29%[7]	3%
Chumbley et al. (2021)	Yes	No	Unreported	17%
Smith (2021)	Yes	No	35%	Unreported

[5]The authors did report the participant answers by test.

[6]This reflects the proportion of individuals who completed the test sets but were excluded from analysis because they had not had two years of training.

[7]The authors did not report the number of participants who agreed to participate. 107 participants completed some the test sets. The authors excluded all but 76 of them from analysis for the results reported in the abstract due to the participant being "unqualified" or working outside of the United States or Canada. Note, other studies have explicitly included examiners outside of the United States and Canada (e.g., Hamby et al. (2019) and Keisler, M. A., Hartman, S., and Kil, A. (2018)). The authors indicated the excluded participants had committed more errors than those included.

C Alicia Carriquiry CV

October 2021

ALICIA L. CARRIQUIRY
RESUME

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EDUCATION

- Ph.D. in Statistics and Animal Science, Iowa State University, May 1989.
- M.Sc. in Statistics, Iowa State University, December 1986.
- M.Sc. in Animal Science, University of Illinois at Urbana, May 1985.
- Ing. Agr., Universidad de la República, Uruguay, December 1981.

EXPERIENCE

President's Chair in Statistics, Iowa State University, October 2016 – date.

Director, Center for Statistics and Applications in Forensic Evidence, June 2015 – date.

Associate Provost, Iowa State University, January 2000 – June 2004.

Director of Graduate Education, Department of Statistics, Iowa State University, August 2004 to October 2014.

Associate Chair, Department of Statistics, Iowa State University, August 2008 to October 2014.

Distinguished Professor, Department of Statistics, Iowa State University, July 2010 -- date.

Professor, Department of Statistics, Iowa State University, July 2001 – July 2010.

Associate Professor, Department of Statistics, Iowa State University, July 1995 – July 2001.

Assistant Professor, Department of Statistics, Iowa State University, August 1990 – July 1995.

Adjunct Professor, MS Program in Bioinformatics and Biological Statistics, Universidad de la República del Uruguay, Montevideo, Uruguay, March 2009 – date.

Adjunct Professor, Doctoral Program in Statistics, Pontificia Universidad Católica de Chile, Santiago, Chile, July 2007 – December 2014.

Visiting Professor, Institute of Statistics and Decision Sciences, Duke University, Spring 1997.

Visiting Professor, Department of Statistics, Pontificia Universidad Católica de Chile, Santiago, Chile, Fall 1993, Fall 1996 and 2007 – 2008.

Post-doctoral Research Associate, Department of Economics and Center for Agricultural and Rural Development (CARD), Iowa State University, January – August 1990.

AWARDS AND HONORS

Florence N. David Award, Committee of Presidents of Statistical Societies, 2021.

Zellner Medal, International Society for Bayesian Analysis, 2021.

Foundational Lecturer, International Society for Bayesian Analysis, 2020.

Elected Associate Member of the American Academy of Forensic Sciences, 2020.

Invited to join the Intelligence Science and Technology Experts Group (ISTEG) of the National Academies of Science, Engineering and Medicine, 2019.

Founders Award, American Statistical Association, 2018.

Named Technical Advisor to Association of Firearm and Toolmark Examiners (AFTE) 2018 – 2023.

Elected Fellow of AAAS, 2016.

Elected to the National Academy of Medicine, 2016.

Appointed President's Chair in Statistics, 2016

Elected Fellow of ISBA, 2014.

Promoted to Distinguished Professor at Iowa State University, 2011.

Presidential Invited Lecture at the annual meeting of the Western North American Region of the International Biometrics Institute, Seattle, Washington, 2010.

Plenary lecture at the annual meeting of the Texas Defense Lawyers Association, Houston, TX October 2009.

Elected Fellow of the Institute of Mathematical Statistics, 2006.

Drafting Expert in the FAO-WHO Workshop on Nutritional Risk, held in Geneva, Switzerland, on May 2 – 6 2005.

Keynote address at the Statistics Applied to Agriculture conference, Kansas, April 2005.

20/20 Visionary Award, Iowa State University, October 2000.

Distinguished International Service Award, Iowa State University, April 2000.

Elected Fellow of the American Statistical Association 1999.

Elected member of the Iowa State University Nutritional Sciences Council. December 1998.

Elected Member of the International Statistical Institute 1995.

Invited to the Forum, “Meeting the Challenge. Health, Safety, and Food for America,” organized by the Executive Office of the Office of Science and Technology Policy, and by the National Academy of Sciences. Washington, D.C., November 21 – 22 1994.

Member of Sigma Xi, Mu Sigma Rho, and Gamma Sigma Delta.

SERVICE (since 1993)

Editorial Activities:

Guest Editor, *Statistical Science* special issue on reproducibility in statistical research. 2021 – 2022.

Editorial Board, *Annual Review of Statistics and Its Application,* 2017 – date.

Editor, *Electronic Encyclopedia of Statistics*, 2009 – 2013. In representation of the International Statistical Institute.

Associate Editor, *The Annals of Applied Statistics,* January 2007 – May 2012.

Editor, *Bayesian Analysis*, July 2003 – June 2006.

Editor, *Statistical Science*, January 1998 – December 2007.

Editorial Board, *Case Studies in Bayesian Statistics IV, V, VI, VII, VIII*. September 1997 – August 2008.

National Panels and Committees and Advisory Boards:

Institute for Mathematics and Statistics Innovation (IMSI), Scientific Advisory Committee, 2021 – 2024.

National Academies of Science, Engineering and Medicine, Intelligence Science and Technology Experts Group (ISTEG). Member, 2019 – date.

Center for Integrity in Forensic Sciences, University of Wisconsin Madison, Board of Advisors, 2018 – date.

National Academy of Medicine, Committee to Review Dietary Reference Intakes for Sodium and Potassium, 2018 – 2019

National Academy of Sciences, Report Review Committee, 2017 – 2019, 2020 – 2022.

National Academy of Sciences, Standing Committee on Applied and Theoretical Statistics, 2003 – 2006, 2017 – 2019, 2020 – 2022.

National Academy of Sciences, Division of Behavioral and Social Sciences Education, 2016 – 2019, 2020 – 2023.

National Institutes of Health, Advisory Committee on Review of DRIs for Chronic Disease Outcomes, 2014 – 2015.

National Academy of Medicine and National Research Council, Committee to Review the WIC benefits package, 2014 – 2016.

National Academy of Medicine and National Research Council, Committee on Evaluating the Veteran’s Affairs Mental Health Services, 2013 – 2017, Chair of the committee.

National Academy of Sciences, Committee on Assessing the Value of Research on Advancing National Goals, 2012 – 2013.

US Department of Transportation, Advisory Council on Transportation Statistics, 2012 – 2014.

National Academy of Sciences, Committee on Advancing Institutional Transformation for Minority Women in Academia: a Workshop, 2011 – 2012.

National Academy of Sciences, Committee to Assess the Feasibility of Estimating the Number of Illegal Border Crossings between Mexico and the United States, 2011 – 2012, Chair of the committee.

US Environmental Protection Agency, Scientific Advisory Board, 2012 – 2014.

Institute of Medicine, Committee to Review the Child and Adult Care Food Program, 2009 – 2010.

National Academy of Sciences, Vitamin D and Calcium Review Committee (consultant), 2009 – 2010.

National Academy of Sciences, Standing Committee on National Statistics (CNSTAT), 2008 – 2014.

National Academy of Sciences, Standing Committee on Social Science Evidence to Use in Policy Decision-Making. 2007 – 2012.

US Environmental Protection Agency, Human Studies Review Board, 2006 – 2008.

National Academy of Sciences, Committee on Assessing the Technical Feasibility of a National Ballistics Database, 2004 – 2007.

National Academy of Sciences, Committee on Gender Differences in the Careers of Science, Engineering and Mathematics Faculty, 2004 – 2007.

National Academy of Sciences, Board on Technology and the Law: Advisability and Ethics of the Use of Third Party Intentional Dosing Studies with Human Subjects by the Environmental Protection Agency, 2002 – 2003.

National Research Council, Committee on National Statistics: Estimating Eligibility and Participation Rates in the Women and Infant Children (WIC) Program, 2000 – 2003.

Food and Nutrition Board, Institute of Medicine, National Academy of Sciences: Committee on Uses and Interpretations of Dietary Reference Intakes, 1997 – 2003.

Report Monitor of four National Academy of Sciences reports and reviewer of over 12 reports.

Conferences: Organizing or Program Committees: Multiple, both in the United States and abroad.

Academic review, advisory and visiting committees:

Review Board, Committee on National Statistics, Chair, March 2019.

External Review Committee, Army Research Office, Research Triangle, NC. August 2018.

Data Safety Monitoring Committee, NewLink Genetics, 2010 – 2018 (Chair from 2014 – 2018).

External Review Committee, Department of Statistics, Universidad de la República, Montevideo, Uruguay, February 2018.

External Review Committee, Department of Statistics, Virginia Tech University, April 2017.

External Review Committee, Department of Statistics, Colorado State University, November 2015.

External Review Committee, Department of Statistics, University of Nevada at Reno, February 2015.

External Auditing Review Committee, Institute of Mathematical Statistics (IMS), April 2014.

External Review Committee, Graduate Program in Statistics, University of Toronto, Canada, October 2009.

External Review Committee, Department of Statistics, Universidad de la República del Uruguay, Montevideo, Uruguay, 2008.

External Advisory Board, Centro de Investigaciones Matemáticas (CIMAT) (Center for Mathematics Research), Guanajuato, Mexico, 2007 – 2009.

Advisory Board member for Department of Statistics, Carnegie Mellon University, 2006.

External review committee for Department of Statistics, Harvard University, 2003 – 2006.

External Review Team (Chair) for Department of Statistics, Universidad Nacional de Colombia, Bogotá, Colombia, August 1998.

Professional Associations:

<u>American Statistical Association:</u>

Chair, Wilks Award Committee, 2018 – 2021.

Chair, Section on Bayesian Statistical Sciences, 2013 (Elected).

Vice President, 2007 – 2009 (Elected).

Chair, Budget Committee, 2009.

Chair, Task Force on Graduate Education in Statistics in Vietnam, 2005 – 2006.

Task Force on Science Policy, 2006 – 2007.

Fellows Committee, Section on Statistics and the Environment, 2005 – 2007.

Strategic Planning Committee on Meetings, member, 2000.

Program Chair, Joint Statistical Meetings, 1999.

Committee on Meetings, 1998 – 2000.

Biometrics Section, member of the Executive Committee (Proceedings Editor) 1995 – 1997.

Section on Bayesian Statistical Sciences, member of Nominations Committee, 1996.

Iowa Chapter, President-Elect, 1995 –1996, President, 1996 – 1997 (Elected).

Program Chair, Biometrics Section, Joint Statistical Meetings, 1997.

International Society for Bayesian Analysis (ISBA)

Committee on Fellows, 2019 – 2022 (Chair, 2021).

Board of Directors, 2018 – 2020.

Chair, Bylaws Committee, 2018 – 2020.

Chair, Nominations Committee, 2002 (Elected).

President, 2001 (Elected).

Co-Chair, Ad-hoc Journals Committee, 2000 – 2003.

President-Elect, 2000 (Elected).

Member, Board of Directors, 1998 (Elected).

Program Chair, 1996 – 1997.

Program Committee, Fifth World Meeting, Oaxaca, Mexico, 1995.

Program Committee and co-Chair of Finance Committee, Seventh World Meeting, Crete, Greece, 2000.

National Institute of Statistical Sciences (NISS)

Executive Committee member, 2000 – 2002.

Chair, Jerome Sacks Award Committee, 2002.

Member of the Board of Trustees, 1998 – 2003 and 2004 – 2008 (Elected).

Member of the Corporation, 2001 – 2003 (Elected).

Institute of Mathematical Statistics (IMS)

Member, Committee on Fellows, 2018 – 2020 (Chair 2020).

Member, External Audit Committee, 2014.

Chair, Committee to Select Officers, 2011.

Chair, Committee to Establish an IMS Meetings Cycle in Latin America, 2007 – 2008.

Member of the Executive Committee 1999 – 2005.

Member, Nominations Committee, 1999.

Committee on Meetings, and Joint Meetings Advisory Committee, 2001 – 2005.

Committee of Presidents of Statistical Societies (COPSS)

Chair, Diversity, Equality, and Inclusion Task Force, 2020 – 2021.

Chair, Fisher Lectures, 2017 – 2018.

Member, Elizabeth Scott Award Committee in representation of the Institute of Mathematical Statistics (IMS). 1998 – 2000 (Chair in 2000).

International Biometric Society Eastern North American Region (ENAR)

Member of the Regional Advisory Board (RAB), 1996 – 1999 (Elected).

International Statistical Institute (ISI)

Chair, Short Course Committee, World Statistical Congress, 2015.

Member, Council of the Bernoulli Society, 2013 – 2017.

Editor, Electronic Encyclopedia of Statistical Sciences, 2009 – 2012.

Member, ISI Council, 2007 – 2009 (Elected).

Nominations Committee, 2009 – 2010.

Publications Committee, 2008 – 20011.

Proposal and Manuscript Panels and Review

National Institutes of Health, Biostatistical Methods and Research Design Study (BMRD) Section, 2013 – 2015.

National Science Foundation Education and Human Resources Core Research Review Panel, 2013.

National Institutes of Health, Kidney, Nutrition, Obesity and Diabetes Study Section, 2011 – 2012.

National Science Foundation Review Panel. February 2011.

National Science Foundation Review Panel. December 2010.

National Science Foundation Review Panel. December 2009.

National Institutes of Health, Kidney, Nutrition, Obesity and Diabetes Study Section, 2005 – 2008.

National Science Foundation Review Panel for Statistics proposals, December 2004.

National Science Foundation Review Panel for Industry/University research cooperation, February 2000.

National Science Foundation Review Panel on Digital Government, February 1999.

Environmental Protection Agency and National Science Foundation Review Panel for Partnership for Environmental Research, May 1999.

National Science Foundation Review Panel for Statistics research proposals, December 1999.

Refereed research proposals for United States Department of Agriculture, the National Council on Science and Technology of Chile, the National Science Foundation, South African Foundation for Research Development, Environmental Protection Agency, National Institutes of Health, Department of Agriculture and the Iowa Pork Producers Association.

Refereed papers for Journal of the American Statistical Association, Biometrics, The American Statistician, Theoretical and Applied Genetics, Génétique Sélection Evolution, Revista Chilena de Estadística, Revista Colombiana de Estadística, Revista Brasileira de Estadística, American Journal of Public Health, Communications in Statistics (Theory and Methods), Journal of Computational and Graphical Statistics, Statistics and Probability Letters, Biometrika, International Journal of Agricultural Economics, Journal of Nutrition, Metrika, Statistical Science, Journal of the American Dietetics Association, Public Health Nutrition, American Journal of Agricultural Economics, Journal of Agricultural, Biological and Environmental Statistics, Journal of the Royal Statistical Society, Springer-Verlag Publications, Elsevier Publications, Wiley Publications, National Academy of Sciences, Journal of Statistics Education.

Iowa State University:

Search committee for Vice President for Research, 2020.

Ad-Hoc committee to review appointments of NTER faculty, 2014.

Search committee for Dean of the College of Liberal Arts and Sciences, 2011.

Member of the Iowa Computational Biology Laboratory, 1998 – date.

Plant Sciences Initiative, Strategic Planning Committee for Laurence H. Baker Center for Bioinformatics and Biological Statistics, 1999 – 2000.

Bioinformatics and Computational Biology interdisciplinary major, Curriculum Development Committee member, 1999 – 2000.

Plant Sciences Institute, member of PSI Council, 2000 – 2004.

Plant Sciences Institute, search committee for Institute director, member, 2000.

Committee on Strategic Planning for Information Technology at Iowa State University, member, 2000.

Advisory Committee, International Institute for Theoretical and Applied Physics, member. 2000 – 2001.

Search committee for Dean of the College of Veterinary Medicine, representative of Provost, 2000.

Search committee for Dean of the College of Agriculture, representative of Provost, 2001.

Search committee for Dean of the College of Business, representative of Provost, 2002.

Search committee for Chief Information Officer, representative of Provost, 2003.

Search committee for Dean of the College of Family and Consumer Sciences, representative of Provost, 2003.

Search committee for Dean of the College of Veterinary Medicine, representative of Provost, 2003.

Search committee for Dean of the College of Engineering, representative of Provost, 2004.

College of Agriculture, Iowa State University:

Member, International Agriculture Programs Faculty Advisory Committee, Iowa State University, 1993 – 2000.

College of Liberal Arts and Sciences, Iowa State University:

Committee to Review Nominations for Distinguished Professors (Chair), 2011 – 2014.

Awards Committee, 2009 – 2014.

Promotion and Tenure Committee, College of Liberal Arts and Sciences, 2004 – 2006.

Liberal Arts and Sciences Minority Advisory Board, 1996.

Member of the Liberal Arts and Sciences Committee on Academic Standards, August 1995 – December 1999.

Department of Statistics, Iowa State University:

Distinguished Lectures Committee Chair, 2016 – 2018

Admissions Committee 2009 – 2014 (Chair, 2009 – 2014).

Search Committee, 1992 – 1997, 2000, 2002 – 2005, 2014, 2016, 2018 – 2019.

Advisory Committee on Promotion and Tenure, 2009 – 2011, 2018 – date.

Snedecor Hall Renovation and Expansion committee, 2006 – 2007.

Co-Director of Graduate Education, 2004 – 2014.

Strategic Planning committee, Chair, 2004 – 2005.

Advisory Committee to the Department Chair, 2003 – 2006.

Capital Campaign Committee, 1995 – 1998.

Non-thesis Master Exam Committee, Department of Statistics, 1993 – 1995, 1997 – 1998 (Chair 1995 – 1996).

Seminar Committee, 1991 – 1992, 1998 – 1999.

GRANTS AND CONTRACTS (Funded)

Uemura, E., **Carriquiry, A. L.**, and Kliemann, W. Mathematical Approach to Modeling Dendritic Growth. National Institutes of Health (NIH), May, 1991. $300,000 over three years.

Carriquiry, A. L. and Kliemann, W. Mixed Linear Models and Quantitative Genetics. Iowa Agriculture Experiment Station Innovative Research Grant. 1991. $3,810 over one year.

Carriquiry, A. L. and Jensen, H. H. Assessing the Health Risk Associated with Groundwater Contamination. Iowa State University Research Grant, Spring 1991 Competition. $7,500 over one year.

Bouzaher, A. and **Carriquiry, A. L.** Multiproduct Yield Prediction when Products are not Independent. May 1991. Iowa Corn Promotion Board. $17,000 over one year.

Bouzaher, A., **Carriquiry, A. L.**, and Jensen, H. H. Efficiency Analysis of Ukrainian Agriculture. National Council for Soviet and East European Research. May 1992. $48,000 over 15 months.

Carriquiry, A. L. and Jensen, H. H. Collection of Data on Inputs in the Ukraine for Estimating Agricultural Productivity and Impacts of the Economic Reform. Office of International Cooperation and Development, USDA. January 1993. $6,761 over one year.

Jensen, H. H. and **Carriquiry, A. L.** NIS/Baltic Research Exchange, Agriculture Experiment Station, Iowa State University. March 1994. $2,700 over one year.

Johnson, S. R. and **Carriquiry, A. L**. Research Budget Expenses. Egyptian Cultural and Educational Bureau. March 1994. $13,000 over two years.

Johnson, S. R., Fuller, W. A., **Carriquiry, A. L.**, Jensen, H.H., and Nusser, S. M. Cooperative Agreement with Human Nutrition Information Service (HNIS) USDA. October 1994. $203,625 over one year.

Carriquiry, A. L. International Travel Grant. American Statistical Association. June 1995. $1,600.

Carriquiry, A. L. International Travel Grant. College of Agriculture, Iowa State University. July 1995. $1,600.

Carriquiry, A. L. and Martinez, S. International Cooperation Programs, National Science Foundation. October 1995. $35,280.

Kliemann, W., Breidt, F. J., Budhiraja, A., **Carriquiry, A.L.**, Mirkovic, D., and O'Donnell, B. Nonlinear Filtering Approaches to Multitarget Tracking. Office of Naval Research (ONR). November 1995. $604,342 over 3 years.

Del Pino, G., Marshall, G., and **Carriquiry, A. L.** Topics in nonlinear mixed models. Fondo de Ciencia y Tecnologia (FONDECYT), Chile. $15,000 over 2 years.

Carriquiry, A. L. and Nusser, S. M. Estimating usual intakes and biochemical measurement distributions for NHANES III. National Center for Health Statistics, Department of Health and Human Services. October 1996. $25,000 for one year.

Carriquiry, A. L. International Travel Grant. American Statistical Association. June 1997. $1,800.

Carriquiry, A. L. Data collection and processing in Extension. Extension Service, Iowa State University. June 1997. $5,500.

Carriquiry, A. L. International Travel Grant. College of Liberal Arts and Sciences, Iowa State University. July 1997. $1,050.

Carriquiry, A. L. and Nusser, S. M. Statistical issues associated to NHANES III. National Center for Health Statistics, Centers for Disease Control and Prevention. October 1997. $48,000 for one year.

Nusser, S.M. and **Carriquiry, A. L.** Development of sampling methods to support the USDA. Nutritional Data Laboratory, U.S. Department of Agriculture. April 1998. $31,650 for one year.

Carriquiry, A. L. Cooperation with Argentina. National Science Foundation. May 1998. $32,100 for one year.

Carriquiry, A. L. Analysis of nonresponse patterns in the Supplementary Nutrition Survey of Elderly Americans. National Center for Health Statistics, Centers for Disease Control and Prevention. October 1998. $84,000 for one year.

Carriquiry, A. L., Daniels, M., and Stern, H. Statistical treatment of class evidence. Federal Bureau of Investigation (FBI). October 1998. $150,000 for one year.

Carriquiry, A. L. Analysis of antioxidant intake data. Food and Nutrition Board, IOM. 1999. $9,045 over three months.

Carriquiry, A.L. and Rotniztky, A. Eighth Latin American Congress on Probability and Mathematical Statistics, La Habana, Cuba. National Science Foundation, January 2001. $31,070 for one year.

Devaney, B. and **Carriquiry, A. L.** Using the new Dietary Reference Intakes to assess nutrient adequacy among vulnerable groups. Economic Research Service, USDA. May 2001. $247,000 for 18 months.

Carriquiry, A.L. PC software for dietary assessment. National Cancer Institute, NIH. November 2001. $25,000 for one year.

Carriquiry, A.L. Ninth Latin American Congress on Probability and Mathematical Statistics. Punta del Este, Uruguay. National Science Foundation, January 2004. $16,500 for one year.

Carriquiry, A.L. International Society for Bayesian Analysis 2004, Vina del Mar, Chile. National Science Foundation, March 2004. $12,000 for one year.

Meeker, W.Q., **Carriquiry, A.L.,** Cook, D., Maitra, R., Nettleton, D., Opsomer, J. Computing equipment for the Statistics Department at Iowa State University. SCREMS program, National Science Foundation. January 2004. $127,000 for one year.

Carriquiry, A.L. Bayesian analysis of traffic safety data. Iowa Department of Transportation. September 2004. $75,000 for three years.

Carriquiry, A.L., Meeker, W.Q., Morris, M., Vardeman, S. and Wu, H. Statistics for the Physical and Engineering Sciences: A Research Training Group. $1,101,547 for four years. National Science Foundation, July 2005.

Jensen, H.H., **Carriquiry, A.L.** and Schalinski, K. Assessing intake of choline in at-risk groups. Egg Nutrition Council, August 2006. $45,000 for one year.

Wolt, J., **Carriquiry, A.L.,** Correia, A., Hurd, S., Jensen, H.H., O'Connor, A., Rodriguez, L., Sandve, G. and Stecker, G. Enabling graduate learning in risk analysis with emphasis on food, agriculture and veterinary medicine. Higher Education Commission, May 2006. $146,813 over two years.

Srinivasan, R., Carter, D., Harkey, D., Eccles, K., Council, F., Persaud, B., Lyon, C., and **Carriquiry, A.L.** Evaluation of safety strategies at signalized intersections. NCHRP 17-35 Transportation Research Board, June 2006. $750,000 over three years.

Jahns, L. and **Carriquiry, A.L.** Epidemiologic tools to assess obesity-related energy and other nutrient intake. USDA NRI, December 2006. $345,000 over three years.

Kurkalova, L., Kling, K., **Carriquiry, A.L.** Economic benefits and water quality consequences of ethanol production in the upper Mississippi river basin. USDA NCR-SARE, October 2006. $676,000 over three years.

Hallmark, S., Maze, T., **Carriquiry, A.L.** and Boyle L.N. Development of analytical tools to evaluate road departure crashes using naturalistic driving study data. Federal Highway Administration. December 2006. $99,000 over two years.

Hallmark, S., Maze, T., **Carriquiry, A.L.** and Boyle L.N. Development of analytical tools to evaluate road departure crashes using naturalistic driving study data – Phase II. Federal Highway Administration. April 2008. $130,000 over two years.

Carriquiry, A.L. Planning food fortification in developing nations. World Health Organization. January 1 2008 – December 31 2009. $79,400.

Welk, G., Nusser, S.M. and **Carriquiry, A.L.** A measurement error approach to estimating usual daily physical activity distributions. National Institutes of Health. October 1 2008 – September 30 2012. $2,453,000.

Carriquiry, A.L. Measurement error in non-linear models – An application to serum vitamin D. National Institutes of Health. October 1 2009 – September 30 2011. $176,000.

Carriquiry, A.L. A comparison of various methods for estimating usual food intake distributions. National Institutes of Health. October 1 2009 – September 30 2011. $162,000.

Carriquiry, A.L. XI Latin American Congress on Probability and Mathematical Statistics. National Institutes of Health, Office of Dietary Supplements. October 1 2009 – March 31 2010. $8,500.

Genschel, U., **Carriquiry, A.L.**, Dougherty, B., Johnson, E., Kliemann, W. Exploring the STEM gender gap: Introductory college mathematics and statistics instruction and its association with self-efficacy. National Science Foundation. January 1 2011 – December 31 2012. $543,000.

Wiser, R., Balent-Kurti, P., Holland, J., Nelson, R. Lauter, N., **Carriquiry A.**, Payne, G. Genetic and histological dissection of phenotypic variation in quantitative resistance to maize diseases. National Science Foundation. November 15 2011 – November 14 2014. $3,997,779. Carriquiry is PI for the Iowa State portion, which amounts to approximately $950,000.

Carriquiry, A.L. Bayesian methods in traffic safety. Iowa Department of Transportation. January 2014. $125,000 for two years.

Carriquiry, A.L., Baldwin, D., Fienberg, S.E., Kafadar, K., Stern, H. NIST Center of Excellence in Forensic Science and Statistics. $19,999,722 over 5 years. June 1 2015 – May 31 2020.

Carriquiry, A.L., Garrett, B, Kafadar, K., Mejia, R., Morris, K., Stern, H. NIST Center of Excellence in Forensic Science and Statistics Renewal. $20,000,000 over 5 years. June 1 2020 – May 31 2025.

PUBLICATIONS, REFEREED

1. **Carriquiry, A. L.**, Gianola, D., and Fernando, R. L. 1987. Mixed Model Analysis of a Censored Normal Distribution with Reference to Animal Breeding. *Biometrics*, **43**:929-939.

2. Nusser, S. M., **Carriquiry, A. L.**, Jensen, H. H., and Fuller, W. A. 1990. A Transformation Approach to Estimating Usual Intake Distributions. *Proceedings of the Second Annual Kansas State University Conference on Statistics Applied to Agriculture*. Manhattan, KS 120-132.

3. **Carriquiry, A. L.**, Jensen, H. H., and Nusser, S. M. 1991. Modeling Chronic vs. Acute Human Health Risk from Contaminants in the Food. In: J. A. Caswell (ed.) *The Economics of Food Safety*, Elsevier, New York, 69-89.

4. **Carriquiry, A. L.**, Ireland, W., Kliemann, W., and Uemura, E. 1992. Statistical Evaluation of Dendritic Growth Models. *Bulletin of Mathematical Biology*, **53**:579-589.

5. Bouzaher, A. and **Carriquiry, A. L.** 1992. Multiproduct Yield Prediction when Products are not Independent. *Proceedings of the Third Annual Kansas State Conference on Statistics Applied to Agriculture.* Manhattan, KS 102-114.

6. Fink, D., and **Carriquiry, A. L.** 1992. Having Babies or Not – Household Composition in Rural Iowa and Nebraska, 1900-1910. *Great Plains Quarterly*, **12**:157-168.

7. Harville, D. A., and **Carriquiry, A. L.** 1992. Classical and Bayesian Prediction as Applied to an Unbalanced Mixed Linear Model. *Biometrics*, **48**:987-1003.

8. Bouzaher, A., Archer, D., Cabe, R., **Carriquiry, A. L.**, and Shogren, J. F. 1992. The Effects of Environmental Policy on Trade-Offs in Agri-chemical Management. *Journal of Environmental Management*, **36**:69-80.

9. Bouzaher, A., Lakshminarayan, P. G., Cabe, R., **Carriquiry, A. L.**, Gassman, P., and Shogren, J. F. 1993. Metamodels and Nonpoint Pollution Policy in Agriculture. *Water Resources Research*, **29**:1579-1587.

10. Mansur, L., **Carriquiry, A. L.**, and Rao-Arelli, M. 1993. Resistance to Race 3 of the Soybean Cyst Nematode. *Crop Science*, **33**:1249-1253.

11. Johnson, S. R., Bouzaher, A., **Carriquiry, A. L.**, Jensen, H. H., and Lakshminarayan, P. G. 1994. Production Efficiency and Agricultural Reform in Ukraine. With discussion. *American Journal of Agricultural Economics*, **76**:629-635.

12. Uemura, E., **Carriquiry, A. L.**, Kliemann, W., and J. Goodwin. 1995. Mathematical Modeling of Dendritic Growth *in vitro. Brain Research*, **671**:187-194.

13. Jensen, H. H., Lakshminarayan, P. G., Bouzaher, A., **Carriquiry, A. L.**, Johnson, S. R., and Sabluk, P. 1996. Stochastic frontier analysis of technical efficiency of Ukrainian crop and livestock enterprises and implications for reform. **Ukrainian Economic Review**, **2**:4--22.

14. Nusser, S. M., **Carriquiry, A. L.**, Dodd, K. W., and Fuller, W. A. 1996. A Semiparametric Approach to Estimating Usual Intake Distributions*. Journal of the American Statistical Association*, **91**:1440-1449.

15. Breidt, F. J., and **Carriquiry, A. L.** 1996. Improved quasi-maximum likelihood for stochastic volatility models. In: Lee J. C., Johnson, W. O., and Zellner, A. (eds.) *Modeling and Prediction: Honoring Seymour Geisser*. Springer-Verlag, 228-247.

16. Babcock, B. A., **Carriquiry, A. L.**, and Stern H. S. 1996. Evaluation of soil test information in agricultural decision making. *Journal of the Royal Statistical Society (C), Applied Statistics*, **45**:447-461.

17. Guenther, P. M., Kott, P. S., and **Carriquiry, A. L.** 1997. Development of an approach for estimating usual nutrient intake distributions at the population level. *Journal of Nutrition*, **127**:1106-1112.

18. **Carriquiry, A. L.** 1997. Bayesian legal decision-making: impossible task? In: Allen, R.J., and Redmayne, M. (eds.) *Bayesianism and Juridical Proof*. International Journal of Evidence and Proof, Special Issue, 299-304.

19. Allen, R. J., and **Carriquiry, A. L.** 1997. Factual ambiguity and a theory of evidence reconsidered: a dialogue between a statistician and a law professor. 31 *Israel Law Review*, 464-505.

20**. Carriquiry, A. L.**, and Fienberg, S. E. 1998. Log linear models. Armitage, P., and Colton, T. (eds.). *Encyclopedia of Biostatistics* **3**:2333-2349.

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125. Allen, L.H., **Carriquiry, A.L.,** Murphy, S.P. 2019. Proposed harmonized nutrient reference values for populations. *Advances in Nutrition,* 00: 1-15. doi.org/10.1093/advances/nmz096.

126. **Carriquiry, A.L.,** Reid, N., Slavkovic, A.B. 2019. Stephen Elliott Fienberg 1942-2016, Founding Editor of the *Annual Reviews of Statistics and Its Application. Annual Reviews of Statistics and Its Application,* 6: 1-18. doi.org/10.1146/annurev-statistics-030718-105334.

127. Angeles-Agdeppa, A., Ye, S., Denney, L., Tanda, K.V., Octavio, R.A.D, **Carriquiry, A.L.,** Capanzana, M.V. 2019. Food sources, energy and nutrient intakes of adults: 2013 Philippines National Nutrition Survey. *BMC Nutrition Journal,* 18: 1-12. doi.org/10.1186/s12937-019-0481-z.

128. Angeles-Agdeppa, A., Denney, L., Toledo, M.B., Obligar, V.A., Jacquier, E.F., **Carriquiry, A.L.,** Capanzana, M.V. 2019. Inadequate intakes in Filipino schoolchildren and adolescents are common among those from rural areas and poor families. *Food and Nutrition Research,* 63: 1-12.

129. **Carriquiry, A.,** Hofmann, H., Tai, XH., VanderPlas, S. 2019. Machine learning in forensic applications. *Significance Magazine,* 16(2): 29-35.

130. Basulto-Elias, G., **Carriquiry, A.L.,** De Brabanter, K., Nordman, D. 2020. Bivariate kernel deconvolution with panel data. *Sankhia B.* doi.org/10.1007/s13571-020-00226-x.

131. Crawford, A., Ray, A., **Carriquiry, A.** 2020. A database of handwriting samples for applications in forensic statistics. *Data in Brief,* 28. doi.org/10.1016/j.dib.2019.105059.

132. Park, S., **Carriquiry, A.** 2020. An algorithm to compare 2D footwear outsole images using maximum clique and SURF. *Statistical Analysis and Data Mining.* doi.org/10.1016/j.dib.2020.105508.

133. Garton, N., Niemi, J. **Carriquiry, A.L.** 2020. Knot selection in sparse Gaussian processes with a variational objective function. *Statistical Analysis and Data Mining,* 13:324-336. doi.org/10.1002/sam.11459.

134. Crawford, A.M., Berry, N.S., **Carriquiry, A.L.** 2020. A clustering method for graphical handwriting components and statistical writership analysis. *Statistical Analysis and Data Mining.* In press.

135. Murphy, S.P., Yaktine, A.L., **Carriquiry, A.L.**. 2020. Planning nutritionally adequate diets for groups: Methods used to develop recommendations for a Child and Adult Care Food Program. *Advances in Nutrition.* doi.org/10.1093/advances/nmaa119.

136. Park, S., **Carriquiry, A.** 2020**.** Similarity of two-dimensional images: An application to the forensic comparison of footwear impressions. *Journal of Applied Statistics.* In press.

137. Raatz, S.K., Johnson, L.K., **Carriquiry, A.L.**, King, W.C., Kalarchian, M.A., Devlin, M.J., Marcus, M.D., Mitchell, J.E. 2021. Reported nutrient intake over seven years after Roux-en-Y gastric bypass in the longitudinal assessment of bariatric surgery – 3 (LABS – 3) psychosocial study. *Surgery for Obesity and Related Diseases.* In press.

138. Hofmann, H., VanderPlas, S., **Carriquiry, A.L.** 2021**.** Treatment of inconclusives in the AFTE range of conclusions. *Law, Probability and Risk.* In press.

PAPERS SUBMITTED OR IN PREPARATION

1. Garton, N., Niemi, J., **Carriquiry, A.L.** Being revised for *Journal of Machine Learning Research.* January 2020.

2. Crawford, A.M., **Carriquiry, A.L.** , Ommen, D.M. A Bayesian approach to the forensic analysis of handwriting. Submitted to *Annals of Applied Statistics*.

3. Garton, N., **Carriquiry, A.**, Ommen, D., Niemi, J. Submitted to *Statistical Science.* December 2020.

4. Lee, H.N., Qiu, Y. **Carriquiry, A.**, Ommen, D. Optimal matching rule with application in forensic science. In preparation.

5. Reis, D., **Carriquiry, A.** A Bayesian two-part model to evaluate compliance with physical activity guidelines by US adults. In preparation.

6. Moursi, M., Angel, MD., De Moura, FF., Angeles-Agdeppa, I., Atmarita, A., Gironella, GM., Muslimatun, S., **Carriquiry, A.** An ex-ante analysis of the impact of rice biofortified with zinc on dietary zinc inadequacy: Evidence from Bangladesh, Indonesia and the Philippines. Review requested, *American Journal of Clinical Nutrition.* August 2020.

7. Curley, B., **Carriquiry, A.L.,** Fuller, W.A. Nonlinear measurement error approach to modeling the association between vitamin D intake and serum 25(OH)D in adults. In preparation.

8. Joseph, M., **Carriquiry, A.L.,** Fuller, W.A. A change-point model with errors in variables: An application assessing the association between iPTH and 25(OH)D in adults. In preparation.

VOLUMES WRITTEN OR EDITED

Case Studies in Bayesian Statistics, Volume IV. 1998. Gatsonis, C., Kass, R., Carlin, B. **Carriquiry, A. L.**, Gelman, A., Verdinelli, I., and West, M. (eds.). Springer-Verlag, Lecture Notes in Statistics, 138. New York.

Case Studies in Bayesian Statistics, Volume V. 2002. Gatsonis, C., Kass, R., Carlin, B. **Carriquiry, A. L.**, Gelman, A., Verdinelli, I., and West, M. (eds.). Springer-Verlag, Lecture Notes in Statistics, 162. New York.

Case Studies in Bayesian Statistics, Volume VI. 2002. Gatsonis, C., Kass, R., **Carriquiry, A. L.**, Gelman, A., Higdon, D., Pauler, D., and Verdinelli, I.(eds.). Springer-Verlag, Lecture Notes in Statistics 167, New York.

Dietary Reference Intakes: Applications in Dietary Assessment 2000. Murphy, S., Arab, L. Barr, S., Borra, S., **Carriquiry, A**., Devaney, B., Dwyer, J., Habitch, J.P., King, J., Kuhnlein, H. . Institute of Medicine, National Academy Press, Washington, D.C. 285 pp.

Estimating Eligibility and Participation for the WIC Program: Phase I Report. 2001. Betson, D., Buescher, P. **Carriquiry, A.L.,** Currie, J., DaVanzo, J., Geweke, J.F., Greenberg, D., Inman, R.P., Lepkowski, J., Scholtz, J.K., Suitor, C.W. National Academy Press, Washington, D.C. 86 pp.

Estimating Eligibility and Participation for the WIC Program: Final Report. 2003. Betson, D., Buescher, P. **Carriquiry, A.L.,** Currie, J., DaVanzo, J., Geweke, J.F., Greenberg, D., Inman, R.P., Lepkowski, J., Scholtz, J.K., Suitor, C.W. National Academy Press, Washington, D.C. 162 pp.

Dietary Reference Intakes: Applications in Dietary Planning. 2003. Barr, S., Agurs-Collins, T.D., **Carriquiry, A.L**., Coulston, A.M., Devaney, B., Dwyer, J.T., Hunt, J.R., Murphy, S., and Tarasuk, V. Institute of Medicine, National Academy Press.

Intentional Human Dosing Studies for EPA Regulatory Purposes: Scientific and Ethical Issues. 2004. Childress, J., Taylor, M.R., Bruckner, J., **Carriquiry, A.**, Clayton, E.W., Doull, J., Greely, H.T., Harlow, S.D., Lave, L.B., Lo, B., Louis, T.A., Rodricks, J.V., Schroeder, C.H., Temple, R. National Academy Press. 208 pp.

Ballistic Imaging. 2008. Rolph, J.E., Meiran, E.S., Blumstein, A., **Carriquiry, A.L**., Chumbley, S., Cook, P.J., De Graef, M., Donoho, D.M., Eddy, W.F., Gray, G., Grimson, E., Huttenlocher, D., Meyer, M., Nair, V., Ninivaggi, A., Pisenti, D.W., Pregibon, D., Reininga, H.M., Stewart, J.K., Stonebraker, M., Weschler, H., Weertman, J. National Academy Press, 322 pp.

*Gender Differences at Critical Transitions in the Careers of Science, Engineering, and Mathematics Faculty.*2010. Canizares, C., Shaywitz, S., Abriola, L., Buikstra, J., Carriquiry, A., Ehrenberg, R. Girgus, J., Leibowitz, A., Morawetz, C.S., Taylor, T., Wu, L., Yu, X. National Academy Press. National Academy Press, 365 pp.

Child and Adult Care Food Program- Aligning Dietary Guidance for All. 2011. Murphy, S.P., Birckhead, N.D., **Carriquiry, A.L.**, Chernoff, R. Coto-Moreno, S., Cullen, K.W., Fox, M.K., Henchy, G., Jensen, H.H., Russell-Tucker, C., Stallings, V.A., Tucker, K.L. National Academy Press, 296 pp.

Using Science as Evidence in Public Policy. 2012. Prewitt, K., Bohrnstedt, G.W., Bradburn, N.M., **Carriquiry, A.L.,** Cartwright, N.D., Cooper, H., Farrell, M.J., Fienberg, S.E., Jasanoff, S.S., Jervis, R.L., Littan, R.E., Morning, A., Pollak, R.A., Schneider, S.H., Schwandt, T.A., Verba, S. National Academy Press. National Academy Press, 110 pp.

Options for Estimating Illegal Entries at the U.S.-Mexico Border. 2013. **Carriquiry, A.L.,** Majmundar, M. Eds. National Academy Press, 156 pp.

Furthering America's Research Enterprise. 2014. Celeste, R.A., Griswold, A., Straf, M. Eds. National Academy Press, 200 pp.

Evaluation of the Department of Veterans Affairs Mental Health Services. 2018. **Carriquiry, A.**, Mitchell, A., Aiuppa, L. Eds. National Academy Press, 440 pp.

Statistics in the Public Interest: In Memory of Stephen E. Fienberg. **Carriquiry, A.L.**, Eddy, W., Tanur, J.M. Springer. In press.

TEACHING AND INSTRUCTION

PhD students:

- Kevin W. Dodd, 1999 (joint with W. Fuller, Statistics). National Cancer Institute.
- Chad Hart, 1999 (joint with S. Lence, Economics). Iowa State University, Dept. of Economics.
- Soledad Fernández, 2001 (joint with R. Fernando, Animal Science). The Ohio State University, Dept. of Biostatistics.
- Tanzy Love, 2005. Tenured Associate Professor, University of Rochester, Dept. of Statistics.
- Gabriel Camano, 2006. Universidad de la Republica, Uruguay, Dept. of Statistics.
- Wuyan Zhang, 2007 Abbott Laboratories.
- Wen Li, 2009 (joint with C. Yu and W. Kliemann). Merck Laboratories.
- Wei He, 2011 (joint with R. Fernando). Monsanto.
- Kristian Schmidt, 2012. Capital One, Richmond, VA.
- Yu-Yi Hsu, 2013. Food and Drug Administration, Washington, DC.
- Maria Joseph, 2013. General Dynamics, Des Moines, IA.
- Hui Lin, 2013 (joint with Chong Wang). Google Research, Mountain View, CA.
- Reka Howard, 2016 (joint with W. Beavis). Tenure-track assistant professor, Dept. of Statistics, U Nebraska Lincoln.
- Guillermo Basulto, 2016 (joint with D. Nordman and Kris de Brabanter). Scientist, INTRAN, ISU.
- Brenna Curley, 2017 – Tenure-track assistant professor, Dept. of Mathematics, Moravian College, PA.
- Eduardo Trujillo, 2017 (joint with D. Nordman) – Assistant research professor, Clinical Research and Leadership, George Washington University.

- Daniel Ries, 2017 – Scientist, Sandia National Laboratory, Albuquerque, NM.
- Soyoung Kim, 2018. Tenure-track assistant professor, National Pusan University, Busan, South Korea.
- Amy Crawford, 2020 (joint with D. Ommen). Statistical Scientist, Berry Consulting, Austin, TX.
- Nate Garton, 2020 (joint with J. Niemi). Commonwealth Computer Research, Inc., Charlottesville, VA.
- Jason Saporta, 2022 expected (joint with J. Tian).

MSc students:

- 38 students completed their MSc in Statistics under my supervision since 1990.

Have supervised, in addition, a Bachelor of Science and a Master of Science thesis from the Pontifical Catholic University of Chile, a Master of Science thesis from the Catholic University of Valparaiso, Chile, a Master of Science thesis from the Universidad Nacional Autónoma de México, and the MS of three students in the Department of Nutrition, University of Antioquia, Colombia. Was member of the doctoral committee of Dr. Lisa Jahns, School of Public Health, University of North Carolina at Chapel Hill. Was External Examiner of the doctoral dissertation of Mr. Robert Denham, The University of Newcastle, Australia. Was External Examiner of a doctoral student in the University of Aaborg, Denmark.

Undergraduate students:

Honors Students: Anyesha Rey, Dept. of Statistics, ISU. Emily Allen, Dept. of Statistics, ISU.
Elsewhere: Alexandria Arabio, Forensic Science major in Cedar Crest College in Allentown, PA. Madison McGregor, Forensic Science major in Columbia College in Columbia, MO.

Have mentored multiple undergraduate students who participated in Research Experiences for Undergraduates in the Dept. of Statistics and in CSAFE, ISU.

<u>Courses taught</u>
Introductory Statistics Stat 101 (2 times).
Introduction to Business Statistics Stat 226 (1 time).
Business Statistics Stat 326 (1 time).
Applied Business Statistics Stat 328 (1 time).
Applied Multivariate Methods Stat 407 (4 times).
Statistical Methods for Research Workers Stat 401 (3 times).
Design of Experiments for Research Workers Stat 402 (1 time).
Introduction to Bayesian Data Analysis Stat 444 (6 times).
Honors Project Stat 490 (1 time).
Statistical Methods Stat 500 (1 time).
Multivariate Analysis Stat 501 (4 times).
Response Surface Methodology Stat 513 (3 times).
Bayesian Analysis Stat 544 (3 times).
Assessment of Nutritional Status FSHN 572 (1 time, as part of a team).
Mixed Linear Models and Longitudinal Data Analysis (1 time, Chile).

INVITED PRESENTATIONS AND SEMINARS (After 1990)

Bayesian estimation of variance components in mixed linear models. IV Congress on Genetics Applied to Livestock Production. Edinburgh, Scotland. July 1990.

Classical and Bayesian approaches to the estimation of variance components in mixed linear models. X Winter School on Probability and Statistics. CIENES and Pontificia Universidad Católica de Chile. July 1991.

Topics on Bayesian estimation from components of variance models. First Congress of Mathematics Capricornio. Universidad Católica del Norte, Antofagasta, Chile. August 1991.

Statistical aspects of the genetic evaluation of livestock. Forum on Livestock Production at the Onset of MERCOSUR. Instituto Nacional de Investigaciones Agropecuarias (INIA). Montevideo, Uruguay, August 1991.

Approximate Inference for posterior means in mixed linear models. Department of Statistics, Universidad Nacional Autónoma de México. Mexico City, Mexico. February 1992.

Topics on estimation and prediction from components of variance models. XI Winter School on Probability and Statistics. Pontificia Universidad Católica de Chile and CIENES. Santiago, Chile.
July 1992. (Series of 5 invited lectures.)

Computation of posterior modes in mixed linear models. XX Annual Meeting of the Chilean Statistical Society, Antofagasta, Chile. November 1992.

Posterior surfaces in mixed linear models. NSF-NBER Workshop of the Americas on Recent Advances in Bayesian Statistics and Econometrics. Caracas, Venezuela. December 1992.

Bayesian approaches to prediction in mixed linear models. Department of Statistics, Carnegie-Mellon University, Pittsburgh, PA. March 1993.

An overview of Bayesian prediction in components of variance models. Department of Statistics, Purdue University, West Lafayette, IN. April 1993.

Modern approaches to prediction in mixed linear models. IV Statistics Symposium, Universidad Nacional de Colombia, Bogotá, Colombia. June 1993.

Classical and Bayesian approaches to components of variance models. Semana de la Estadistica. Universidad Católica de Valparaiso, Valparaiso, Chile. October 1993.

Estimation of usual intake distributions. Department of Statistics, Pontificia Universidad Católica de Chile, Santiago, Chile. October 1993.

Bayesian estimation of signal to noise ratios. NSF Conference on Bayesian Hierarchical Models. Rio de Janeiro, Brazil. December 1993.

Stochastic volatility models: Introduction and an Application. Department of Statistics, Iowa State University, Ames, IA. January 1994.

Stochastic volatility models for futures returns. Department of Finance, Iowa State University, Ames, IA. March 1994.

Estimating usual Intake distributions. U.S. Department of Agriculture, Human Nutrition Information Service. Hyattsville, MD. April 1994.

Economic - environmental models: Applications in agriculture. Department of Natural Resources, Universidad Autónoma de Chihuahua, Chihuahua, Mexico. May 1994.

Dietary assessment: A comparison of different procedures. Food and Drug Administration, Center for Food Safety and Applied Nutrition, Washington, D.C. June 1994.

Robust QML for stochastic volatility. International NSF-NBER Forecasting, Prediction and Modeling in Statistics and Econometrics Meeting. Hsinchu, Taiwan, December 1994.

Improved quasi-maximum likelihood for stochastic volatility models. Learning and Knowledge: 19th Annual Conference of the German Classification Society. Basel, Switzerland, March 1995.

Exploring stationary surfaces for Markov chain Monte Carlo iterations. Department of Statistics, University of Washington, Seattle, WA. May 1995.

ISU Method and software for estimating distributions of usual nutrient intake. Agricultural Research Service (ARS), US Department of Agriculture (USDA), Hyatsville, MD. May 1995.

Estimation of the usual intake distribution of ratios of dietary components. Agricultural Research Service (ARS), US Department of Agriculture (USDA), Hyattsville, MD. May 1995.

[Métodos de estimación en problemas de volatilidad estocástica.]. II Congreso Iberoamericano de Estadistica, Oaxaca, Mexico, September 1995.

Change-point problems in agriculture: The case of response to fertilizer. III World Meeting of the International Society for Bayesian Analysis (ISBA). Oaxaca, Mexico, September 1995.

Assessing the dietary status of populations. Department of Biostatistics, University of Minnesota, Minneapolis, MN. October 1995.

Assessing the proportion of the population at dietary risk: A brief commentary. Meeting of the Food and Nutrition Board, Institutes of Medicine, National Academy of Sciences. Washington, D. C., December 12 1995.

Statistical issues in multi-target tracking. Tracker Workshop. NRaD, U.S. Navy, San Diego, California, February 6 – 8 1996.

Transformation of dietary intake records into estimates of population intakes. Invited special address in the Session: *New Perspectives Underlying Recommended Dietary Allowances: Food and Nutrition Board Update*, Washington, D.C., April 17 1996.

A Bayesian hierarchical approach to change point problems. German Cancer Research Institute, Heidelberg, Germany, June 17 1996.

Mixed models with dynamic random effects. III Congreso Latinoamericano de Sociedades de Estadistica (III CLATSE). Santiago, Chile. October 9 1996.

Methodological issues in defining dietary recommendations. Defining Dietary Recommendations Workshop. Center for Human Nutrition and Biostatistics Department, Johns Hopkins University, Baltimore. October 24 1996.

Improved maximum likelihood for stochastic volatility estimation. Department of Statistics, Pontificia Universidad Católica de Chile, Santiago, Chile. November 1997.

Estimation of genetic trend. IV World Congress of the International Society for Bayesian Analysis (ISBA). Capetown, South Africa. December 19 1996.

Analyses of dietary intake data. Institute for Statistics and Decision Sciences, Duke University, Durham, NC. April 1997.

Highest density gates for multiple target tracking. V Congreso de Matemáticas Capricornio. Antofagasta, Chile, July 30 1997.

Metamodeling for environmental policy evaluations. Joint Statistical Meetings, Anaheim, August 10, 1997.

Risk assessment based on 24 – hr food intake data. Joint Statistical Meetings, Anaheim, August 13 1997.

Statistical issues in the analysis of dietary intake data. Department of Food Science and Human Nutrition, Iowa State University, Ames, IA. April 1998.

Bayesian methods in dietary assessment. VII Annual Meeting of the Portuguese Statistical Association. Tomar, Portugal, June 9 1998.

A maximum entropy approach to estimating the prevalence of nutrient inadequacy. Sixth Purdue Symposium on Statistics, Workshop on Nutrition and Statistics. Purdue University, West Lafayette, Indiana, June 18 1998.

Assessing the prevalence of nutrient inadequacy. 81st Annual Meeting and Exhibition of the American Dietetic Association. Kansas City, Kansas, October 19 1998.

Using reversible jump MCMC to estimate the density of usual nutrient intake. Department of Statistics, Purdue University, West Lafayette, IN. March 1999.

Analyses of dietary intake data. Department of Statistics, University of Iowa, Iowa City, IA. April 1999.

Preliminary methodological investigation of the Supplementary Nutrition Survey of Older Americans. Experimental Biology Meetings, Washington, D. C., April 19 1999.

Issues in the analysis of complex dietary intake surveys. Department of Statistics, Pontificia Universidad Católica de Chile, Santiago, Chile. June 1999.

Analysis of the non-response in the Supplementary Nutritional Survey of Older Americans. National Conference on Health Statistics, Centers for Disease Control and Prevention. Washington, D.C., August 4 1999.

A Bayesian approach to estimate the density of a random variable observed with measurement error. Department of Biostatistics, University of Rochester, Rochester, NY. October 1999.

Adjusting intake distributions and estimating prevalence of nutrient inadequacy. Department of Nutrition and Epidemiology, School of Public Health, University of North Carolina, Chapel Hill, NC. November 1999.

Do bullets have fingerprints? Fourth International Conference on Forensic Statistics, North Carolina State University. Raleigh, North Carolina, December 6 1999.

A hierarchical model to adjust for heterogeneous measurement error. Sixth World Meeting of the International Society for Bayesian Analysis, Crete, Greece, May 31 2000.

A method to assess the proportion of undernourished individuals in a population. Sixth International Conference on Dietary Assessment. Tucson, Arizona. September 19 2000.

Technical efficiency in the use of a single input. Workshop of the Midwest Econometrics Group. Chicago, October 20-21 2000.

Exploring the surface of a product form poly-t density. Department of Biostatistics, University of Minnesota, Minneapolis, MN. December 2000.

Estimation of the distribution of a random variable measured with error. Workshop on Robust Statistics. Argentinean Academy of Exact Sciences, March 4 – 9 2001. Buenos Aires, Argentina.

Forensic statistical methods for ballistic trace evidence. Los Alamos National Laboratory, Santa Fe, NM. May 2001.

An analytical approach to estimation in mixed models. IV Bayesian Statistics Workshop. Northern Catholic University, Antofagasta, Chile, October 1 2001.

Non-linear, non-Gaussian models for target tracking. Meetings of the Chilean Statistical Society, Antofagasta, Chile, October 3 2001.

Assessing nutrient adequacy in the U.S. Meeting of the American Society of Public Health, Atlanta, GA, October 22 2001.

Statistical methods for assessing trace evidence. I Congreso Bayesiano de América Latina, Ubatuba, Brazil, February 4 2002.

An analysis of the volatility of the British pound to guide arbitration. Department of Statistics, Stanford University, Palo Alto, CA. February 2002.

Using the Dietary Reference Intakes for group and individual assessment. School of Public Health, University of North Carolina at Chapel Hill, NC. March 2002.

Estimating usual intake distributions. Workshop on the Integrated NHANES survey: What We Eat in America. United States Department of Agriculture and Department of Health and Human Services, Rockville, Maryland, June 20-21 2002.

An analysis of the volatility of the British pound to guide arbitration. Fifth International Conference on Forensic Statistics, Venice, Italy, September 1 2002.

Estimating the distribution of usual nutrient and food intakes. Fifth International Conference on Dietary Assessment, Bangkok, Thailand, January 26 2003.

Estimated association between added sugar and micronutrient intake using nationwide food consumption data. ILSI, March 22 2003.

Challenges in the application of the Upper Tolerance Levels (UL) to dietary assessment. ILSI, March 23 2003.

Assessing usual nutrient intakes. National Cancer Institute, September 3 2003.

Series of invited lectures at the Latin American Congress on Nutrition, Acapulco, Mexico, November 10 – 14 2003.

EDA, Bayes, and the subjectivist versus objectivist controversy. Panel discussion, Eighth World Meeting of ISBA, Viña del Mar, Chile, May 22 – 27 2004.

The probative value of bullet lead evidence. Sixth International Conference on Forensic Statistics, College of Law, Arizona State University, Tempe, AZ, March 17-19 2005.

The analysis of microarray data. Keynote address, Conference on Statistics Applied to Agriculture, Kansas State University, Manhattan, KS, April 25 2005.

Estimation of usual nutrient exposure. Workshop on Nutrient Risk Assessment, World Health Organization, Geneva, Switzerland, May 2-6 2005.

An analysis of the volatility of exchange rates in a financial forensic problem. Dept. of Economics, Iowa State University, Ames, IA. May 2005.

Quantitative approaches to dietary assessment. Conference of the Brazilian Society of Nutrition, Sao Paulo, Brazil, November 17 2005.

Sampling issues in the construction of nutrient compositional databases. Conference of the Brazilian Society of Nutrition, Sao Paulo, Brazil, November 18 2005.

Incorporating multiple array scans in the analysis of microarray data. Departments of Statistics and Biostatistics, University of Wisconsin at Madison, WI. December 2005.

The many flavors of Bayesian analysis: an illustration using four-lane to three-lane conversion data from Iowa. Annual meeting of the Transportation Research Board, Washington, D.C., January 2006.

Sources of error in forensic analyses; what matters and what doesn't. Joint Statistical Meetings, Seattle. August 7 2006.

Dietary assessment using intake data from complex surveys. Annual meeting of the Colombian Society of Nutrition, Medellin, Colombia, August 10 2006. (Keynote address).

Estimating the probability of a coincidental match in bullet lead analysis. Department of Statistics, Michigan State University, Lansing, MI. March 2007.

Graduate statistics education in Vietnam. Joint Statistical Meetings, Salt Lake City, Utah, August 2007.

Statistical issues in food intake assessment and planning. Academy for Educational Development, Washington, D.C. August 2007.

Statistical methods to guide food and nutrition policy in developing countries. Infinite Possibilities Conference. Raleigh, NC, November 1 2007.

Challenges in the analysis of periodically consumed foods and other substances. Office of Dietary Supplements, National Institutes of Health. Bethesda, MD. December 5 2007.

Revisiting stochastic volatility models. Department of Statistics, Catholic University of Chile. May 2008.

Clustering posterior densities. Conference in Honor of Daniel Gianola's 65th Birthday. University of Wisconsin – Madison, May 6 – 9 2009.

Divergence metrics to cluster densities. Department of Statistics, University of Toronto, Canada. September 2009.

Assessing the probative value of evidence. Plenary talk. Annual Meeting of the Texas Defense Lawyers Association, Houston, TX., October 21 2009.

How well are women faring? A comparison of men and women in RI universities at critical transition points. Washington Statistical Society, Washington, D.C. October 28 2009.

Statistical challenges in the analysis of dietary intake observations. National Academy of Sciences, Washington, DC. February 2010.

How well are women faring? A comparison of men and women in RI universities at critical transition points. Presidential Invited Address. Annual Meeting of the Western American Region of the International Biometric Society. June 2010.

Designing and analyzing dietary intake data. Conference on Probability and Statistics. Renmin University, Beijing, China, July 2010.

Evaluating and planning intakes and their impact on nutrition policy in The Philippines. Food and Nutrition Research Institute. September 2010.

Dietary and physical activity assessment – some methodological issues. Joint Statistical Meetings, Miami, FL, August 2011.

Statistics in nutrition and health. Department of Biostatistics, University of Rochester, NY. October 2011.

Analyzing physical activity data to guide policy. XII Latin American Congress on Probability and Mathematical Statistics, Viña del Mar, Chile, March 2012.

Software for dietary assessment. ICDAM, Rome, Italy, May 2012.

Using toxicological risk assessment principles from a nutrition perspective. ILSI, Washington, June 2012.

A risk/benefit approach to assess nutrient intake – Do we need a new DRI? ILSI Annual Meeting, Miami, January 2013.

Biomarkers in nutrition epidemiology. ENAR Meetings, Orlando, FL, March 2013.

A measurement error model for physical activity data. International Conference on Diet and Activity Methods. June 2013.

Argentina and its corrupt statistical system -- When intervention by the judiciary is a good thing. World Statistical Congress, Hong Kong, China, August 2013.

Statistical issues in nutrition epidemiology. Department of Statistics, University of Nebraska, Lincoln, NE. September 2013.

IMAPP: A new tool to assess and plan intakes. International Congress on Nutrition. Granada, Spain, September 2013.

Statistics and public policy. StatFest. Rice University, Houston, TX. October 2013.

A statistician's look at STAR METRICS – Sample size, validation, measurement error. STAR METRICS Level I Workshop. Bethesda, MD, November 2013.

Measurement error in biomarker data. National Institutes of Health, Office of Dietary Supplements. Gaithersburg, MD. November 2013.

Statistical tools to work with big data. Pontifical Catholic University of Chile, Santiago, Chile, November 2014.

Adjustment for within-person variability in serum 25(OH)D. Workshop on Vitamin D Assessment, Office of Dietary Supplements, NIH. Bethesda, MD. December 2014.

Design, analysis and interpretation of national food consumption surveys. Ministerio de Bienestar Familiar, Bogota, Colombia. July 2015.

How to Lie with Statistics and the Veterans Administration. Joint Statistical Meetings, Seattle, WA. August 2015.

Statistical methods in nutrition epidemiology. International Center for Tropical Agriculture, Cali, Colombia. September 2015.

Survey non-response and approaches to prevent and correct its effects. Annual Meeting, Sociedad Uruguaya de Estadistica, Montevideo, Uruguay. October 2015.

From daily intakes to usual intake distributions. Latin American Congress on Nutrition, Punta Cana, Dominican Republic. November 2015.

Introducing CSAFE. Midwest Crime Lab Directors' Meeting, Kansas Criminal Bureau of Investigations, Topeka, KS, June 2016.
Statistics and applications in forensic evidence. Annual Meeting of the International Biometric Society. Victoria, BC, July 2016.

Statistics for pattern evidence. World Congress of ISBA, Sardinia, Italy, July 2016.

Bivariate kernel deconvolution density estimation: an application to vitamin D absorption. Workshop on Advances and Critical Needs in Measurement Error Modeling. Banff International Research Station, Banff, Canada, August 2016.

Databases in forensic research and casework: completeness, representativeness, usefulness. Workshop on Probability and Statistics in Forensic Science. Isaac Newton Institute, University of Cambridge, Cambridge, UK. September 2016.

Advances in automated matching of bullet lands. Annual Meeting of the Royal Statistical Society, Manchester, UK. September 2016 (had to cancel at the last minute.)

Putting science in forensic sciences (and in many other places). Celebration of Stephen Fienberg. Carnegie Mellon University, Pittsburgh, October 2016.

How to select a research topic. Conference for Women in Statistics. Charlotte, NC. October 2016.

Remembering Stephen E. Fienberg. International Conference in Forensic Statistics, Minneapolis, MN September 2017.

Statistics and the law. Annual Meeting of the Sociedad Uruguaya de Estadistica, Montevideo, Uruguay, September 2017.

Inference for the 21st century: beyond p-values. Symposium on Statistical Inference, Washington, DC October 2017.

Forensic statistics. Women in Statistics Conference, San Diego, CA, October 2017.

Statistics and the fair administration of justice. American Association for the Advancement of Science annual meeting. Austin, TX, February 2018.

The analysis of dietary intake data. School of Medicine, Peking University, Beijing, China, May 2018.

Statistics and forensic evidence. Department of Statistics, Peking University, Beijing, China, May 2018.

Quantitative evaluation of evidence. American Bar Association annual meeting, Fordham University, New York City, NY, June 2018.

Two-step approach for firearms examination. Association of Firearms and Toolmark Examiners annual meeting, Charleston, WV, June 2018.

Design of food consumption surveys in Latin America. Meeting of the Pan-American Health Association, Mexico City, Mexico, July 2018.

Sample size estimation for nationwide food consumption surveys. National Institute of Nutrition, Hanoi, Vietnam, July 2018.

Machine learning in forensic science. ASA annual meeting, Vancouver, BC, August 2018.

Research program in CSAFE. International Association of Identification annual meeting, San Antonio, TX, August 2018.

Statistics in the Courts. American Bar Association, Judicial Section annual meeting. Chicago, IL, August 2018.

Design of a nationwide food consumption survey in Kenya. FAO, Nairobi, Kenya, August 2018.

Machine learning and forensic evidence. Division of Behavioral and Social Sciences and Education, National Academy of Sciences, Washington, DC. October 2018.

Building successful professional collaborations. Conference for Women in Statistics (Plenary talk). Cincinnati, OH. October 2018.

Nutrient and food consumption in Colombia. University of Antioquia, Medellin, Colombia, October 2018.

Statistics and the law. Science Achievement Lecture, College of Science, Pennsylvania State University, State College, PA. November 2018. Inaugural Lecture.

Statistical challenges in the analysis of pattern evidence. Center for Integrity in Forensic Sciences Inaugural Meeting. Washington University School of Law, St. Louis, MO. December 2018.

Learning algorithms and forensic evidence. Women in Data Science Conference, College of Engineering, Stanford University. February 2019.

Statistics and the Fair Administration of Justice. Hari Shankar Lecture. Department of Mathematics, University of Northern Iowa. April 2019.

Statistics and the evaluation of forensic evidence. Sandia National Lab, Albuquerque, NM. May 2019.

Forensic analysis of handwriting. Latin American Congress on Bayesian Statistics (COBAL). Pilar Iglesias Lecture. Pontifical Catholic University of Peru, Lima. June 2019.

Machine learning and forensic evaluation of pattern evidence. Joint Statistical Meetings, Denver, CO. July 2019.

Decisions in the forensic context. SAMSI Working Group on Statistical Decision Theory. Raleigh, NC. August 2019.

Similarities between outsole impressions using SURF. Annual meeting of the International Association for Identification, Reno, NV. August 2019.

Using machine learning to match striae pattern on land-engraved areas of bullets. SimStat Conference, Salzburg, Austria. September 2019.

Using machine learning to match striae pattern on land-engraved areas of bullets. Annual meeting of the European Network of Forensic Science Institutes, Section on Firearms and Toolmarks. Krakow, Poland. October 2019.

Data science and forensic applications. 45th Annual Meeting of the Chilean Statistical Society. Puerto Varas, Chile. October 2019.

Statistics and the fair administration of justice. Iowa Louis Stoke Alliance for Minority Participation (LSAMP) , University of Northern Iowa, Waterloo, IA. February 2020.

Statistical learning algorithms and the evaluation of forensic evidence. Third Data Science Symposium, College of Liberal Arts and Sciences, South Dakota State University, Brookings, SD. February 2020.

A statistician's look at Risk Assessment Tools. Annual Conference, Judicial Division of the American Bar Association. Austin, TX. February 2020.

Quantifying the similarity between shoe outsole impressions. Annual Meeting of the American Academy of Forensic Sciences, Anaheim, CA. February 2020.

Assessing and planning nutrient intake for populations. US-AID, Washington, DC. February 2020.

P-values are rarely used in forensic science – That is (not) too bad. NISS Webinar, May 6 2020. (Virtual)

Who wrote it? A hierarchical model for forensic handwriting analysis. Dept. of Statistics, University of California Irvine, October 29 2020. (Virtual)

Research and training in CSAFE. Canadian Forensic Science Firearms Symposium, November 4 2020. (Virtual)

Statistics, mathematics, and the fair evaluation of evidence. Canadian Mathematical Society, Inaugural MITACS Innovation Lecture, December 4 2020. (Virtual)

[Note: Most of the conferences to which I was invited to speak after March in 2020 were rescheduled for 2021.]

Toward more science in forensic science. Law School, College of William and Mary. March 3 2021. (Virtual)

The forensic analysis of handwriting. Webinar, CSAFE, March 11 2021. (Virtual)

Machine learning and the fair evaluation of forensic evidence. Women in Data Science, ISU. March 25 2021. (Virtual)

A hierarchical model for forensic handwriting analysis. Department of Statistics, University of Nebraska Lincoln. March 31 2021. (Virtual)

Forensic handwriting analysis at CSAFE. Annual Conference of the European Association of Questioned Document Examiners (ENFHEX). June 17 2021. (Virtual)

CSI Bayes: Comparing and interpreting images in forensic evaluations. World Meeting of the International Society for Bayesian Analysis, plenary Foundational Lecture. June 29 2021. (Virtual)

Footwear research in CSAFE. Annual meeting of the International Association for Identification. Nashville, August 3 2021.

Statistics in the pursuit of justice: A more principled strategy to analyze forensic evidence. Joint Statistical Meetings, F.N. David Lecture. August 12 2021. (Virtual)

Pattern evidence research in CSAFE. Annual meeting of the American Society of Crime Lab Directors. Boston, August 24 2021.

Toward the quantitative evaluation of patterns evidence. Department of Forensic Science, University of Cordoba, Argentina. September 4 2021. (Virtual)

Forensic handwriting analysis. Annual meeting of the Scientific Association of Forensic Examiners (SAFE). October 1 2021. (Virtual)

CSI Statistics: How the principled use of quantitative methods can contribute to the fair administration of justice. Department of Mathematics and Statistics, Carleton College. Math Across the Cannon Lecture. Northfield, October 12 2021.

Quantifying the similarity between images for forensic analysis. Department of Mathematics and Statistics, Carleton College and St. Olaf College. October 13 2021.

The forensic analysis of handwriting. Congreso Latinoamericano de Sociedades de Estadistica, Plenary Lecture. October 18 2021. (Virtual)

TBA. Department of Statistics, University of Michigan. Ann Arbor, November 5 2021.

SHORT COURSES TAUGHT (After 1990)

[Tópicos sobre Regresión Lineal y No Lineal.] Curso-Taller Interamericano Para Usuarios de Estadística. Organization of American States/CIENES. Santiago, Chile. June 1990.

Bayesian Econometrics. Department of Agricultural Economics. University of California, Berkeley. May 1993.

[Modelo de Efectos Mixtos y Mejores Predictores Lineales, Insesgados (BLUP).] IV Statistics Symposium, Universidad Nacional de Colombia, Bogotá, Colombia. June 1993.

Topics in Regression Analysis. Interamerican Center for Statistics. Organization of American States/CIENES. Santiago, Chile. September 1993.

Sampling Techniques and PC CARP. Sampling Techniques and Applications. Organization of American States/CIENES. Santiago, Chile. October 1993.

Applied Bayesian Analysis: hierarchical models, numerical methods, and applications in agriculture. International Statistics Symposium: Statistics in Agriculture and the Environment. Santa Marta, Colombia, June 1995.

Bayesian approaches to linear models. International Statistics Symposium: Bayesian Statistics. Santa Marta, Colombia, June 1996.

Bayesian decision theory. African Educational Workshop. Capetown, South Africa, December 1996.

Using the new Dietary Reference Intakes (DRIs) to assess nutrient adequacy. Workshop on Measurement Error Adjustment Evaluation. School of Public Health, University of North Carolina, November 4 1999.

Statistical methods in forensic science. Short course presented to investigators and agents at the Federal Bureau of Investigations (FBI). May 8 and 9 2000.

Quantitative assessment of nutritional status, Latin American Congress on Nutrition, November 2003.

Bayesian methods in agriculture, Conference on Statistics in Agriculture, Kansas State University, Manhattan, KS. April 24 2005.

An introduction to Bayesian data analysis. ENAR Meetings, Tampa, Florida, March 26 2006.

An Introduction to Bayesian data analysis. CDC, Atlanta, Georgia, May 2006.

Bayesian data analysis. Universidad de Costa Rica, May 2007. (Invited, but had to cancel at last minute)

Analysis of geo-spatial data. VI Escuela de Invierno de Analisis Estocastico y sus Aplicaciones, Universidad de Valparaiso, Chile. July 2008.

Collection, analysis and interpretation of dietary intake data. Instituto Nacional de Salud Pública, Cuernavaca, Mexico. August 2010.

Collection, analysis and interpretation of dietary intake data. Food and Nutrition Research Institute, Manila, Philippines. September 2010.

Design and analysis of micro-array experiments. MS Program in Bioinformatics, Universidad de la República, Uruguay. November 2010.

Chewing over the numbers: how food consumption data drive Nutrition policy. Iowa State University, College of Liberal Arts and Sciences. Dean's Lecture Series, November 2010.

An introduction to statistical thinking -- Iowa Public Defender's Office. Tama, Iowa, June 2011.

Dietary assessment. Universidad La Molina, Lima, Peru. October 2011.

Collection, analysis and interpretation of dietary intake data. Food and Nutrition Research Institute, Jakarta, Indonesia. May 2012.

Collection, analysis and interpretation of dietary intake data. Instituto Nacional de Salud Pública, Cuernavaca, Mexico. August 2012.

Assessing and planning intakes. Ministry of Health. Jakarta, Indonesia. January 2013.

Design, analysis and interpretation of nationwide food consumption surveys. Ministry of Health and Human Services. Quito, Ecuador, April 2013.

Design, analysis and interpretation of nationwide food consumption surveys. Ministry of Health and Human Services. Bogota, Colombia, December 2013.

Design, analysis and interpretation of nationwide food consumption surveys. Ministry of Family Wellbeing. Bogota, Colombia, July 2015.

Design, analysis and interpretation of nationwide food consumption surveys. School of Medicine, University of Buenos Aires. Buenos Aires, Argentina, May 2016.

Introduction to statistics for forensic practitioners. Tri-County Regional Forensic Laboratory, Andover, MN. September 2016.

Using PC-SIDE to analyze the 2015 national food consumption survey of The Philippines. Food and Nutrition Research Institute, Manila, Philippines. December 2016.

Evaluating and planning intakes. Institute of Public Health, Cuernavaca, Mexico. August 2017.

Methods to analyze and interpret consumption information from the 2015 Food Consumption Survey in Colombia. Ministry of Health and Human Services, Bogota, Colombia. September 2017.

Collecting, analyzing and interpreting food consumption information. Ministry of Health, Buenos Aires, Argentina. December 2018.

Collecting, analyzing and interpreting food consumption information. Department of Nutrition, Universidad de La Republica, Montevideo, Uruguay. October 2019.

An introduction to machine learning for forensic applications. Annual Meeting of the American Academy of Forensic Sciences, Anaheim, CA. February 2020.

Statistical thinking for forensic practitioners. Texas Forensic Science Commission, Fall 2020.

Sampling for forensic practitioners. CSAFE, Fall 2021.

PROFESSIONAL PRACTICE

International (1991-2015, not updated between 2015 and 2017):

FAO Kenya. Design of a food consumption survey for Kenya. 2018 – 2019.

Food and Health International (FHI360). Technical assistance on design and analysis of food consumption surveys in Nigeria, Vietnam and Kenya. 2018 – 2019.

New York Academy of Sciences. Planning intakes. 2018 – 2020.

Food and Nutrition Research Institute, Manila, Philippines. Analysis of the 2015 food consumption survey. 2018.

Ministry of Health. Bogota, Colombia. Design and methods in the 2015 national food consumption survey. 2013.

Ministry of Health and Human Services, Quito, Ecuador. Training on dietary assessment methods and analysis of the 2012 nutrition survey. 2013

Ministry of Health, Jakarta, Indonesia. Training on dietary assessment methods and analysis of the 2010 nutrition survey. 2013.

Food and Nutrition Research Policy, Philippines. Analysis of the 2003 National Nutrition Survey and training of FNRI personnel in the analysis and interpretation. 2009 – 2011.

Harvest Plus. Baseline analysis and modeling of fortification strategies in Bangladesh, Philippines and Indonesia. 2010 – 2012.

Universidad de Chile, Departamento de Nutricion. Encuesta Nacional de Consumo de Alimentos (ENCA2010), consultant. 2008 – 2012.

Pontificia Universidad Católica de Chile, Escuela de Salud Pública Encuesta Nacional de Salud (ENS2008), co-investigadora. 2008.

Ministerio de Salud Pública, Chile Encuesta Nacional de Consumo de Alimentos (ENCA) – Statistical Consulting. May 2008 – 2010.

International Food Research Policy Institute Analysis of nutrient intake data from a survey of women and children in Uganda. July – September 2008.

Academy for Educational Development Analysis of nutrient intake data from the 2005 food intake survey in Palestine, 2005. September – December 2008 and September – December 2009.

Academy for Educational Development Analysis of nutrient intake data from a multiregional food intake survey in Uganda. 2008.

Academy for Educational Development Analysis of nutrient intake data from the 2003 Philippines survey of women and children. June 2007 – 2010.

International Food Research Policy Institute Analysis of nutrient intake and diet diversity data using data collected in Bangladesh. January 2007 – December 2007.

WHO Designing and evaluation food fortification programs in the developing world. A background paper and a suite of computer programs (with their manuals) will be produced in the context of this project. June 2007 – December 2008.

WHO/FAO Expert on assessing exposure for nutritional risk assessment. May, 2005. A background paper and a report were written in connection to this assignment.

Colombia 2004 – 2007 – Advisor to the Ministry of Health and Human Services on the design and analysis of a dietary intake survey. Two reports written to the Ministry of Health and Human Services of Colombia.

New Zealand 2000 – 2002. Advisor to the Ministry of Health and Human Services in New Zealand on the design and analysis of a dietary intake survey of children.

Center for Indigenous People's Nutrition and Environment, McGill University, Canada 1999 – 2000. Analysis of a dietary intake survey conducted in Baffin Island to assess the nutritional status and intake patterns of Innuit populations. A manuscript is under preparation. One MSc student in Statistics (D. Zaun) based his MSc Creative Component on this project.

EUROSTAT 1997 – 2000. Joint organization of a meeting to discuss the uses of Bayesian methods in Official Statistics. Collaboration resulted in ISBA 2000, the Sixth World Conference of ISBA, co-sponsored by EUROSTAT.

University of Pasto, Colombia. 1997 – 1999. Analysis of production data of *cuyes*, (guinea pigs), to assess the performance of breeding programs. *Cuyes* provide the main source of protein in the diet of native Colombian and Equatorian populations in the region. Report submitted to the Dean of the College of Agriculture, 2000.

National University of Colombia. 1993 – 1998. Advice on the establishment of a graduate program in Statistics in Santa Fé de Bogotá, Colombia. Chaired the committee established by the ASA charged with accreditation of the MSc program in Statistics at the National University in Colombia, and reviewed plans for a doctoral program in Statistics at the same institution. A report was written and submitted to the President of the National University of Colombia.

Pontifical Catholic University of Chile. 1995 – 1997. Collaborated in the writing of the proposal for the creation of a PhD in Statistics at the Catholic University in Chile, that was sent to the Secretary of Education of Chile for approval. The PhD program in Statistics at the Pontifical Catholic University of Chile, the first in the country, was approved and launched in 1999.

Ministry of Social Affairs, Vilnius, Lithuania. Spring 1993. Analysis of household expenditure survey data, including design issues. Estimation of proportion of families living in poverty.

Agriculture CANADA. 1992 – 1994. Development of an integrated agro-ecological economic system to estimate economic and environmental impacts of agricultural activities in Western Canada. Several reports were written under this project.

Ministry of Agriculture/USAID, Lusaka, Zambia. Spring, 1992. Adjustment for nonresponse of the 1991 Household Expenditure Survey. A final report to the Ministry of Agriculture and to USAID was written. Software for non-response adjustment was written and provided to Zambian officials.

Ukrainian Institute of Agrarian Economics, Kiev, Ukraine. September 1991 – 1994. Issues relating to collection of data on farm productivity, and efficiency analysis, including the estimation of efficient frontiers. Several reports and three published articles have been written under this project.

Institute of Economics, Riga, Latvia. Fall 1991 – 1993. Design of household expenditure surveys, adjustment for nonresponse, and impact analysis due to price restructuring. No report written.

National Association of Milk Producers/GTZ, Montevideo, Uruguay. June 1991 and June 1992. Organization of a national scheme for selection of genetically superior dairy animals. Including sampling schemes, creation and management of data bases, and development and adaptation of statistical procedures for estimating breeding values of animals. A report was written.

National (1991-2013, not updated since then):

Consultant to **CDC** on development of calibration equations for of urine sodium collected from partial voids. 2011 – 2013.

Consultant to **CDC** on analysis of iodine intake data. 2012.

Consultant to the **Institute of Medicine** on estimation of the distribution of serum vitamin D biomarkers and their association with levels of PTH. 2009 – 2011.

Consultant to **Centers for Disease Control and Prevention (CDC)** on analysis of folate and folic acid intake and its association with the incidence of birth defects in the United States. 2010.

Consultant to **Center for Disease Control and Prevention (CDC)** on analysis of food and supplement intake data. 2007 – 2008.

Consultant to **ABT Associates**. Analysis of food intake data collected from a nation-wide school breakfast program. 2006.

Consultant to **Mathematica Policy Research**. Design and analysis of food intake data collected from a federally funded nationwide school lunch program. 2003.

Expert witness in a murder trial in October 2001. Was certified as an expert in the **State of Alaska**.

Kemin Industries, Des Moines, IA. Design and analyses of lutein bioavailability trials. 2003.

Consultant to **ABT Associates** in project entitled *Evaluation of the School Breakfast Program Pilot Project.* 2001.

Department of Public Safety, Oklahoma. Analysis of traffic stop, warning, and citation data by the special drug interdiction units, to investigate whether troopers in certain special operations units engage in racially motivated stops and citations. 2000 – 2001.

Collaboration with Dr. Hank Harris, **School of Veterinary Medicine, Iowa State University**, Dr. Scot Hurd, National Animal Disease Center, USDA, and Dr. Barry Weisman, Nextran, on estimation of the risk of public health impacts of xeno-transplantations. The work involved estimation of risks, elicitation of expert opinion, and combination of expert opinions into a probability model. 1999 – 2000.

Consulting for **Nutrition Research Group**, 1999. Analysis of boron intake data. Using boron intake data collected by Nutrition Research Group, we estimated usual boron intake distributions for various gender/age groups. Report written.

Consulting for **Environ**, 1999 – 2002. Analyses of iron, vitamin A, copper, and zinc intake data, and iron and vitamin A blood biomarker data. Using data from the two major nationwide dietary surveys, we assessed the nutritional and health status of all gender/age groups. Report written.

National Pork Producers Council, Des Moines, Iowa. Statistical analyses of marketing data and data arising from taste panel tests. 1997 – 1999. Two reports written.

National Center for Health Statistics, Centers for Disease Control and Prevention. 1996 – 1999. Analysis of the Third National Health and Nutrition Examination Survey and of the Supplementary Survey of Older Americans. Work has included research on non-response patterns and imputation for the surveys, assessment of the nutritional status of populations, estimation of prevalence of nutrient inadequacy, and development of statistical methods to estimate distribution of usual nutrient intakes with limited data on individual daily intakes. Various reports, several MSc Creative Components (Y. Liu, G. Camaño) and two manuscripts have resulted from this project.

Affiliate, Law and Economics Consulting Group, San Francisco, California. Statistical analyses of financial data, including derivatives in the S&P500, and foreign exchange spot, futures, and options returns. 1994 – 1997. Two reports written. One published paper resulted from this work as well.

United States Environmental Protection Agency (USEPA), Office of Policy Analysis. 1992 – 1995. Development of an objective system to evaluate the environmental and economic impacts of livestock production. Statistical aspects of the project include sampling, experimental design, design of computer experiments, and model fitting. Various reports written under this project. One published manuscript resulted from this work.

Consulting for the **United States Environmental Protection Agency** (USEPA), Washington, DC, USA. 1991 – 1995. Assessment of risks from ground water, surface water, and air contamination from agriculture non-point source pollution. One published manuscript resulted from this project.

Consulting for the **United States Department of Agriculture**, Human Nutrition Information Service, Washington, DC, USA. January 1990 to 1998. Estimation of distributions of usual intake of nutrients, and of the proportion of individuals in the (sub)populations deficient in those nutrients. Various reports, three published manuscripts, various MSc creative components (B. Bai, J. Goyeneche, K. Dodd) and one doctoral dissertation (K. Dodd) resulted from this work.

D Heike Hofmann CV

Heike Hofmann

Contact:

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Department of Statistics and Statistical Laboratory
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Degrees:

Ph.D.	Augsburg University (Germany)	Statistics	Dec. 2000
M.Sc.	Augsburg University (Germany)	Mathematics (minor in Computer Science)	Feb. 1998

Professional Experience:

Iowa State University appointment:

Professor in Charge	Data Science	Jan 2021 – June 2023
Interim Professor in Charge	Data Science	Nov 2019 – Dec 2020
Full Professor	Statistics	Aug 2013 – present
Associate Professor	Statistics	Aug 2007 – Aug 2013
Assistant Professor	Statistics	Jan 2002 – Aug 2007

Iowa State University affiliations:

Core CSAFE faculty	Aug 2015 – present
Core Member Bioinformatics and Computational Biology	May 2009 – present
Human Computer Interaction	May 2009 – present

Positions elsewhere:

Post-Doc	AT&T Labs Florham Park NJ	Statistics	March 2001 – Dec 2001
Post-Doc	Augsburg University	Mathematics Department	Dec 2000 – March 2001

Awards and Honors

ISI Elected Member 2021.

ISU Interdisciplinary Team Research Award 2021, Data Sciences for the Public Good with Todd Abraham, Cassandra Dorius, Shawn Dorius, Jim Reecy, Christopher Seeger, and Adisak Sukul.

ISU Extension and Outreach Excellence in Research-Based Programming Award 2021 to the Data Science for the Public Good Young Scholars Program team

Kingland Faculty Fellow 2020–2022

Outstanding Achievement in Teaching LAS, 2020

ASA SPAIG award for CSAFE and NIST partnership; key contributor, 2018.

Mid Career Excellence in Research/Artistic Creativity LAS, 2016

Elected Fellow of the ASA 2015.

Early Excellence in Research/Artistic Creativity LAS, 2006

Best Papers/Competitions:

Managerial Gender Diversity and Firm Performance: An Integration of Different Theoretical Perspectives] Best Macro Paper 2016, with Schwab A., Werbel J.D., and Henriques P.L.. Published in Group & Organization Management, 41(1), 5–31, 2016, doi: `10.1177/1059601115588641`.

Visualizing statistical models: Removing the blindfold. ASA-Wiley Best SAM Paper Award 2016, with H. Wickham and D. Cook.

Redesigning the traditional logo sequence plot First place in the Redesign Competition of IEEE VisWeek (with H. Hofmann-Sieber), 2013.

Delayed, Cancelled, On Time, Boarding, ... flying over the USA Second Prize with Dianne Cook and students from the Statistical Graphics working group, ASA Data Exposition 2009.

Glaciers melt as Mountains warm Second Prize with Dianne Cook and Hadley Wickham, ASA Data Exposition 2006.

Boom and Bust of Technology Companies at the Turn of the 21st Century First Prize with Dianne Cook, Hadley Wickham, Junjie Sun and Christian Röttger, IEEE InfoVis Data Contest 2005.

Best Student Papers (I was involved in an advisory role):

The generalized parallel coordinate plot. ASA Statistical Graphics Paper Competition, author: Yawei Ge, 2020.

Matching Bullets. ASA Statistical Imaging Paper Competition, author: Eric Hare, 2016.

Using the geomnet Package: Visualizing African Slave Trade, 1514 – 1866. ASA Statistical Graphics Paper Competition, author: Sam Tyner, 2016.

intRo. ASA Statistical Computing Paper Competition, authors: Andee Kaplan and Eric Hare (with Di Cook), 2015.

The curse of three dimensions: Why your brain is lying to you. ASA Statistical Graphics Paper Competition, author: Susan VanderPlas, 2014.

Are you Normal? The Problem of Confounded Residual Structures in Hierarchical Linear Models. ASA Statistical Graphics Student Paper Competition, author: Adam Loy, 2013.

Where's Waldo: Closer Look at Line-up Plots ASA Statistical Graphics Student Paper Competition, author: Niladri Roy-Chowdhury (with Dianne Cook), 2012.

Visual Statistical Inference for Regression Parameters ASA Statistical Graphics Student Paper Competition, author: Mahbub Majumder (with Dianne Cook), 2011.

External Grants

NISS 153701 *Interactive Visualization for Education Data and Statistics* $34,364.00, 09/01/2021-05/31/2022

NSF 19-564 *CNS - SCC: 2020–2023, $1,500,000 Overcoming the Rural Data Deficit to Improve Quality of Life and Community Services in Smart Connected Small Communities*, Kimberly Zarecor (PI), Biswa Das, David J Peters, Susan VanderPlas, Zhengyuan Zhu, HH (senior personnel)

(Non-competitive) 2017–2021: $136,249 Statistical Computing for Exploratory Data Analysis, Schneider Electric.

GSOC 2019: $6,000 in summer funding for graduate student on the project *Parallel Coordinate Plots in ggplot2* (with Dianne Cook).

GSOC 2017: $5,000 in summer funding for graduate student on the project *Systematic living reviews* (with Annette O'Connor).

GSOC 2017: $5,000 in summer funding for graduate student on the project *Methods for quantile-quantile plots in ggplot2* (with Adam Loy).

GSOC 2016: $5,000 in summer funding for graduate student on the project *ggmosaic: a geom for mosaic plots in ggplot2*.

NSF DMS 1007877: *Collaborative Research on Statistical Inference for Data Displays*, PI with Co-PIs Dianne Cook, Andreas Buja, Hadley Wickham, $189,974, funded Sep 2010 - August 2014

NIH proposal:*Advancing Drug Development from medicinal plants using transcriptomics and metabolomics*, Co-PI (out of about 10), PIs: Joseph Chappell (University of Kentucky), Sarah O'Connor, Dean Dellapenna, $3,027,575, funded from Sep 30 2009 - Aug 31 2010. My contribution: statistical analysis of plant material collected at Iowa State.

NSF DMS 0706949:*Statistical Graphics Research in Association with GGobi*, Co-PI with Dianne Cook (PI), $416,461, funded 2007 - 2012

NSF MCB 0416730:*Functional Genomics of the Biotin Metabolic Network of Arabidopsis*, Co-PI, $379,996.00, funded (09/01/04 - 08/31/06).

NSF DBI 050267: *Arabidopsis 2010: MetNet: Integrated Software for Arabidopsis Systems Biology Research*, Senior Personnel, $969,634, funded (09/01/05 - 08/31/07).

Internal Grants

(Non-competitive) 2016–2021 subaward over $1,27m from CSAFE *Statistical analysis of Bullet matching.*

2017 Honors Summer Research Grant: $1,000 funding for Freshman Honor student Ryan Goluch
2016 PIIR DDSI: *Bridging the digital divide in data science: invention and refinement of shared data science infrastructures* PI: Hridesh Rajan, I am one of about ten Co-PIs.
LAS Strategic Initiatives Proposals, GE Health Data, $30,000 (with D. Cook), 2011.
LAS Foreign Travel Grant, $860, 2008.
LASCAC COLL grant, *mysql Database for online storage of course material*, $4,000.
LAS Foreign Travel Grant, $513, 2005.

Refereed Journal Articles

2021

1. Hofmann H., VanderPlas S., Carriquiry A.: Treatment of Inconclusives in the AFTE Range of Conclusions, Law, Probability and Risk, 19(3-4), 2021, 317–364.
2. VanderPlas S., Röttger Chr., Cook D., Hofmann H.: Statistical Significance Calculations for Scenarios in Visual Inference, STAT, 10(1), e337, 2021, doi:`http://dx.doi.org/10.1002/sta4.337`.
3. Goode K.*, Hofmann H.: Visual Diagnostics of a Model Explainer – Tools for the Assessment of LIME Explanations, Statistical Analysis and Data Mining, 14(2), 185–200, February 2021, doi:`https://doi.org/10.1002/sam.11500.`

2020

4. Lyu A.*, Berg E., Hofmann H.: Empirical Bayes small area prediction of sheet and rill erosion under a zero-inflated lognormal model, Biometrical Journal, Dec 2020, 62 (8), 1859–1878, doi:`10.1002/bimj.202000029`.

5. Laurent A.* , Lyu A.*, Kyveryga P. , Makowski D. , Hofmann H., Miguez F.: Interactive web-based data visualization and analysis tool for synthesizing on-farm research networks data, Research Synthesis Methods, 2020, doi:`10.1002/jrsm.1440`.
6. VanderPlas S., Hofmann H., Nally M., Klep T., Cardoval C.: Comparison of three similarity scores for bullet LEA matching, Forensic Science International, Mar 2020, #110167, doi:`10.1016/j.forsciint.2020.110167`.
7. VanderPlas S., Hofmann H., Cook D.: Testing Statistical Charts: What makes a good graph?, *Annual Review of Statistics and Its Application*, doi:`10.1146/annurev-statistics-031219-041252`.

2019

8. Rice K.*, Genschel U., Hofmann H., A Robust Approach to Automatic Groove Identification in 3D Bullet Land Scans, *Journal of Forensic Sciences*, 30(1), 2019, doi:`10.1111/1556-4029.14263`.
9. Krishnan G.*, Hofmann H.: Adapting the Chumbley Score to Match Striae on Land Engraved Areas (LEAs) of Bullets, *Journal of Forensic Sciences*, 64 (3), 728–740, 2019, doi:`10.1111/1556-4029.13950`.
10. Carriquiry, A., Hofmann, H., Tai, X.H. and VanderPlas, S.: Machine learning in forensic applications, *Significance*, 16, 29–35, 2019. doi:`10.1111/j.1740-9713.2019.01252.x`
11. VanderPlas S., Goluch R.*, Hofmann H.: Framed! Reproducing 150 year old charts , *Journal of Computational Statistics and Graphics*, published online: Apr 2019, `https://doi.org/10.1080/10618600.2018.1562937`.

2018

12. Almeida A.*, Loy A., Hofmann H.: ggplot2 Compatible Quantile-Quantile Plots in R , *The R Journal*, 10(2); 248–261, 2018, doi:`https://journal.r-project.org/archive/2018/RJ-2018-051/RJ-2018-051.pdf`.
13. Roy Chowdhury N., Cook D., Hofmann H., Majumder M., Zhao Y., Measuring Lineup Difficulty by Matching Distance Metrics with Subject Choices in Crowd-Sourced Data. *Journal of Graphical and Computational Statistics*, 27(1), 132–145, 2018, doi:`10.1080/10618600.2017.1356323`.

2017

14. Hofmann H, Wickham H., Kafadar K.: Letter Value Boxplots, *Journal of Graphical and Computational Statistics*, 26(3), 469–477, 2017, doi: `10.1080/10618600.2017.1305277`.
15. Hare E., Hofmann H., Carriquiry A.: Algorithmic Approaches to Match Degraded Land Impressions., *Law, Probability and Risk*, 16(4), 203–221, 2017, doi:`10.1093/lpr/mgx018`.
16. VanderPlas S., Hofmann H.: All of this has happened before. All of this will happen again: Data Science; a response to D. Donoho's paper on Data Science , invited submission to Journal of Graphical and Computational Statistics, 26 (4), 775-778, 2017, doi: `10.1080/10618600.2017.1385474`.
17. Hare E., Hofmann H., Carriquiry A.: Automatic Matching of Bullet Lands., *Annals of Applied Statistics*, 11(4), 2332–2356, 2017, doi: `10.1214/17-AOAS1080`.
18. Loy A., Hofmann H., Cook D.: Model Choice and Diagnostics for Linear Mixed-effects Models Using Statistics on Street Corners, *Journal of Graphical and Computational Statistics*, 26(3), 478–492, 2017, doi:`10.1080/10618600.2017.1330207`.
19. Tyner S., Briatte F., Hofmann H., Three approaches to visualizing networks in the ggplot2 framework, *R Journal*, 9(1), 27–59, 2017, doi: `http://rjournal.github.io/archive/2017/RJ-2017-023/index.html`.
20. Kaplan A., Nordman D., Hofmann H.: An interactive graphical method for community detection in network data, *Computational Statistics*, 32(2), 535–557, 2017, doi:`10.1007/s00180-016-0663-5`.

21. VanderPlas S., Hofmann H.: Clusters Beat Trend!? Testing Feature Hierarchy in Statistical Graphics, *Journal of Graphical and Computational Statistics*, 26(2), 231–242, 2017, doi:10.1080/10618600.2016.1209116.

2016

22. Schloerke B., Wickham H., Cook D., Hofmann H.:, Escape from Boxland: Generating a Library of High-Dimensional Geometric Shapes, *R Journal*, 8(2), 243–257, 2016, download: https://journal.r-project.org/archive/2016-2/schloerke-wickham-cook-etal.pdf.
23. Cheng X., Cook D., Hofmann H.: Enabling Interactivity on Displays of Multivariate Time Series and Longitudinal Data, *Journal of Computational and Graphical Statistics*, 25(4), 1057–1076, 2016 , doi:10.1080/10618600.2015.1105749.
24. Loy A., Follett L., Hofmann H.: Variations of Q-Q plots – the Power of our Eyes, *The American Statistician*, 70 (2), 202–214, 2016, doi:10.1080/00031305.2015.1077728.
25. Schwab A., Werbel J.D., Hofmann H., Henriques P.L.: Managerial Gender Diversity and Firm Performance: An Integration of Different Theoretical Perspectives, *Group & Organization Management*, 41(1), 5–31, 2016, doi: 10.1177/1059601115588641, selected as 2016 Best Macro Paper.

2015

26. Cheng X., Cook D., and Hofmann H.. Visually Exploring Missing Values in Multivariable Data Using a Graphical User Interface. *Journal of Statistical Software*, 68 (6), 2015, doi:10.18637/jss.v068.i06.
27. Loy A., Hofmann H.: Are you normal? The Problem of Confounded Residual Structures in Hierarchical Linear Models, *Journal of Computational and Graphical Statistics*, 24(4), 1191–1209, 2015 (accepted in 2014), doi: 10.1080/10618600.2014.960084.
28. VanderPlas S., Hofmann H.: Signs of the sine illusion - why we need to care, *Journal of Computational and Graphical Statistics*, 24(4), 1170–1190, 2015 (accepted in 2014), doi: 10.1080/10618600.2014.951547.
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30. Timo Sieber and Eric Hare and Heike Hofmann and Martin Trepel: Biomathematical Description of Peptide Library Properties, *PLoS ONE* 10(6), 2015, e0129200, doi: 10.1371/journal.pone.0129200.
31. Hare E., Buja A., Hofmann H.: Manipulation of Discrete Random Variables with discreteRV, *R Journal*, 7(1), 185–194, 2015.
32. Alekel DL, Genschel U, Koehler KJ, Hofmann H, Van Loan MD, Beer B, Hanson LN, Peterson CT, Kurzer MS. The Soy Isoflavones for Reducing Bone Loss (SIRBL) Study: Effect of a three-year trial on hormones, adverse events, and endometrial thickness in postmenopausal women. *Menopause*. 22(2):185–197, 2015. PubMed #25003624 (in process). PMCID:PMC4286538 NIHMSID #608546.
33. Stanfill, B., Genschel, U., Nordman D., Hofmann H. Nonparametric Confidence Regions for the Central Orientation of Random Rotations, *Journal of Multivariate Analysis*, 125, 106–116, 2015, doi:10.1016/j.jmva.2014.12.003.

2014

34. Roy Chowdhury N., Cook D., Hofmann H., Majumder M., Lee E.K., Toth A.: Using Visual Statistical Inference to Better Understand Random Class Separations in High Dimension, Low Sample Size Data, *Computational Statistics*, 1–24, 2014, doi: 10.1007/s00180-014-0534-x.

35. Xie Y., Hofmann H., Cheng X.: Reactive Programming for Interactive Graphics, *Statistical Science*, 29(2), 201–213, 5/2014, doi: `10.1214/14-STS477`.

36. Follett L., Hofmann H., Genschel U.: Effects of the BP Oil Spill: A graphical Exploration, *Computational Statistics*, Volume 29, Issue 1-2, pp. 121–132, February 2014

37. Stanfill B., Hofmann H., Genschel U.: rotations: An R Package for SO(3) Data, *The R Journal*, 6(1), 68–78, 06/2014.

38. Andee Kaplan and Eric Hare and Heike Hofmann and Dianne Cook: Can You Buy a President? Politics After the Tillman Act, *CHANCE*, vol 27 (1), 2014.

2013

39. Stanfill B., Genschel U., Hofmann H.: Point Estimation of the Central Orientation of Random Rotations. *Technometrics*, 55(4), 524–535, 12/2013. DOI: `10.1080/00401706.2013.826145`

40. Zhao Y, Cook D, Hofmann H, Majumder M, Roy Chowdhury N: Mind Reading: Using an Eye-Tracker to See How People are Looking at Lineups. *International Journal of Intelligent Technologies and Applied Statistics*, 6(4), 393–413, 12/2013.

41. Loy A., Hofmann H.: HLMdiag: A Suite of Diagnostics for Hierarchical Linear Models in R. *Journal of Statistical Software*, 56 (5), 23 pages, 2013, DOI: `http://www.jstatsoft.org/v56/i05`.

42. Majumder M., Hofmann H., Cook D.: Validation of Visual Statistical Inference, Applied to Linear Models. *Journal of the American Statistical Association*, 108(503), 942–956, 2013. DOI:`10.1080/01621459.2013.808157`

43. Hofmann H, Unwin A., Cook D.: Good Practices for Graphics in R, *R Journal*, Volume 5, number 1, pp. 117–130, June 2013.

44. Loy A., Hofmann H.: Diagnostic Tools for Hierarchical Linear Models, *Wiley Interdisciplinary Reviews: Computational Statistics.*, Volume 5, Issue 1, pp. 48 – 61, January/February 2013.

45. Emerson J., Green W., Schloerke B., Cook D., Hofmann H., Wickham H.: The Generalized Pairs Plot. *Journal of Computational and Graphical Statistics*, 22:1, 79-91, 2013.

46. Newell, M., Cook, D., Hofmann, H. and Jannink, J.-L.: An algorithm for deciding the number of clusters and validation using simulated data with application to exploring crop population structure, *Annals of Applied Statistics*, Vol. 7, No. 4, 1898-1916, 2013. DOI: `http://dx.doi.org/10.1214/13-AOAS671`

2012

47. Wickham H., Hofmann H., Wickham C., Cook D.: Glyph-maps for Visually Exploring Temporal Patterns in Climate Data and Models. *Environmetrics*, Volume 23, Issue 5, pp 382 – 393, August 2012.

2011

48. Wickham H., Cook D., Hofmann H., Buja A.: tourr: An R package for exploring multivariate data with projections. *Journal of Statistical Software*, vol. 40, no. 2, pp. 118, 2011.

49. Shedd-Wise KM, Alekel DL, Hofmann H, VanLoan MD: Three-year soy isoflavone intervention has moderate effects on pQCT bone measures in postmenopausal women. *Journal of Clinical Densitometry, Assess Skeletal Health*, 2011. DOI: 10.1016/j.jocd.2010.11.003.

50. Matvienko OA, Alekel DL, Bhupathiraju SN, Hofmann H, Ritland LM, Reddy MB, Van Loan MD, and Perry CD.: Androidal fat mass is the strongest and most consistent predictor of cardiometabolic risk in healthy postmenopausal women. *Cardiology Research and Practice*, Article ID 904878, doi:10.4061/2011/904878, 2011.

51. David Rockoff, Heike Hofmann: How good is your Eyeballing? *CHANCE*, vol 24 (2), 2011.

52. Hofmann H., Cook D., Kielion C., Schloerke B., Hobbs J., Loy A., Mosley L., Rockoff D., Huang Y., Wrolstad D., Yin T.: Delayed, Canceled, on Time, BoardingÉ Flying in the USA. *Journal of Computational and Graphical Statistics*, Vol. 20, No. 2, 287-290, 2011.
53. Marie Vendettuoli, Erin Doyle, Heike Hofmann: Clustering microarray data to determine normalization method. *Advances in Computational Biology*, Springer, pp. 145–153, 2011.

2010

54. Hofmann-Sieber H., Wild J., Fiedler N., Tischer K., von Einem J., Osterrieder N., Hofmann H., Köstler J. and Wagner R.: Impact of ETIF Deletion on Safety and Immunogenicity of EHV-1 Vectored Vaccines. *Journal of Virology*, p. 11602–11613, 2010.
55. J. Hobbs, H. Wickham, H. Hofmann, and D. Cook: Glaciers melt as mountains warm: A graphical case study. *Computational Statistics*, Invited submission. Special issue for *ASA Statistical Computing and Graphics, Data Expo 2007*, 25(4), 569–586, 2010.
56. Mosley L., Cook D., Hofmann H., Kielion C., and Schloerke B.: Monitoring the Election Visually., *CHANCE*, vol 23 (3), 2010.

2009 or earlier

57. Buja A., Cook D., Hofmann H., Swayne D.F., Lawrence M., Lee E.K., Wickham H.: Statistical Inference for Exploratory Data Analysis and Model Diagnostics. *Philosophical Transactions of the Royal Society, A* (Invited), no 367, 4361–4383 2009.
58. Wickham H., Lawrence M., Cook D., Buja A., Hofmann H., Swayne D.: The plumbing of interactive graphics. *Computational Statistics*, May, 2009, 24, 2, 207–215.
59. Buja A., Swayne D.F., Littman M., Dean N., Hofmann H., Chen L.: Interactive Data Visualization with Multidimensional Scaling. *Journal of Computational and Graphical Statistics*, 17, 2, 444–472, 2008.
60. Yan A, Kloczkowski A, Hofmann H, Jernigan RL.: Prediction of side chain orientations in proteins by statistical machine learning methods. *Journal of biomolecular structure & dynamics*, 3, 275–288, 2007.
61. Hofmann H.: Interview with a Centennial Chart. *CHANCE*, 20 (3), pp. 26–35, 2007.
62. Cook D., Hofmann H., Nikolau B., Wurtele E., Lee Eun-kyung, Yang H.: Exploring gene expressions using plots. *Journal of Data Science*, 5(2), 2007, pp. 151-182.
63. Ahn J.S., Cook D., Hofmann H.: A Projection Pursuit Method on the multidimensional squared Contingency Table. *Computational Statistics*, Vol 18, pp. 605–626, 2003
64. Wurtele E.S., Dickerson J.D., Cook D., Hofmann H., Li J., Diao L.:MetNet: software to build and model the biogenetic lattice of Arabidopsis. *Comparative and Functional Genomics*. Vol 4, pp.239–245, 2003.
65. Hofmann H.: Constructing and reading mosaicplots. *Journal of Computational Statistics and Data Analysis*, Vol 43, No. 4, pp. 565-580, 2003.
66. Unwin A., Hofmann H., Wilhelm A.: Direct Manipulation Graphics for Data Mining. *International Journal of Image and Graphics*, Vol. 2, No. 1, pp. 49-65, 2002.
67. Hofmann H.: Generalised Odds Ratios for Visual Modelling. *Journal of Computational and Graphical Statistics*, 10, pp 628-640, 2002.
68. Hofmann H., Unwin A. Wilhelm A.: Data Mining and Statistics - Introduction. *Computational Statistics*, 16(3),pp. 317-321, 2001.
69. Hofmann H., Wilhelm A.: Visual Comparisons of Association Rules. *Computational Statistics*, 16(3), pp 399-416, 2001.

70. Wilhelm A., Hofmann H.: Graphics for Categorical Data and their Applications in Data Mining. In C. Provasi (Ed.), *Modelli Complessi e Metodi Computazionali Intensivi per la Stima e la Previsione*, pp. 51-56, 2001.
71. Hofmann H.: Exploring Categorical Data: Interactive Mosaic Plots. *Metrika*, 51(1), 11-26, 2000.
72. Hofmann H., Theus M.: Selection Sequences in MANET. *Computational Statistics*, 13(1), 77-87, 1998.
73. Unwin A., Hawkins G., Hofmann H., Siegl B.: Interactive Graphics for Data Sets with Missing Values - MANET. *Journal of Computational and Graphical Statistics*, 5(2), pp. 113-122, 1996.

Refereed Proceedings from Major Conferences:

2016
1. VanderPlas S. Hofmann H.: Spatial Reasoning and Data Displays, *IEEE Transactions on Visualization and Computer Graphics*, InfoVis 2015, vol 22, no 1, pp. 459–68, Jan 2016. DOI:`10.1109/TVCG.2015.2469125` (Acceptance rate about 25%)

2013
2. Hofmann H., Vendettuoli M., Common Angle Plots as perception-true visualizations of categorical associations, *IEEE Transactions on Visualization and Computer Graphics*, InfoVis 2013, vol 19, no 12, pp. 2297–2305, Dec 2013. DOI:`10.1109/TVCG.2013.140` (Acceptance rate 25%)

2012
3. Hofmann H., Follet L., Mahbub M., Cook D., Graphical Tests for Power Comparison of Competing Designs, *IEEE Transactions on Visualization and Computer Graphics*, InfoVis 2012, vol 18, no 12, pp. 2441– 2448, Dec 2012. (Acceptance rate 27%)

2011
4. Wickham H., Hofmann H.: Product Plots *IEEE Transactions on Visualization and Computer Graphics*, InfoVis 2011, vol 17, no 12, pp. 2223 – 2230, 2011. (Acceptance rate 25%)

2010
5. Wickham H., Cook D., Hofmann H., Buja A.: Graphical inference for infovis (best paper). *IEEE Transactions on Visualization and Computer Graphics*, **16**, pp. 973–979, 2010. (Acceptance rate 26%)

Books:

1. Unwin A., Theus M., Hofmann H. (co-editors): Graphics of Large Datasets. Springer, 2006.
2. Hofmann H.: Graphical Tools for the Exploration of Multivariate Categorical Data. BOD, 2001.

Book Chapters:

1. Susan VanderPlas, Alicia Carriquiry, Heike Hofmann, James Hamby, Xiao-Hui Tai: An Introduction to Firearms Examination for Researchers in Statistics, in Handbook of Forensic Statistics, ed. by D. Banks, K. Kafadar, D. Kaye, and M. Tackett, Boca Raton Florida: CRC Press, 2020.
2. Hofmann H.: Mosaic plots and their Variants. in Handbook of Computational Statistics (Volume III) Data Visualization, 2008.
3. Hofmann H.: How to Visualize a Million Categories. in Graphics of Large Datasets, 2006.
4. Unwin A., Hofmann H.: New Interactive Graphics Tools for Exploratory Analysis of Spatial Data. Innovations in GID 5, ed Carver, 1997.

Software

R packages (only CRAN published packages are listed):

- x3ptools – Summer 2018, on CRAN, now on version 0.0.3.9000
- toolmaRk (Jeremy Hadler) – Spring 2018, on CRAN, now on version 0.2.0
- qqplotR (Alexandre Almeida, Adam Loy) – Summer 2017, on CRAN
- ggmosaic (Haley Jeppson) – Summer 2016, on CRAN
- eechidna (with Di Cook, Rob Hyndman, Thomas Lumley, Ben Marwick, Carson Sievert, Nicholas Tierney, Nathaniel Tomasetti, Fang Zhou) – Spring 2016, on CRAN
- bulletr (Eric Hare) – Fall 2015, on CRAN
- geomnet (Samantha Tyner) – Fall 2015, on CRAN
- gglogo – Fall 2014, on CRAN since Summer 2016, now on version 0.1.3
- peptider (Eric Hare) – Fall 2013, on CRAN
- vinference – Fall 2013
- discreteRV (Eric Hare) – Summer 2013, on CRAN
- ggboxplots – Fall 2012
- ggparallel – Fall 2012 – now, CRAN maintenance (version 0.2.0)
- dbData (Susan Vanderplas) – Fall 2012
- dbGUI (Dason Kurkievic) – Fall 2011
- HLMDiagnostics (Adam Loy), on CRAN
- lvboxplots (Hadley Wickham), on CRAN; added geom functionality in Spring 2016
- MergeGUI (Xiaoyue Cheng), on CRAN
- MissingDataGUI (Xiaoyue Cheng), on CRAN

Invited Talks

TBD 2021

August 2022(?), Comstat, Bologna, Italy, originally planned for Aug 2020.

Two-Pronged Study of Bullets Fired by Consecutively Rifled Barrels
(with Melissa Nally, Houston FSC) Dec 2021, NIJ Forensic Technology Center of Excellence Firearm Webinar Series.

Drawing inference from lineups
Oct 2021, Seminar on Data Visualization, CIMAT/INEGI.

Scientific Advances in Toolmark Comparisons
Jan 2021, 6th Annual Questioning Forensics Conference.

2020

Machine Learning in Forensic Science
July 2020, JSM, Philadelphia, online format.

Visualizing US Elections
July 2020, DSSV, Durham, NC, now online format.

A framework for visual inference
June 2020, SDSS, Pittsburgh, PA, now online format.

2019

Immediate interactivity in statistical graphics
Sep 2019, Directions of Statistical Computing (DSC), Stanford University, CA.

Bullet matching with machine learning methods
Sep 2019, talk given by A. Carriquiry, SimStat, Vienna, Austria.

Lessons (To Be) Learned in Dynamic and Interactive Graphics
Aug 2019, JSM, Denver, Co.

Bullet matching with machine learning methods
June 2019, NISS workshop on Preventing Gun Violence, Arlington, VA

Visual Inference: leveraging the power of our eyes.
Mar 2019, DAGstat, Munich, Germany.

2018

Visual Inference: leveraging the power of our eyes.
Oct 2018, Departmental Seminar, Carnegie Mellon University.

A discussion of visual inference.
Sep 2018, Fields Institute, Toronto.

Case validation studies for automatic bullet matching.
Aug 2018, JSM, Vancouver.

Interactive graphics - then and now.
May 2018, SDSS, Baltimore.

2017

Visual Inference - Examples and Discussion.
July 2017, ISI conference, Marrakech, Marokko.

2016

Cutting-edge research in modern statistical sciences: Modern Tools and Impact in data science.
August 2016, JSM.

Visualization for IDA.
July 2016, STRATOS initiative, Banff.

Visual Inference - Examples and Discussion.
April 2016, Seminar, WEHI, Melbourne, Australia.
April 2016, Department seminar, Melbourne University, Melbourne, Australia.
Mar 2016, Department seminar, UTS, Sydney, Australia.

Matching bullets.
Mar 2016, Numbat working group, Monash University, Australia.

Visual Inference - Examples and Discussion.
Mar 2016, Department seminar, Monash University, Australia.

Clusters beat trend!? Testing feature hierarchy in statistical graphics.
Feb 2016, WOMBAT conference, Melbourne, Australia.

2015

Power and Significance of Visual Inference
April 2015, Data Visualization & Exploration Tools (Bio-IT World & Expo), Boston, MA.

2014

Discussion of Graphical Inference
Jan 2014, CCASA, Chicago, IL.

Discussion of Graphical Inference
Jan 2014, NORC, Chicago, IL.

2013

Redesigning the traditional Logo plot
Oct 2013, BioVis, Atlanta, GA.

Discussion of Graphical Inference
Aug 2013, Meaningful Use of Complex Medical Data, Los Angeles, CA.

Tools for Interactive Graphics
Aug 2013, Census Bureau, Washington, D.C.

Painting a Picture of Life in the US - Statistics and the Census Bureau
Aug 2013, JSM 2013, Montreal, Canada.

Graphical Inference
April 2013, Interface Meeting, Orange County , CA.

Discussion of Graphical Inference
Jan 2013, Society for Technology in Anesthesiology Annual Meeting, Scottsdale, AZ.

2012

Interactive Graphic systems in R
Dec 2012, SAMSI-FODAVA workshop on Interactive Visualization and Analysis of Massive Data, NC.

Discussion of Graphical Inference
Oct 2012, University of Chicago Illinois, IL.

Facing Off: Power of Visual and Classical Tests
May 2012, Interface Meeting, Houston, Texas.

Can we say that something's there?
Mar 2012, Augsburg University, Germany.

Statistical Inference for Graphics
Feb 2012, Information Visualization, Visual Data Mining and Machine Learning, Dagstuhl Seminar 12081, Germany.

Statistics Course: Visual Communication
Feb 2012, Miami University, OH.

2011

Visual Inference (Best of Interface)
Dec 2011, Joint Meeting of Taipei International Statistical Symposium and 7th Conference of the Asian Regional Section of the IASC, Taipei.

Interactive Statistical Graphics for Data Exploration
May 2011, Conference on Probability, Statistics, and Data Analysis, IISA, Raleigh, NC.

Main Direction for Rotation Matrices
April 2011, Augsburg University, Germany.

2010

Inference for Graphical Displays
Oct 2010, Workshop on Extreme Scale Visual Analytics, Salt Lake City, UT.

Let the Data Figure!
June 2010, Interface Symposium, Seattle, WA.
January 2010, Antony Unwin's 60th Birthday, Augsburg, Germany.

Body Composition - Statistical Vantage Point
May 2010, NRWC Workshop, Ames, IA.

2009 or earlier

Graphical Exploration of Very Large Data
Oct 2009, Army Conference on Applied Statistics, Tempe. AZ.

Visual Assessment of Airline Carriers
May 2009, EURISBISÕ09, Sardinia, Italy.

Incorporating Interactive graphics into Metabolomics Data Pre-processing)
(with Dianne Cook, Michael Lawrence, Suh-yeon Choi, Eve Wurtele) March 2009, ENAR, San Antonio.

Visualizing Large Data
May 2008, Large Data Vis Conference, Bremen.

Visualization of Categorical Data
May 2008, Augsburg University.

Statistical Lessons learned from the Netflix Challenge (with ISU Statistics Team)
October 2007, Winona State University, Winona, MN.

Longitudinal Data in `R` (with Di Cook)
August 2007, useR! Conference, Ames, Iowa.

Scagnostics for Projection Pursuit
August 2007, Joint Statistical Meetings, Salt Lake City, UT.
Oct 2007, University of Iowa, Iowa City, MN.

Modeling Massive Data Sets: The Netflix Challenge from a Statistical Perspective (with Dan Nettleton)
May 2007, Spring Research Conference, Ames, Iowa.

Scagnostics for Projection Pursuit
Feb 2007, ENAR meeting, Atlanta, GA.

Variations of Mosaic plots
Aug. 2006, CSC Conference: Workshop on Data and Information Visualization 2006, Berlin, Germany.
Aug. 2006, Compstat 2006, Rome, Italy.

Boom and Bust of High-Tech Industry at the turn of the Millenium - Data Challenge
Oct. 2005, InfoVis, Minneapolis, MN (part of the award ceremony).

Interactive biplots for visual modelling
Aug. 2004, Compstat 2004, Prague, Czech Republic.

How to visualize a million bins
Aug. 2003, Joint Statistical Meeting, San Francisco.

How to visualize a million bins
June 2003, International Meeting of the Psychometric Society, Cagliari, Italy.

Graphics - an Ace up a Statistician's Sleeve
June 2003, WNAR President's Invited Address June 2003, Golden, Colorado.

Graphical Opportunities in Exploring Microarray Data
May. 2003, Toxicogenomics: Through the Eyes of Informatics, organized by the Virginia Bioinformatics Institute and NIEHS, Washington D.C.

How to visualize a million bins
Oct. 2002, 3rd Workshop of Data Visualisation, Rain am Lech, Germany.

How to visualize one million points
Dec. 2001, University of Augsburg, Germany.

Visualisation of Association Rules
June 2001, Interface Symposium, Santa Ana, CA.

Mosaics, Mosaics, and Mosaics
May 2001, 2nd Workshop of Data Visualisation, Washington D.C.

Do you know your feelings? - A statistical analysis of linguistic data
Nov. 2000, Int'l Symposium on Data Mining & Statistics, Augsburg, Germany (talk in German).

Generalised Odds Ratios for Visual Modelling
May 2001, AT&T Research Labs, Statistics Seminar, Florham Park, NJ.
April 2001, Iowa State University, IA.
Feb. 2001, University of Madison, WI.
Aug. 2000, Iowa State University, IA.

MANET - an interactive graphical system
Feb. 2000, Cambridge University, UK.
Aug. 1997, AT&T Research Labs, Florham Park, NJ.

Interactive Statistical Graphics
Oct. 2000, CWI Amsterdam, The Netherlands.

Visualisation in Data Mining - Screening Multivariate Categorical Data
Aug. 1999, ISI'99, Helsinki, Finland.

GUI and Command-line - Conflict or Synergy?
June 1999, Interface '99, Chicago.

Interactive Biplots
Oct. 1998, NTTS'98, New Techniques and Technologies for Statistics, Sorrent, Italy.

Mosaicplots in an interactive graphical system
June 1998, Yale University, New Haven.

Visualising and Working with Categorical Data
June 1998, Lucent Technologies, Chicago.
June 1998, Visual Insight, Chicago.

Can we see what is not there? Exploring and keeping track of missings
Aug. 1997, Joint Statistical Meetings, Anaheim.

Advising:

Graduate Advising:

M.Sc. in progress
Andrew Maloney (Spring 2021)

M.Sc. completed
Wangqian Ju (Summer 2021)
Charlotte Roiger (Spring 2021)
Yawei Ge (Fall 2020)
Joseph Zemmels (Spring 2020)
Eryn Blagg (Spring 2020)
Taikgun Song (Summer 2018)
Kiegan Rice (Fall 2017)
Joe Papio (Summer 2017, Statistics with David Peterson, Political Science)
Sam Helmich (Spring 2015, Statistics)
Samantha Tyner (Spring 2015, Statistics)
Krisoye Smith (Fall 2014, Statistics)
Alex Shum (Spring 2014, Statistics)
Eric Hare (Spring 2014, Statistics)
Andee Kaplan (Spring 2014, Statistics, with Dan Nordman)
Lendie Follett (Spring 2014)
Takisha Harrison (Spring 2013, Statistics, with Ulrike Genschel)
Carson Sievert (Spring 2013)
Dason Kurkievicz (Spring 2012, Statistics, with Ulrike Genschel)
Karsten Maurer (Fall 2011, Statistics)
Bryan Stanfill (Summer 2011, Statistics, with Ulrike Genschel)
Xiang Wu (Fall 2010, Statistics)
Yunhui Cao (Spring 2010, Statistics)
David Rockoff (Spring 2010, Statistics)
Adam Loy (Fall 2009, Statistics)
Danielle Wrolstad (Summer 2009, Statistics)
Rachel Graham (Spring 2008, Statistics)
Dominik Birkmeier (Summer 2007) (Statistics)
Aimin Yan (Summer 2007) (Statistics)
Jie Zhu (Fall 2006) (co-major with Economics)
Hong Bai (Fall 2006) (co-major with Economics)
Junjie Sun (Spring 2006) (co-major with Economics)
Suzanna Stevens (Fall 2005) (Statistics),
Jeff Thostenson (Fall 2005) (Statistics)),
Lifeng You (Spring 2004) (Statistics),

Ph.D. in progress
Wangqian Ju (Statistics)

Yawei Ge (Statistics, with Yumou Qiu)
Joseph Zemmels (Statistics, with Susan VanderPlas, UNL)
Ganesh-Krishnan (Statistics/HCI)
Jason Saporta (Statistics, with Alicia Carriquiry)

Ph.D. completed
Haley Jeppson (Statistics, Fall 2021)
Katherine Goode (Statistics, Summer 2021)
Xiaodan Liu (Summer 2020, Statistics, with Emily Berg)
Kiegan Rice (Summer 2020, Statistics, with Ulrike Genschel)
Natalia Acevedo-Luna (Summer 2019, BCB co-major with Geetu Tuteja)
Samantha Tyner (Fall 2017, Statistics)
Natalia da Silva (Summer 2017, co-major with Di Cook)
Eric Hare (Spring 2017, Statistics)
Carson Sievert (Fall 2016, Statistics)
Karsten Maurer (Summer 2015, Statistics)
Dr Maurer is an Assistant Professor at Miami University, OH.
Susan VanderPlas (Spring 2015, Statistics)
Dr VanderPlas is an Assistant Professor at the University of Nebraska Lincoln.
Niladri Roy Chowdhury (Spring 2014, co-advisor: Dianne Cook),
Dr Roy Chowdhury is working for Novartis Inc in New Jersey.
Yihui Xie (Fall 2013, co-advisor: Dianne Cook),
Dr Xie is Software Engineer at RStudio, Inc. He is the author of the R package knitr, which has been transformative in that both he and Dr Wickham have been mentioned by name in David Donoho's white paper on '50 years of Data Science' (`http://courses.csail.mit.edu/18.337/2015/docs/50YearsDataScience.pdf`) as having large impact on the community: *This effort may have more impact on today's practice of data analysis than many highly-regarded theoretical statistics papers.* (Donoho, 2015)
Mahbub Majumder (Summer 2013, co-advisor with Dianne Cook)
Dr Majumder is an Associate Professor of Statistics in the Department of Mathematics at the University of Nebraska at Omaha.
Marie Vendettuoli (Summer 2013, BCB and HCI; co-advisors: Dianne Cook, Eve Wurtele),
Dr Vendettuoil is a Computer Scientist at USDA.
Adam Loy (Summer 2013)
Dr Loy is an Assistant Professor of Statistics in the Department of Mathematics and Statistics at Carleton College, MN.
Hadley Wickham (Spring 2008, Statistics; co-advisor with Dianne Cook),
Dr Wickham is Chief Scientist at RStudio, Inc. He is adjunct assistant professor of Statistics at Rice University, and Honorary Associate Professor of Statistics at Auckland University. He has been elected a Fellow of the American Statistical Association in 2015. He is a member of the R Foundation and currently serves as the President of the R Consortium. His work is hugely influential among the statistical computing community: he authored six of the top ten R packages in 2015; each of these packages was downloaded at least 400,000 times.

Professional Practice

1. Workshops & Conference Organization

   - *Data Science for the Public Good*, lead of the Summer 2021 Young Scholar program for ISU (five faculty, nine undergrads, three graduate fellows, two graduate student assistants); mentor and instructor for one of the projects and teams.

- *Data Science for the Public Good*, mentor and instructor in the Summer 2020 Young Scholars program.
- *Randomforests: properties and limitations / same gun or different gun? - Quantifying the Similarity Between Bullet Striations*, half day workshop (with Alicia Carriquiry), AAFS, Anaheim, CA, Feb 2020.
- *Visualization of Biological Data in R*, 2.5 day program (with Dianne Cook), SISBID, Seattle, July 2016. July 2017, July 2018, July 2019, July 2020 (online), July 2021 (online), July 2022 (online).
- *Intro to R, Visualizing Data*, two sessions (ca 6h total), Midwest Big Data Summer School, Iowa State, June 2016, July 2017, June 2018.
- *Statistical methodology in firearm examination* CSAFE sponsored 1.5 day workshop to train Firearm and toolmark examiners on statistical methodology, introduce participants to the lab facilities on the ISU campus of CSAFE, and provide details on automatic matching (and some of its limitation). 8 FTEs from different locations (Houston FSI, St Louis PD, Denver PD, and Virginia PD) attended the workshop, as well as our technical advisor Alan Zheng from NIST, Dec 2018.
- *Workshop Series in R*, five day program, organization, run by graduate students (Haley Jeppson, Joe Papio, Sam Tyner) at Iowa State, May 2017.
- *Workshop Series in R*, four day program, organization, run by graduate students (Eric Hare, Andrea Kaplan, and Samantha Tyner) at Iowa State, May 2016.
- *Workshop Series in R*, four day program, organization, run by graduate students (Carson Sievert, Andrea Kaplan, and Eric Hare) at Iowa State, June 2015.
- *Workshop Series in R*, evening classes, organization, run by graduate students (Karsten Maurer, Carson Sievert, Susan VanderPlas, and Eric Hare) at Iowa State, Fall 2014.
- *Workshop Series in R*, four day program, organization, run by graduate students (Karsten Maurer, Susan VanderPlas, and Eric Hare) at Iowa State, May 2014.
- *Workshop Series in R*, four day program, organization, run by graduate students (Karsten Maurer, Susan VanderPlas, and Eric Hare) at Iowa State, August 2013.
- *Workshop Series in R*, five day program, organization, run by graduate students (Adam Loy, Karsten Maurer, and Susan VanderPlas) at Iowa State, May 2013.
- *Graphics in R and ggobi* with Dianne Cook, Winston Chang and Yihui Xie, IEEE Infovis tutorial, Oct 2012.
- *Workshop Series in R*, five day program, organization, run by graduate students (Adam Loy, Karsten Maurer, and Dason Kurkievicz) at Iowa State, August 2012.
- *Workshop Series in R*, five 5h workshops, run with graduate students (Adam Loy, Karsten Maurer, and Dason Kurkievicz) at Iowa State, May 2012.
- *Graphics in R*, invited one-day workshop, Miami University, Feb 2012.

- SARMA/Ties workshop, *Visualization of Climate Data*, with H. Wickham and D. Cook, Reykjavik, Aug 14-18, 2011.
- *Looking at Data* (with Dianne Cook, Hadley Wickham), Washington DC, July 2009.
- *Visualizing Data with R* (with Dianne Cook), Iowa State University, July 2009.
- CE course *Graphics of Large Datasets* with Antony Unwin taught as a full day short course at the Joint Statistical Meetings 2008 in Denver, CO.
- Member of the organizing committee of useR! 2007 conference, Ames, IA.
- CE course *Graphics of Large Datasets* with Antony Unwin taught as a full day short course at the Joint Statistical Meetings 2007 in Salt Lake City.
- Workshop for the ASA Alaska chapter (with Dianne Cook), *Visualizing Multivariate Data*, June 2003.
- CE Workshop *Visual Data Mining* at the Joint Statistical Meetings, Indianapolis 2000.
- CE Short Course *Graphical Methods for Categorical Data* (with Antony Unwin) at the Interface Meeting, Chicago 1999.

Service

1. Committee Work

Fall 2019 –	VPR Internal Funding Proposal Evaluation Committee
Fall 2017	VPR committee member for internal review of the Virtual Reality Applications Center
Fall 2016 –	University Curriculum Advisory Board for Data Science
Spring 2016 - Spring 2017	LAS Development Committee for Major in Data Science
Fall 2015 - Fall 2020	LAS P&T Committee
Spring 2019	Chair Search Committee

2. Committee Work (in the Statistics Department)

Spring 2019 –	Data Science Curriculum Advisory Board (Chair since Spring 2020)
Fall 2019	Ad Hoc Committee for Improving Statistics MS and PhD Exam Procedures
Fall 2019	Search Committee (CSAFE)
Fall 2018 –	Computation Advisory Committee
Fall 2018 –	Honors and Awards Committee
Fall 2015 – Spring 2018	Advisory Committee on Tenure and Promotion (Chair: Fall 2017 – Spring 2018)
Fall 2017	Search Committee
Fall 2017	Search Committee (CSAFE)
Fall 2015 – Fall 2017	P&T Committee (Chair in 2017)
Fall 2014	Search Committee joint with Political Science
Fall 2012	Search Committee joint with Computer Science
Fall 2011 - Spring 2012	Curriculum Committee
Fall 2011 - Spring 2013	Admissions Committee
Fall 2011 - Spring 2012	Library
Fall 2011 - Spring 2015	Student/Faculty Committee on Instruction
Spring 2002 - Spring 2011, Fall 2012 - Spring 2013	Computation Advisory Committee (Chair: Fall 2009 - Spring 2011)
Fall 2008 - Spring 2015	Undergraduate Committee
Fall 2008 - Spring 2009	Diversity Committee
Spring 2008	Search Committee
Fall 2007	Search Committee
Fall 2005-Spring 2007	MS Exam Committee
Fall 2005	Social Committee
Fall 2003 - Spring 2005	Graduate Admission
Spring 2003	Search Committee
MS Exam question	May 2005, 2006, 2007, Jan 2006, 2007, 2008, 2009, 2010

3. Committee Work (for BCB) Spring 2014, Spring 2015, Spring 2016 Graduate Admission Committee

4. Statistical Society

   - Member of ASA Advisory Committee on Forensic Science 01/2022 – 12/2024.
   - Member of Program Committee Infovis 2013, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022.
   - Member of the Student Paper Competition Award committee of the Statistical Computing and Graphics Sections 2018
   - Ad-hoc Reviewer for the French Science Foundation, Fall 2021 (one proposal).
   - Ad-hoc Reviewer for the Belgian Science Foundation, Fall 2017 (one proposal).
   - NSF Panel Member, Oct 2013.
   - Board Member of Interface, 2012–2014, 2017–.
   - External Reviewer for Doctoral Thesis 2019
   - Reviewer for the Austrian Science Foundation, Fall 2012 (one proposal).
   - Judge of NSF IGERT Poster Competition 2011, May 15-16, (Evaluated and ranked 20 poster contributions).
   - ASA Statistical Graphics Past Chair, JSM 2013.

- ASA Statistical Graphics Chair, JSM 2012.
- ASA Statistical Graphics Chair Elect, JSM 2011.
- ASA Statistical Graphics Program Chair, JSM 2010.

5. Conference Organization

- *Analysis and interpretation of bullet and cartridge case evidence using 3D technologies*, two day NIST Center of Excellence workshop (with Alicia Carriquiry) at Iowa State - Dec 2020.
- Organizer Interface session: "Interactive Graphics in R", 2015.
- *Painting a picture of the United States* session organizer, invited session, JSM 2013.
- *Data Expo '13: Soul of the Community*, organizer, JSM 2013.
- Session Organizer of Invited Session, *Man AND Machine: the Conversation using the language of interactive graphics*, Interface 2012.
- Session Organizer of Topic Contributed Session, *Advances in Statistical Graphics*, JSM 2011.
- Session Organizer of Invited Session, *Dealing with Large Data*, JSM 2008.
- Member of the program committee of the fourth International Conference on Coordinated & Multiple Views in Exploratory Visualization (CMV2006), July 4th, London, UK.
- Session Organizer, *Discrete Data*, JSM 2002.
- Member of the Organizing Committee: Third International Workshop on Data Visualization for large data sets and Data Mining, October 6 - 9, 2002, Augsburg, Germany.
- Member of the Organizing Committee: International Symposium on Data Mining and Statistics, November 20-21, 2000, University of Augsburg, Germany.

6. Refereeing and Editing

Guest Editor of the *Computational Statistics'* special issue on Soul of the Community, 2014.

Associate Editor for *Journal of Computational and Graphical Statistics*, Feb 2002 - Jan 2005.

Associate Editor for *Computational Statistics*, Oct 2002 - Oct 2004.

Co-Editor of "Graphics for Large Datasets".

Guest Editor of the *Computational Statistics'* special issue on Data Mining and Statistics, vol. 16 (3), 2001.

Referee for book and book chapters (Springer, Chapman &Hall), and journal submissions (JCGS, TAS, CSDA, JSS, R Journal, TCGV, Bioinformatics, ...)

E Kori Khan CV

KORI KHAN

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Email: kkhan@iastate.edu

EDUCATION

THE OHIO STATE UNIVERSITY, Columbus, OH

MS, STATISTICS, December 2016
PHD, STATISTICS, August 2020
Advisor: Catherine A. Calder

THE OHIO STATE UNIVERSITY, Columbus, OH

JD cum laude, May 2015

THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL, Chapel Hill, NC

BSPH, with highest distinction, May 2012

ACADEMIC POSITIONS

IOWA STATE UNIVERSITY, Ames, IA

ASSISTANT PROFESSOR IN STATISTICS — August 2020-Present

PROFESSIONAL EXPERIENCE

TEACHING

IOWA STATE UNIVERSITY — August 2020-Present
Regression for Social and Behavioral Sciences (Fall 2020)
Statistical Methods for Research Workers (Spring 2021)

OHIO STATE UNIVERSITY — August 2016-August 2017
Math and Statistics Learning Center
Recitation Leader: Statistics for Business Sciences
Teaching Assistant: Statistical Modeling for Discovery II
Teaching Assistant: Bayesian Analysis and Statistical Decision Making

COLUMBUS STATE COMMUNITY COLLEGE — August 2014-Present
Calculus and Statistics Learning Support Specialist

STATISTICAL RESEARCH

INSTITUTE FOR POPULATION RESEARCH AT OHIO STATE — August 2017-August 2019
Graduate Research Assistant

Moritz College of Law Civil Clinic May 2016-September 2016
Statistical Consultant

Legal Clinical Work

Moritz College of Law Justice for Children Clinic January 2015-May 2015
Student Legal Intern, Columbus, OH

Moritz College of Law Civil Law Clinic August 2014-May 2015
Student Legal Intern, Columbus, OH

Legal Aid of Nebraska Summer 2014
Migrant Outreach Law Clerk, North Platte, NE

Legal Aid Society of Columbus Summer 2013
Litigation Law Clerk, Columbus, OH

Legal Research

Professor Amna Akbar at the Ohio State University May 2013-August 2015
Research Assistant, Columbus, OH

Professor Marc Spindelman at the Ohio State University May 2014-May 2015
Research Assistant, Columbus, OH

Professor Amy Cohen at the Ohio State University May 2013-May 2015
Research Assistant, Columbus, OH

Election Law @ Moritz College of Law January 2014-May 2015
Research Assistant, Columbus, OH

PUBLICATIONS

Peer-Reviewed

1 Browning, C. R., Calder, C. A., Boettner, B., Tarrence, J., **Khan, K.**, Soller, B., and Ford, J. L. (2021). Neighborhoods, activity spaces, and the span of adolescent exposures. *American Sociological Review*, 86(2):201–233.

2 **Khan, K.** and Calder, C. A. (2020). Restricted spatial regression methods: Implications for inference. *Journal of the American Statistical Association*, pages 1–13.

In Progress

1. **Khan, K.** & Barrett, C., Re-thinking spatial confounding in spatial generalized linear mixed models
2. **Khan, K**, Luo H., & Xi, W., Computing with R-INLA: Accuracy and reproducibility with implications for the analysis of COVID-19 data (submitted)
3. **Khan, K.**, The missing data problem in the American criminal justice system
4. **Khan, K.** & Hughes, E., A database of criminal trials in Franklin County, OH

TALKS

1. Universidad Pública de Navarra, January 28, 2021 (invited)
   Spatial Confounding and Restricted Spatial Regression Methods
2. STAB Seminar, University of Washington, November 17, 2020 (invited)
   Restricted Spatial Regression Methods and Implications
3. Computational and Financial Econometrics. London, UK. December 14-16, 2019 (contributed)
   Restricted Spatial Regression Methods: Implications for Inference
4. Joint Statistical Meetings. Vancouver, B.C. July 28 - August 2, 2018 (contributed)
   A Bayesian Multilevel Dirichlet Regression Model for Adolescent Activity Pattern Data

RESEARCH FUNDING

NIST Forensic Science Center of Excellence: Trial Transcipts (non-competitive) May 2021 - May 2022
(co-PI with Alicia Carriquiry)
Total Funding: $145,962

ADVISING

POS Committee member

Jason Saporta (Ph.D Stats)	Fall 2021 – Present
Joseph Zemmels (Ph.D Stats)	Fall 2021 – Present
Spencer Wadsworth (M.S. Stats)	Fall 2021 – Present

SERVICE

Organized Seminars

Source Code on Trial (organizer)	March 2021

Professional Service and Outreach

Organization of Scientific Area Committees Statistic Task Group	October 2021 – Present
Medicine Scientific Area Committee's Forensic Nursing Subcommittee	October 2021– Present
Scientific Literacy Project	August 2020 – Present
Organization of Scientific Area Committees Scientific & Technical Review Panel	August 2020 – March 2021
AP Statistics Reader	June 2016, June 2017, June 2018
Young Mathematicians Conference	August 2016
Ohio State Science Fair Judge	May 2016, 2017, 2018
Central District Science Day Judge	March 2016
Julia Robinson Math Festival	May 2015

Committees

MS and PhD Exam Committee	2021
Undergraduate Recruitment Committee	2021
Admissions Committee	2021

STATCOM Advisor 2020-Present
Policy Chair, Sexual Violence Committee at Ohio State University 2013-2014

Referee

Bayesian Analysis, *Environmetrics*, *The American Statistician* , *Journal of the American Statistical Association*

BAR ADMISSIONS

West Virginia, United States District Court for the Southern District of West Virginia, Iowa

HONORS AND AWARDS

Distinguished University Fellowship, 2 years, 2015, 2019
Whitney Award, 2019 (Best Research Associate)
Lubrizol Fellowship, Summer 2017
Hite Family Endowment Recipient, full tuition, 2012-2015
Dean's Scholar 2013-2014 (Top 15%)
CALI Excellence for the Future Award, Middle East Conflict, 2014 (top grade)
CALI Excellence for the Future Award, Dispute Resolution in Employment, 2015 (top grade)
Taylor Summer Undergraduate Research Fellow, 2010

Last updated: December 21, 2021

F Susan Vanderplas CV

Susan Vanderplas

Curriculum Vitae

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3310 Holdrege Street
Lincoln, NE 68483-0961
402-472-7290
susan.vanderplas@unl.edu
srvanderplas

Education

2015 **PhD**, *Statistics*, Iowa State University.
Dissertation: The Perception of Statistical Graphics

2011 **MS**, *Statistics*, Iowa State University.

2009 **BS**, *Psychology & Applied Mathematical Sciences*, Texas A&M University.

Professional Experience

2020 **Assistant Professor**, *Statistics Department*, University of Nebraska, Lincoln.

2018–2019 **Research Assistant Professor**, *Center for Statistics and Applications in Forensic Evidence*, Iowa State University.

2018–2019 **Statistical Consultant**, *Nebraska Public Power District*.
Provided individual mentoring and project leadership to continue the Business Intelligence Embedded Agent program and provide support for R-related projects.

2015–2018 **Statistical Analyst**, *Nebraska Public Power District*.

2015–2015 **Postdoc**, *Iowa State University Office of the Vice President for Research*.

Scholarship

Contribution percentages estimated from git contributions using `git fame` where possible. Not all projects have github repositories for which this is meaningful.

Journal Publications

14. 2021 Hofmann, Heike, **Susan Vanderplas**, and Alicia Carriquiry (2021). "Treatment of Inconclusives in the AFTE Range of Conclusions". In: *Law, Probability, and Risk*. Submitted Oct 2020, Accepted Dec 2020.
Contribution: Writing (50%).

13. 2020 **Vanderplas, Susan**, Christian Röttger, Di Cook, and Heike Hofmann (Nov. 2020). "Statistical Significance Calculations for Scenarios in Visual Inference". In: *Stat*. Accepted Oct 2020.
Contribution: Programming and analysis (30%), Writing (65%).

12. 2020 **Vanderplas, Susan**, Alicia Carriquiry, Heike Hofmann, James Hamby, and Xiao Hui Tai (2020). "An introduction to firearms examination for researchers in statistics". In: *Handbook of Forensic Statistics*. Ed. by Banks, D., Kafadar, K., Kaye, D., and Tackett, M. New York: Chapman and Hall/CRC 2020. DOI: 10.1201/9780367527709.
Contribution: Writing (50%).

11. 2020 **Vanderplas, Susan**, Melissa Nally, Tylor Klep, Cristina Cadevall, and Heike Hofmann (Jan. 2020). "Comparison of three similarity scores for bullet LEA matching". In: *Forensic*

Science International. DOI: 10.1016/j.forsciint.2020.110167.
Contribution: Programming and analysis (20%), Writing (55%).

10. 2020 — **Vanderplas**, **Susan**, Dianne Cook, and Heike Hofmann (Mar. 2020). "Testing Statistical Charts: What Makes a Good Graph?" In: *Annual Review of Statistics and Its Application* 7.1, pp. 13.1–13.28. DOI: 10.1146/annurev-statistics-031219-041252.
Contribution: Writing (85%).

9. 2019 — Rutter, Lindsay, **Susan VanderPlas**, Dianne Cook, and Michelle Graham (2019). "ggenealogy: An R Package for Visualizing Genealogical Data". In: *Journal of Statistical Software* 89.13, pp. 1–31. ISSN: 1548-7660. DOI: 10.18637/jss.v089.i13.

8. 2019 — **VanderPlas**, **Susan**, Ryan Goluch, and Heike Hofmann (2019). "Framed! Reproducing and Revisiting 150 year old charts". In: *Journal of Computational and Graphical Statistics*. DOI: 10.1080/10618600.2018.1562937.
Contribution: Programming and analysis (60%), writing (50%).

7. 2019 — Sievert, Carson, **Susan VanderPlas**, Jun Cai, Kevin Ferris, Faizan Uddin Fahad Khan, and Toby Dylan Hocking (2019). "Extending ggplot2 for linked and animated web graphics". In: *Journal of Computational and Graphical Statistics* 28.2, pp. 299–308. DOI: 10.1080/10618600.2018.1513367.

6. 2017 — **Vanderplas**, **Susan** and Heike Hofmann (2017). "Clusters Beat Trend!? Testing Feature Hierarchy in Statistical Graphics". In: *Journal of Computational and Graphical Statistics* 26.2, pp. 231–242. DOI: 10.1080/10618600.2016.1209116.
Contribution: Programming and analysis (90%), writing (50%).

5. 2017 — *Submitted as an invited response to Donoho's "50 years of Data Science"*.
Hofmann, Heike and **Susan Vanderplas** (2017). "All of This Has Happened Before. All of This Will Happen Again: Data Science". In: *Journal of Computational and Graphical Statistics* 26.4, pp. 775–778. DOI: 10.1080/10618600.2017.1385474.
Contribution: Writing (75%).

4. 2016 — **Vanderplas**, **Susan** and Heike Hofmann (2016). "Spatial Reasoning and Data Displays". In: *IEEE Transactions on Visualization and Computer Graphics*. DOI: 10.1109/TVCG.2015.2469125.
Contribution: Programming and analysis (90%), writing (75%).

3. 2015 — — (2015). "Signs of the Sine Illusion - why we need to care". In: *Journal of Computational and Graphical Statistics* 24.4, pp. 1170–1190. DOI: 10.1080/10618600.2014.951547.
Contribution: Programming and analysis (50%), writing (60%).

2. 2010 — Towfic, Fadi, **Susan VanderPlas**, Casey A Oliver, Oliver Couture, Christopher K Tuggle, M Heather West Greenlee, and Vasant Honavar (2010). "Detection of gene orthology from gene co-expression and protein interaction networks". In: *BMC bioinformatics* 11.Suppl 3, S7. DOI: 10.1186%2F1471-2105-11-S3-S7.

1. 2009 — Hull, Rachel, Heather Bortfeld, and **Susan Koons** (2009). "Near-infrared spectroscopy and cortical responses to speech production". In: *The open neuroimaging journal* 3, p. 26. DOI: 10.2174%2F1874440000903010026.

Other Publications

2. 2019 — Carriquiry, Alicia, Heike Hofmann, Xiao Hui Tai, and **Susan VanderPlas** (2019). "Machine learning in forensic applications". In: *Significance* 16.2, pp. 29–35. DOI: 10.1111/j.1740-9713.2019.01252.x.
Contribution: Writing (50%).

1. 2013 — Budrus, Sarah, Susan Vanderplas, and Dianne Cook (2013). "In tennis, do smashes win matches?" In: *Significance* 10.3, pp. 35–38. DOI: 10.1111/j.1740-9713.2013.00665.x.

In Progress **Perception of Log Scales** Assessment of perception and use of log scales to display exponential growth. Data collection stage.

A Convolutional Neural Network for Outsole Recognition Use CNNs to automate identification of class characteristics in images of footwear outsoles. Revision stage.

Bullet Signature Resampling Method for resampling bullet signatures used to calculate match and non-match score distributions.

Grants

2021 2022 **NIJ R&D in Forensic Science**, *Automatic Acquisition and Identification of Footwear Class Characteristics*, PI, Funded, $380,650 total.

2020 2025 **NIST**, *Center for Statistics and Applications in Forensic Evidence*, PI, Funded ($20 million total, $456,930 sub-award).

2020 2023 **USDA CIGOFF**, *Improving the Economic and Ecological Sustainability of US Crop Production through On-Farm Precision Experimentation*, PI, Funded ($4,000,000 total, $400,000 UNL subcontract split between 3 UNL PIs).

2021 2022 **USDA NIFA AFRI**, *Corn Residue Adaptive Grazing Strategies*, Collaborator, Funded, $300,000.

2020 **USDA NIFA AFRI**, *Practical Framework to Facilitate Adoption of In-Season N Management Technology in Commercial Fields*, Collaborator, Not funded, $300,000.

2020 **NSF**, *AI Institute: AgroAI: The Institute for Advancing Agriculture and Food in a Changing World Using AI*, Collaborator, Not Funded, Total grant $20 million, UNL subcontract request $3,555,327.

2020 2023 **NSF**, *Overcoming the Rural Data Deficit to Improve Quality of Life and Community Services in Smart & Connected Small Communities*, PI, Funded ($1,500,000 total, $123,445 subcontract).

2019 **USDA AFRI-SAS**, *A Cyber-Physical System for Data-Intensive Farm Management*, PI, Not funded, $3,000,000 total.

2019 **NIJ R&D in Forensic Science**, *Statistical Infrastructure for the Use of Error Rate Studies in the Interpretation of Forensic Evidence*, Collaborator, Funded for FY 2019, $197,699 total, $57,596 ISU sub-award.

2018 **NIJ R&D in Forensic Science**, *Passive Acquisition of Footwear Class Characteristics in Local Populations*, PI, Not funded, $383,104.

2018 **NIJ R&D in Forensic Science**, *Evaluating Photogrammetry for 3D Footwear Impression Recovery*, PI, Not funded, $281,755.

Invited Talks

2021 **How do you define a circle? Perception and Computer Vision Diagnostics**, *JSM*, Section on Statistical Graphics, Seattle, WA.

2020 ~~**Do You See What I See? Leveraging Human Perception in Computer Vision Tasks**~~, *JSM*, Section on Statistical Graphics, Online, Session Cancelled due to COVID.

2020 **Perception and Visual Communication in a Global Pandemic**, *Data Science, Statistics, and Visualization Conference*, SAMSI, Online.

2020 **One of these things is not like the others: Visual Statistics and Testing in Statistical Graphics**, *Data Science Symposium*, South Dakota State University, Brookings, SD.

2020 **Big Data, Big Experiments, and Big Problems**, Plant and Animal Genome, San Diego, CA.

2019 **Statistical Lineups for Bayesians**, *JSM*, Section on Statistical Graphics, Denver, CO.

2018 **Clusters Beat Trend!? Testing Feature Hierarchy in Statistical Graphics**, *SDSS*, Reston, VA.

2015 **Animint: Interactive Web-Based Animations Using Ggplot2's Grammar of Graphics**, *JSM*, Seattle, WA.

2014 **The curse of three dimensions: Why your brain is lying to you**, *JSM*, Section on Statistical Graphics Student Paper Session, Boston, MA.

Contributed Talks

2021 **Welcome to Forensic Statistics**, *Data Mishaps Night*, Online.

2018 **Framed! Reproducing 150 year old charts**, *JSM*, Vancouver, BC.

2017 **A Bayesian Approach to Visual Inference**, *JSM*, Baltimore, MD.

2016 **Clusters Beat Trend!? Testing Feature Hierarchy in Statistical Graphics**, *JSM*, Chicago, IL.

2015 **Visual Aptitude and Statistical Graphics**, *InfoVis*, Chicago, IL.

2015 **Animint: Interactive, Web-Ready Graphics with R**, *Great Plains R User Group*, Sioux Center, IA.

2014 **Do You See What I See? Using Shiny for User Testing**, *JSM*, Boston, MA.

2013 **Signs of the Sine Illusion – why we need to care**, *JSM*, Montreal, ON.

Internal Talks

2021 **Exploring Rural Quality of Life Using Data Science and Public Data**, *QQPM Seminar*.

2021 **Inconclusive Conclusions: Biases and Consequences**, *Law and Psychology Brown Bag Seminar*.

2021 **Visual Statistics: Communication and Graphical Testing**, *Animal Science Seminar*.

2021 **How to Make Good Charts**, *Biological and Systems Engineering GSA*.

2020 **Statistical Evaluation of Firearms and Toolmark Evidence**, *Statistics Department Seminar*.

Software

Dates show initial involvement; only packages which are no longer maintained have end dates.

2020 `vinference`, *Analysis of visual inference experiments.*

2019 `ShoeScrubR`, *Cleaning shoe print data for future statistical analysis.*

2019 `groovefinder`, *Identification of grooves in scans of bullet land engraved areas.*

2018 `ShoeScrapeR`, *Acquisition of Shoe Images and Metadata from Online Retailers.*

2018 `bulletxtrctr`, *Automated matching of 3d bullet scans.*

2018 `x3ptools`, *Reading, manipulating, and visualizing x3p files.*

2018 `bulletsamplr`, *Resampling of bullet signatures.*

2018 — **ImageAlignR**, *Image registration algorithms for forensics*.

2013–2015 — **animint**, *animated, interactive web graphics for R using d3.js*.

Teaching

2021 — **Stat 218 - Introduction to Statistics**, *University of Nebraska, Lincoln*, Online, asynchronous.

2020 — **Stat 850 - Computing Tools for Statisticians**, *University of Nebraska, Lincoln*, Hybrid, flipped classroom, synchronous, Course materials: https://srvanderplas.github.io/unl-stat850/.

2020 — **Stat 218 - Introduction to Statistics**, *University of Nebraska, Lincoln*, In person synchronous.
Mean evaluation: 4.2, Median: 4.0

2019 — **Stat 585 - Data Technologies for Statistical Analysis**, *Iowa State University*, In person synchronous.
Co-taught, assisted with curriculum development. Mean evaluation: 4.92, Median: 5.0

2017–2018 — **Business Intelligence Embedded Agent Program**, *Nebraska Public Power District*, Hybrid.
Design and implement a program to mentor employees, providing instruction in data science and opportunities to apply new skills within the company. Lead one-on-one and group mentoring sessions to create a sense of community and reinforce skills learned through online courses. 16 students.

2013–2014 — **R Workshops**, *Iowa State*, In person synchronous.
Introduction to R, ggplot2, data management and cleaning, package development, literate programming, and Shiny.

Mentoring and Advising

Graduate Students

2021 — **Jayden Stack**, *Statistics*, MS, Automatic Recognition of Shoe Class Characteristics.

2020–2021 — **Emily Robinson**, *Statistics*, Ph.D, Perception and Visual Inference.
Co-advised with Reka Howard

2020–2021 — **Denise Bradford**, *Statistics*, Ph.D, Data Science and Interactive Graphics.

2020 — **Ved Piyush**, *Statistics*, MS, Machine Learning and Computer Vision.

2019–2021 — **Joseph Zemmels**, *Statistics*, MS, Ph.D, Analysis and Matching of Cartridge Cases.
Completed MS (Spring 2020). Co-advised with Heike Hofmann.

2019–2020 — **Eryn Blagg**, *Statistics*, MS, Ph.D, Analysis of Wear Development in Three-Dimensional Shoe Scans. .
Completed MS (Spring 2020). Co-advised with Heike Hofmann

2018–2019 — **Miranda Tilton**, *Statistics*, MS, Footwear Class Characteristics and Computer Vision. .
Completed MS (Spring 2019).

Undergraduate Students

2021 — **Xinyu Liu**, *Actuarial Science and Computer Science*, UNL FYRE Program, Machine learning for shoe sole images.

2019 — **Jason Seo**, *Computer Science and Statistics*, Undergraduate Research, R package for visualization of neural networks using the python library keras-vis..

2018–2019 **Talen Fisher**, *Computer Engineering*, Undergraduate Research, Tools for working with x3p files, database design for storing bullet scans and intermediate analysis products..

Summer Research Programs

2019 **Molly McDermott and Andrew Maloney**, *Research Experience for Undergraduates*, Summer 2019, Bullet Scan Quality and Machine Learning.

2019 **Syema Ailia, Emmanuelle Hernandez Morales, Tiger Ji**, *Research Experience for Undergraduates*, Summer 2019, Rapid Quality Control Tools for Confocal Microscopy Scans.

2018 **Ben Wonderlin and Jenny Kim**, *Young Engineers and Scientists*, Summer 2018, Footwear Class Characteristics and Computer Vision.

Outreach

Forensic Practitioners

2021 **Blog Post**, *CSAFE*, Q&A - Treatment of Inconclusive Results in Error Rates of Firearm Studies (Link).

2021 **Webinar**, *CSAFE*, Treatment of Inconclusive Results in Error Rates of Firearm Studies.

2020 **CSAFE Firearms Workshop**, Invited Talk: Open Source Software in Forensics.

Service

Service to the Discipline

2021–2024 **Associate Editor**, *Journal of Computational and Graphical Statistics*.

2020–2023 **Associate Editor**, *R Journal*.

2020–2022 **Graphics Section Program Chair (2021)**, *ASA*, Official duties include planning JSM sessions in 2020 and running the Data Expo in 2022.

2020 **Program Committee (Graphics)**, *Symposium on Data Science and Statistics 2020*, Visualization Track co-chair.

2019–2021 **Gertrude Cox Scholarship Committee Member**, *ASA*.
Assisted with selection of the Gertrude Cox Scholarship recipients and honorable mentions

2019 **Uncoast Unconference Organizing Committee**, Des Moines, IA.
Organized the first R Uncoast Unconference to bring R developers in flyover country together for a 3-day event. Over 50% of the participants at the conference were women or minorities, and participants included students, academics, and industry R programmers with a variety of experience levels in R programming.

2017–2019 **Graphics Section Representative to the Council of Sections**, *ASA*.

Department and Institutional Service

2021 **Data Science Joint Committee**.
Committee of Math, Computer Science, and Statistics departments to develop a comprehensive undergraduate data science program.

2020–2021 **Seminar Organizer**.
Arrange speakers for the department seminar.

2020 **SCIL 101 Poster Judge**, *Fall Semester*.

2019–2020 **Undergraduate Program Committee**.
Design an undergraduate statistics major and submit the proposal to the university.

Training & Professional Development

2021–2022 **Peer Review of Teaching Program**.
Create a course portfolio for Stat 850 in order to assess course design and analyze student engagement and learning

2020 **New Faculty Development Program**.

2020 **Summer Institute for Online Teaching**.
Online course structure and backwards design principles

draft

Final Audit Report 2022-01-03

Created:	2022-01-03
By:	Heike Hofmann (hofmann@iastate.edu)
Status:	Signed
Transaction ID:	CBJCHBCAABAAHNQPRhECT9VGRKomhRKScWoLaXqqi6sx

"draft" History

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EXHIBIT 2

Reply to Response by FBI Laboratory filed in Illinois v. Winfield and Affidavit by Biederman et al. (2022) filed in US v. Kaevon Sutton (2018 CF1 009709)

Susan Vanderplas, Kori Khan, Heike Hofmann, Alicia Carriquiry

July 1, 2022

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1 Preliminaries

1.1 Scope

The aim of this document is to respond to issues raised in Federal Bureau of Investigation[1] and Alex Biedermann, Bruce Budowle & Christophe Champod[2].

1.2 Conflict of Interest

We are statisticians employed at public institutions of higher education (Iowa State University and University of Nebraska, Lincoln) and have not been payed for our time or expertise when preparing either this response or the original affidavit.[3] We provide this information as a public service and as scientists and researchers in this area.

1.3 Organization

The rest of the document precedes as follows: we begin by outlining our main points of agreement with the Federal Bureau of Investigation[4] (hereafter, FBI) and Biedermann, Budowle, and Champod[5] (hereafter, BBC) in Section 2. As a threshold issue, we consider the concept of a general discipline-wide error rate in Section 3 in order to correct statistical misconceptions in Biedermann, Budowle, and Champod[6]. We then describe the statistical concepts underlying our assessment of the discipline of firearms and toolmark examiners in Section 4. Finally, we address specific issues with participant and material sampling (Section 5), study design (Section 6), and the use of inconclusives (Section 7).

[1] *FBI Laboratory Response to the Declaration Regarding Firearms and Toolmark Error Rates Filed in Illinois v. Winfield* (Aff. filed in US v Kaevon Sutton dated May 3, 2022).

[2] *Forensic feature-comparison as applied to firearms examinations: evidential value of findings and expert performance characteristics* (Aff. filed in US v Kaevon Sutton dated April 28, 2022).

[3] Susan Vanderplas et al., *Firearms and Toolmark Error Rates* (Aff. filed in Illinois v Winfield, January 2022).

[4] *Supra* note 1.

[5] *Supra* note 2.

[6] *Supra* note 2.

2 Introduction

Reading the responses submitted to our original affidavit, there are some areas of broad agreement between the anonymous individuals at the FBI, Biederman, Budowle, and Champod, and ourselves:

- There are very good firearms examiners who have a very low false-identification rate.
- Firearms and toolmark examiners are observing real phenomena - the conclusions they draw are based in observable, verifiable markings on the evidence that can provide information about the likely source of the evidence.
- There should be additional research on firearms and toolmark examination focusing on scientific foundations and error rates.

Additionally, we agree with BBC that the current studies are not useful for identifying a domain-wide error rate.

However, we are statisticians. As statisticians, we regularly help other scientists design experiments that are able to make scientifically valid claims about observable phenomena. We have experience working in situations where lives hang in the balance when errors are made: public health, nuclear engineering, and the law, among others. In these situations, it is even more important that experimental designs be as rigorous as possible, and that the conclusions from the studies be interpreted as carefully as possible, because the consequences for being wrong are so serious. It is with this mindset that we approach the topic of error rate studies in firearms and toolmark examination. We make no apologies for the fact that we offer what may seem to be harsh critiques of the state of scientific evidence in this field. Our intent in approaching the discipline in this way is constructive: until the extent of the cancer is identified, treatment cannot begin.

3 Should a Discipline-Wide Error Rate be the Goal?

A fundamental point of contention in BBC is that discipline-wide error rates are not useful or productive. This point seems to be central to their argument, despite not being a focus of our statement. Instead, they argue that the existing validation studies are valuable information regardless of whether they can be generalized to the discipline.[7]

> A domain-wide error rate is, ultimately, a practical impossibility because there is constant variation in (i) the population of examiners (new examiners enter the field, others leave; individual proficiency evolves over time), and (ii) the types of firearms and ammunition manufactured (and subsequently present in general circulation). Thus, it is always possible to argue that existing studies are somehow

[7]Biedermann, Budowle, and Champod, *supra* note 2, pgs 22-23.

> imperfect, which renders the call for a domain-wide, contemporaneously valid error rate ultimately self-defeating. (BBC, pg. 8)

The question of whether a discipline-wide error rate is useful to the court is outside our area of expertise, so we do not address this. We note instead that, it is, in fact, possible to establish valid discipline-error rates with properly designed studies, and we take a moment to address some of BBC's misconceptions about this possibility.

Statistical inference does not require a stable population of examiners or firearms. A common example used to illustrate this fact in introductory statistics courses is a scenario where a company would like to estimate the lifetime of a specific model of light bulb. The company takes a random sample of 30 light bulbs from the production line and measures how long the light bulb takes to burn out. The student is then asked to use the lifetimes of the 30 sample light bulbs to calculate an interval describing the population average lifetime with a certain level of confidence. These calculations are valid even though the company is still manufacturing new light bulbs - that is, the population is not stable.

The perception that a stable population is required to derive inferences is not the only statistical misconception demonstrated by BBC. At the heart of this further confusion are two types of statistics: descriptive statistics, and inferential statistics. **Descriptive statistics** are statistics which describe characteristics of an observed data set, such as "The average height of the men in this room is 5 feet, 9 inches." **Inferential statistics**, by contrast, are statistics which take an observed data set and generalize the information from this data set to a wider set of individuals - the population. Inferential statements might include some discussion of variability, because while the sample value is known, inference to a population involves accounting for the variability inherent in the act of taking a sample from the population. An example would be the statement "We are 95% confident that the average height of a male in the United States is between 5 feet 8.5 inches and 5 feet 9.5 inches."

None of the authors of BBC are statisticians, nevertheless, they state "statisticians' primary focus [is] on inferential statistics" (Biedermann, Budowle, and Champod[8] pg. 22). This is incorrect. There are entire areas of statistical research focused on descriptive statistics. SV and HH specialize in and conduct research on some of these areas. As trained and practicing statisticians, both inferential and descriptive statistics are firmly within all of our areas of expertise.

We assume that BBC meant to imply that we chose to focus on inferential statistics in our initial statement as a matter of preference. We did not- we focused on how validation studies are currently being used. All statements we have reviewed thus far in this case have been inferential statements. For example, Federal Bureau of Investigation[9], page 4 states "In sum, the studies demonstrate that firearm/toolmark examinations, performed by qualified examiners in accordance with the standard methodology, are reliable and enjoy a very low false positive

[8] *Id.*
[9] *Supra* note 1.

rate." A descriptive statement would have read as: "In sum, the studies demonstrated that volunteer participants enrolled in the study enjoyed a low error rate on the test sets they chose to respond to." Similarly, the FBI/Ames study (cited by Federal Bureau of Investigation[10] on page 4) makes the inferential statement "[This] study was designed to provide a representative estimate of the performance of F/T examiners who testify to their conclusions in court."[11] A descriptive statement would read: "This study was designed to provide estimates of the performance of the 173 F/T examiners who participated in the study."

The FBI and BBC cannot have their cake and eat it too– if the use of inferential statements persists, then the problems with study design continue to be a relevant issue (Section 5 and Section 6). The BBC authors argue that we are concealing useful descriptive information by arguing that the validation studies' designs makes them inappropriate for inference. As previously stated, we made no arguments about descriptive information because no one is using validation studies for that purpose. We take a moment to highlight a few points relevant to using descriptive information in the context of error rate studies.

Descriptive information can be of varying quality. The following three statements are all descriptive statements:

- My son only answered one question incorrectly on his math test.
- My son only answered one question incorrectly on his math test, but didn't answer 30% of the questions.
- My son only answered one question incorrectly, but didn't answer 30% of the questions. The questions he skipped were frequently answered incorrectly by his peers.

In day to day life, a speaker conveying the first statement when the third is true would be considered misleading. Yet, error rate studies currently make claims resembling the first statement, despite having collected sufficient information to make at least one of the other two statements. These statements then, in turn, are conveyed to courts, including this one (see Federal Bureau of Investigation[12] at pg. 4). As this example shows, it is possible to create misleading descriptive statistics, but the damage potential is much higher when such statistics are then used for inferential purposes.

With complicated data, misleading descriptive statistics can be created unintentionally. To counteract this, in most other scientific areas, honoring other researchers' requests for de-identified data (data which cannot identify an individual) is considered an essential part of good science. On December 21, 2021 we requested the FBI/Ames study data from Ames lab researchers and were told the FBI has not given Ames researchers permission to share the data. On the same date, we requested the data from the FBI contact, Keith Monson. Our requests have gone unanswered. In any case, whether because the researchers do not have the

[10] *Id.*

[11] Keith L Monson, Erich D Smith & Stanley J Bajic, *Planning, design and logistics of a decision analysis study: The FBI/ames study involving forensic firearms examiners*, 4 Forensic Science International: Synergy 100221 (2022).

[12] *Supra* note 1.

statistical sophistication to take a more nuanced look at their data, or because they do not want to share the data so that others may provide that additional nuance, we are stuck in a situation where the only solution is to describe the shortcomings of the data and studies that are available.

4 Types of Validity

As we will spend the rest of this document discussing validation studies, it is worth taking the time to discuss the different kinds of scientific validity. Different factors in the design of firearms and toolmark studies affect different types of validity. In addition, the consequences for sub-optimal experimental design, study execution, and statistical analysis are different depending on which type of validity is impacted by the sub-optimal choices.

First, let us start off with the notion of **validity** in general. Validity is a measure of how the results of research represent some facet of reality. That is, validity is a mapping between the scientific process of experimentation and analysis of results and the real world. Throughout this section, we'll consider a simple question: How does the amount of water provided influence the growth of plants as measured by the height of the seedling above the ground?

Internal validity[13] is the extent to which the variable manipulated in the experiment (the **independent variable**) can be linked to the observed effect (the **dependent variable**). In our example, the independent variable is the amount of water provided and the dependent variable is the height of the seedlings. **Internal validity** measures how well the experiment can show cause-and-effect or rule out alternate explanations for its findings (e.g. sources of systematic error or bias). Internal validity is often achieved by controlling other factors that may affect the dependent variable. For instance, in our study of water and seed growth, it would be useful to ensure that other factors affecting plant growth (fertilizer, soil quality, light availability) are as consistent as possible so that only the effect of the amount of water is seen in the results.

External validity[14] is the extent to which the experimental results can be generalized beyond the study. That is, given the results of the study, what can I say about the real world? In our example, we would like to be able to say that if our study reveals that seeds grow better when there is more water available, that this would also be true in a garden setting. External validity is always affected by the amount of experimental control we implemented (which affects internal validity) and the number of variables our experiment covers. If we are only varying the levels

[13]While Wikipedia is often not reliable for controversial topics, it does contain good information and examples for many statistical concepts. We link to it throughout this section because it is easily accessible, unlike the statistical textbooks which would provide more respectable citations but might require a library request. The page on internal validity contains a number of good illustrations of how internal validity is established and/or threatened by experimental design considerations. Internal validity, Wikipedia (2022), https://en.wikipedia.org/w/index.php?title=Internal_validity&oldid=1089044842 (last visited Jun 20, 2022).

[14]External validity, Wikipedia (2021), https://en.wikipedia.org/w/index.php?title=External_validity&oldid=1060911552 (last visited Jun 20, 2022).

of water available, for instance, it would be hard for our conclusions to generalize effectively to a garden where e.g. temperature fluctuations may also impact seed growth. When trying to ensure both internal and external validity, experimenters must experimentally manipulate many different factors, ensuring that all combinations of the factors are tested. While this is tedious but feasible in some settings, it is more difficult in other settings where we have less experimental control - for instance, we cannot *assign* sex to people for the purposes of experimentation, but we can ensure that we test individuals of both sexes. When human beings are involved in experiments as participants, external validity is partially dependent on whether our sample matches our population on various dimensions of interest: in tests of examiner error rate, for instance, we probably do not need to ensure that our sample participants' height is a match to the wider population, but we should ensure that the sample's experience is representative of the wider population of firearms and toolmark examiners.

External validity is closely related to the notion of statistical **inference**, which is the ability to make broad statements about a population represented by an experimental sample.

A subset of external validity, **construct validity**[15] is the extent to which an experiment (method, study design, analysis, etc.) measures the real-life thing of interest. For instance, if we are more broadly interested in plant health in our seedling study, we would need to establish that seedling height is a good measure of overall plant health, at least over the range of time we are studying[16]. Showing construct validity requires that there is an unbroken link between the experiment and the real-world phenomenon. Construct validity can be threatened when participants are aware they are being observed (the Hawthorne effect), when there is bias in the experimental design (intentional or unintentional), when participants are aware of researcher expectations and desires, and when there are confounding variables that are not measured or assessed in the experiment. One critique of the closed-set study design[17] is that it under-estimates the false identification rate (in addition to a complete inability to estimate the false elimination rate)[18]; this is a critique based on the study's construct validity (and as a result, its external validity).

An additional concept contained within external validity is **ecological validity**[19]: the extent to which the study's procedures, measurements, and other design variables relate to the

[15] Construct validity, Wikipedia (2021), https://en.wikipedia.org/w/index.php?title=Construct_validity&oldid=1060911505 (last visited Jun 20, 2022).

[16] For instance, it is possible that during the germination and initial sprouting period, plant height is a good measure of health, but that after the initial plant is established, we might need to consider e.g. plant color, number of leaves, root depth, and so on as well. If this is the case, it is important that any statements about the broader construct are careful to identify the time period for which those observations might be valid.

[17] A closed-set study is one in which every unknown to be examined corresponds to a provided known sample. In closed-set studies, examiners can rely on the closest matching known sample to make an identification, even if in a casework situation with the same unknown and known sample, the examiner would return a different result.

[18] Heike Hofmann, Susan Vanderplas & Alicia Carriquiry, *Treatment of inconclusives in the AFTE range of conclusions*, 19 Law, Probability and Risk 317–364 (2021), https://doi.org/10.1093/lpr/mgab002.

[19] Ecological validity, Wikipedia (2022), https://en.wikipedia.org/w/index.php?title=Ecological_validity&oldid=1078684982 (last visited Jun 20, 2022).

real-world context. That is, does a study performed in a laboratory setting generalize to the outside world? For firearms and toolmark error rate studies, experimenters must establish that the study procedures are a good representation of the process of firearms and toolmark examination in casework - if, as in some historical studies, participants evaluated a low-quality photograph of a bullet through a microscope for the study, but need to evaluate actual fired ammunition in casework, the study might potentially lack construct validity. Mock-jury studies often provide individual participants with written transcripts, but this probably does not adequately mimic the experience of sitting on a jury, listening to testimony, observing the different participants in the trial, and then deliberating in a room with other individuals to reach consensus. Experimenters performing such studies may want to follow up the written transcript study with a study involving videos of a mock trial (to assess the effect of sitting through the trial) and then perform an additional group study where participants must deliberate as if on a jury in order to demonstrate that results have good ecological validity.

Another type of validity is **statistical validity**: the extent to which the statistical calculations and tests which summarize the experiment's results are believable. Statistical validity requires that sampling procedures, measurement procedures, and the statistical calculations are all appropriate for the experimental design and for the variables under investigation. This type of validity affects both internal and external validity, because the relationship between the independent and dependent variables is determined through statistical calculations (internal validity) but the ability to make statements about the population (external validity) is also a result of statistical calculations and statistical inference.

It is worth noting that almost any experiment conducted will not have perfect internal, external, statistical, construct, and ecological validity. However, it is important when assessing an experiment to determine whether there are threats to the different types of validity, and, if multiple experiments have been conducted on the same basic topic, whether the total set of experiments collectively demonstrates each type of validity. This is what is required to produce **convergent validity**, an idea mentioned by BBC (pg. 21). As we demonstrated in our initial statement, and will demonstrate again in this response, because the validation studies which currently exist have consistent flaws, it is not possible to take the total set of validation studies and argue that they have convergent validity.

5 Participant and Material Sampling: Threats to External Validity

> One of the primary concerns with error rates provided by "well-designed" studies is that even well designed, well-executed studies cannot compensate for sampling bias in the participant pool. That is, no matter how well the experiment is laid out, if the participants are not a representative sample from the population (in this case, all qualified firearms examiners in the United States), the results of the study do not generalize to that population. (Vanderplas et al., 2022)

In our initial statement, we identified sampling bias as a threat to external validity that we could not bound numerically through statistical measures. That is, we do not have enough information to assess whether studies conducted to date have a representative sample of firearms and toolmark examiners. While the FBI and BBC both remarked upon our "pessimistic" view of e.g. treatment of participant dropout rates, claiming it was incredibly unlikely every non-response would be an error. We stated as much in our initial statement. Our calculations served the intended purpose of providing an upper bound for the possible error rate. Currently, the calculation of error rates are assuming that no additional errors would have been made -which is also unlikely given the number of missing responses. This effectively calculates a lower bound for the error rate. However, unlike us, the researchers putting forth these estimates do not explicitly state their assumptions or that they have calculated a bound. As a result, casual observers (and the court) are left to assume that the error rate is the lower bound, which is misleading.

In the case of participant sampling, however, we cannot create upper and lower bounds for possible error rates. This does not mean that participant sampling concerns are not important to consider, however: biased sampling procedures are a consistent source of potential bias that affects every national validation study conducted in the US to date.

5.1 Voluntary Participation and Validity Concerns

We specifically identified that because studies use voluntary participants, the study participants are likely to differ from the wider population of firearms and toolmark examiners in important ways, but in ways that we cannot statistically quantify.

The FBI correctly identified that there is no way to compel participation from participants in research studies conducted according to current federal guidelines.

> Since 1945, many organizations have adopted codes stating that voluntary and informed consent of human subjects in research is essential. The importance of this concept has been codified in the Code of Federal Regulations, which specifically requires that researchers obtain informed consent when using human subjects (45 C.F.R. § 46.101-122). These rules are binding on all federal agencies and contractors. (FBI 5)

While we cannot speak to whether this type of participation meets the requirements set out in 45 CFR 46.103, we note some error rate studies mention that participants were compelled to participate by their employer[20]. However, we agree that there are reasons why research

[20] "In order to get a broad cross-section of the latent print examiner community, participation was open to practicing latent print examiners from across the fingerprint community. A total of 169 latent print examiners participated; most were self-selected volunteers, while the others were encouraged or required to participate by their employers." (Bradford T. Ulery et al., *Accuracy and reliability of forensic latent fingerprint decisions*, 108 Proceedings of the National Academy of Sciences 7733–7738 (2011), https://www.pnas.org/doi/full/10.1073/pnas.1018707108 (last visited Jun 20, 2022))

studies have to make do with voluntary participation.

With a self-selected sample, it becomes even more critical to take steps to ensure the participants are representative of the population of interest. Interestingly, Federal Bureau of Investigation[21] mentions that clinical trials are conducted on volunteers. This comparison is not perfect[22], but the FBI's reliance on clinical trials is crucial because the sampling design in validation studies is so egregious relative to medicine (and other fields). The National Institute for Health (NIH) is our country's medical research agency. The NIH has very strict funding requirements: researchers are required to establish that their sample will be representative of the population, inclusive of minority groups, and otherwise will meet the very high bar set for experimental design and composition[23]. When working with volunteer participants, researchers use strategies like case matching, where two individuals are matched on every dimension that is feasible within the total set of volunteers and then these two individuals' performance on the drug vs. placebo is compared. In other studies, the full set of volunteers is not included in the study; instead, a demographically representative sample of the wider population is chosen from among the volunteers (within practicable constraints). Stated more broadly, medical researchers take care to ensure that the study design provides for both external and internal validity, working within the constraints of a population of volunteers. This additional care to ensure both internal and external validity is missing in FTE validation studies, which is why we raised the issue of representative samples in the first place.

Unlike medical trials, validation trials do not typically take steps to ensure the population is representative. Some studies make an effort to at least not exclude participants, such as the Ulery et al.[24] study: "In order to get a broad cross-section of the latent print examiner community, participation was open to practicing latent print examiners from across the fingerprint community."

However, many arbitrarily adopt inclusion criteria requiring that participants be active examiners employed by a crime lab, currently conducting firearms examinations, members of AFTE, etc. For example, the FBI/Ames study cited by the FBI[25] has a number of inclusion criteria. It is not clear how the inclusion criteria were applied because the technical report[26] of the study's inclusion criteria disagrees with a peer-reviewed paper's[27] description of the inclusion requirements with the use of "and" and "or" for the listed conditions.

[21] *Supra* note 1.

[22] Examiners control their response to the black-box studies, where most people do not have conscious control over biological responses to e.g. drugs or vaccines, and we pointed out this distinction in our original response

[23] National Institutes of Health, *Inclusion of Women and Minorities as Participants in Research Involving Human Subjects | grants.nih.gov*, NIH Grants & Funding (2022), https://grants.nih.gov/policy/inclusion/women-and-minorities.htm (last visited Jun 18, 2022).

[24] *Supra* note 28.

[25] see Federal Bureau of Investigation, *supra* note 1 page 4

[26] Stanley Bajic et al., *Validation Study of the Accuracy, Repeatability, and Reproducibility of Firearm Comparisons*, 127 (2020).

[27] Monson, Smith, and Bajic, *supra* note 17.

- "Only respondents who returned a signed consent form and were currently conducting firearm examinations and were members of AFTE, or else were employed in the firearms section of an accredited crime laboratory within the U.S. or a U.S. territory were accepted into the study."[28]
- "Participation was limited to fully qualified examiners who were currently conducting firearm examinations, were members of AFTE, and were employed in the firearms section of an accredited public crime laboratory within the U.S. or a U.S. territory."[29]

There is never any justification given for the inclusion criteria, and there is some evidence these inclusion criteria are not representative of practicing F/T examiners. For example, we collected 60 unique expert witness curriculum vitae for F/T examiners from Westlaw Edge. If we use some of the criteria listed for the FBI/Ames study in Monson, Smith, and Bajic[30] only 63% were current AFTE members, 65% were employed by a public agency, and only 38% were both current AFTE members and employed by a public agency. In other words, 62% of these examiners would have been excluded from the FBI/Ames study using less than half of the inclusion criteria defined in that study. More problematically, there is also evidence that some inclusion criteria that have been used have been associated with reduced error rates in other disciplines. For example, Heidi Eldridge, Marco De Donno & Christophe Champod[31] reports that palmar print examiners employed outside of the U.S. disproportionately account for false positives. The FBI/Ames study explicitly excludes F/T examiners employed outside of the U.S.

These sources of bias discussed in this section are subtle, and require a close reading of the study's methods section. While many scientific journals rely on peer review to identify and correct these issues, the review which takes place in trade journals such as the AFTE journal do not necessarily catch and correct issues with the description and presentation of study results. However, all journals rely on the study's authors to describe the study recruitment and selection methods clearly and in detail. This does not typically happen in validation studies.

Statistically, what is required for external validity is to argue that the sample is **representative** of the population characteristics[32]. This burden falls on the experimenters; it is up to them to make the affirmative argument that the sample is representative of the population. We have suggested that polling AFTE members might reach a set of participants who are more

[28] Bajic et al., *supra* note 34.

[29] Monson, Smith, and Bajic, *supra* note 17.

[30] *Id.*

[31] *Testing the accuracy and reliability of palmar friction ridge comparisons–a black box study*, 318 Forensic Science International 110457 (2021).

[32] Contrary to the selected quote in BBC pg. 19, we state this explicitly in our original statement. The suggestion that a full census of the population of examiners is necessary is because such a census would make it easier for researchers to make the representative argument about an individual study. The census would need to consist of demographic characteristics: training, experience, gender, education; tracking this same demographic information in the validation studies would allow researchers to compare the two sets of values and make the argument that the sample is representative of the wider population.

invested in the discipline and that individuals who have the time and/or lower caseloads to participate in studies might not be representative of the wider population of firearms examiners in part because these are things that were not addressed by study authors when describing the participant selection in the study. In order to make this argument, study authors need to track participation, compute demographic summaries of the sample which may be relevant (geography, age, training level, case load, professional memberships), and compare these to the wider population. To support this, it might be helpful if accrediting organizations maintained a register of people who have accreditation in each discipline to assist with having some statistics of the population to compare against.

5.1.1 Statistical Language and Logic

Both the FBI and BBC raised the issue of hypothetical language which was used in our initial affidavit, reproduced here to provide context.

> there are many potential lurking covariates that would meaningfully affect the error rates estimated by the studies. For instance, it is possible that experienced examiners are more likely to volunteer to participate in these studies out of a sense of duty to the discipline: these examiners might have lower error rates due to their experience, which would lead to an estimated error rate that is lower than the error rate of the general population of all firearms examiners (including those who are inexperienced). In fact, in studies which differentiate between trainee and qualified examiners, we find a higher error rate among trainees (Duez et al. 2018). (Vanderplas et al., 2022, pg. 5)
>
> There are many variables which might be expected to increase likelihood of volunteering for a study and also change the expected error rate: education, experience, confidence, amount of time available for study participation. (Vanderplas et al., 2022, pg. 5)

BBC specifically called out these statements:

> This critique is a rhetorically subtle formulation because it uses a true statement (here: higher error rate among trainees) to create a doubt for which no direct evidence is provided. That is, Vanderplas et al. (2022) give no evidence for whether experienced examiners are actually more inclined to participate than less experienced examiners. (BBC pg. 25)

And the FBI also responded:

> The Statement fails to cite any evidence to support this claim. In fact, less experienced examiners were commonly represented as participants in numerous studies. Several studies listed in Table 1 have queried the experience level of participant examiners, and those analyses concluded that experience level did not significantly

affect performance. If sampling bias had affected the outcome of one or more of these studies, one would expect the rate of reported false positives to vary considerably. (FBI pg. 7)

It should be noted that the rhetorical device employed in our original statement is common in statistics; it is not intended to mislead, but it does make the implicit assumption that the reader is familiar with scientific logic. The presence of a confounding variable (a variable whose effect on the response cannot be separated from the explanatory variable) is sufficient to remove our ability to make a causal statement about the association between two variables (e.g. the explanatory variable causes the change in the response variable)[33]. Thus, statisticians will tend to make statements which raise the presence of a confounding (or "lurking") variable (in this case, an examiner's experience, duty, education, confidence, and available time) that might co-vary with the dependent variable (in this case, the likelihood that an examiner self-selects into a study). These statements are almost always hypothetical because the presence of such a variable is sufficient to raise doubt about the results[34]. In this case, the presence of such lurking variables without the ability to compare the volunteer sample's demographics to the wider demographics of the population makes it logically difficult to argue that results from a self-selected sample can be generalized to the population.

In addition, we have asked for the information which would allow us to make these hypothetical statements more concrete by applying statistical techniques for correcting estimates affected by drop-out rates. Unfortunately, our requests have been rebuffed: it is common for forensic scientists to decline or ignore requests to share study data with other researchers. This is contrary to the widespread understanding of the requirements of ethical science[35] as well as the norms for research practice in many other disciplines (even disciplines which collect human-subjects data subject to federal protection). As statisticians, we commonly post our (de-identified) data on sites such as GitHub or FigShare for archival purposes as well as to enable other researchers to access the data, statistical computations, and manuscript preparation records[36].

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[33]Section 4.1 Summary, Nathan Tintle et al., Introduction to statistical investigations (2015).

[34]One easy example of a lurking variable is that the number of baby births are correlated with the number of storks in European countries. It would be relatively easy to falsely draw the conclusion that storks are associated with babies, but this ignores the lurking variable of the geographic size (and population size) of the country. Causation cannot be inferred when there are lurking variables or when the study is observational in nature. Alex Mayyasi, *Do Storks Deliver Babies?*, Priceonomics (2014), https://priceonomics.com/do-storks-deliver-babies/ (last visited Jun 23, 2022).

[35]Howard Bauchner, Robert M. Golub & Phil B. Fontanarosa, *Data Sharing: An Ethical and Scientific Imperative*, 315 JAMA 1238–1240 (2016), https://doi.org/10.1001/jama.2016.2420 (last visited Jun 23, 2022); Clifford S. Duke & John H. Porter, *The Ethics of Data Sharing and Reuse in Biology*, 63 BioScience 483–489 (2013), https://doi.org/10.1525/bio.2013.63.6.10 (last visited Jun 23, 2022); Michael W. Ross, Martin Y. Iguchi & Sangeeta Panicker, *Ethical aspects of data sharing and research participant protections*, 73 American Psychologist 138–145 (2018); Carol Tenopir et al., *Data Sharing by Scientists: Practices and Perceptions*, 6 PLOS ONE e21101 (2011), https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0021101 (last visited Jun 23, 2022).

[36]One example of this is the GitHub repository for our paper on inconclusives in the AFTE range of conclusions, available at https://github.com/heike/inconclusives. All of the data and code are available for anyone to

An additional point of contention here is that the FBI states that "those analyses concluded that experience level did not significantly affect performance". The FBI is overstating their claim here, as well as selecting only studies which support their conclusion. Chapnick et al. (2021)[37] found that error rates for trainees were higher than those for qualified examiners. Baldwin (2014)[38] explicitly did not examine trainee examiners:

> Although it might be desirable to understand how non-practicing or untrained participants might perform under the same circumstances as trained examiners, there are important statistical reasons for not including trainees. The expected rates of error are low enough that dividing our participant pool into subgroups that are trained and not trained would add cost to the study without adding enough participants to allow a precise measurement of error rates for this group of trainees. It was deemed more important to measure the error rates for trained practicing examiners accurately and precisely than to measure the effect of another variable with much less precision and accuracy. (Baldwin 2014, pg. 7)

The only other mention of experience in Baldwin (2014) involves a finding of a weak correlation between the number of inconclusive calls and years of training:

> There are mild inverse correlations between the number of inconclusive/nonresponse calls made with the known different-source cases, and the reported number of years of training (correlation = -0.1393) and number of years of experience (correlation = -0.1034); that is, there is a weak tendency for examiners with more training or experience to make fewer inconclusive calls. (Baldwin 2014, pg. 16)

This is not a conclusion that experience does not affect error rates; while the findings reported here are not evaluated for statistical significance, and may not rise to meet that bar, they do explicitly highlight the possibility that experience is associated with an examiner's rate of reporting inconclusive results. In addition, there is no statistical test of whether error rates are related to experience anywhere else in the Baldwin paper.

Finally, the FBI's final response to our hypothetical, "If sampling bias had affected the outcome of one or more of these studies, one would expect the rate of reported false positives to vary considerably.", is false, likely because it stems from a misunderstanding of the difference between random error and bias. Sampling error is the error in an estimate due to the difference between one sample and the next - that is, who is and is not included in the study - due to random sampling. Random sampling ensures that over many different samples, we still produce **unbiased** estimates because the sampling method itself is not biased. The problem is that when the sampling method itself is biased (and, in many cases, biased in the same structural

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access, in addition to the full set of edits to the manuscript draft over time.

[37] Chad Chapnick et al., *Results of the 3D Virtual Comparison Microscopy Error Rate (VCMER) Study for firearm forensics*, 66 Journal of Forensic Sciences 557–570 (2021), https://onlinelibrary.wiley.com/doi/abs/10.1111/1556-4029.14602 (last visited Dec 6, 2021).

[38] David P. Baldwin et al., *A Study of False-Positive and False-Negative Error Rates in Cartridge Case Comparisons:*, (2014), http://www.dtic.mil/docs/citations/ADA611807 (last visited Jan 29, 2020).

way), we have no statistical guarantees that the resulting estimates are similarly unbiased. In fact, we have reason to suspect that the structural biases might be similar across different studies because the sampling bias is of the same type in each study, which might well lead to a bias in one direction for the collective set of studies.

5.1.2 Assessment of Significance

While participant selection and inclusion bias is one of the biggest issues we identified, in that we cannot easily bound the effect it has on error rates, it is by no means the only issue with existing black-box studies. If the only issue with the studies that are typically cited in court in support of firearms and toolmark analysis as a discipline were that it included self-selected volunteers who may meaningfully differ from the population, then it would be reasonable to interpret the results of these studies with that caveat in mind. However, the situation as it currently stands is one of a rowboat: if there is only one small hole in the rowboat, the boat can stay afloat while its occupants bail it out; if there are many holes in the rowboat of varying sizes, it is much more likely that the boat will sink. So it is with the error rates from these studies: there are many flaws in the studies, and while we can bound the effect on the error rates for some flaws, the overall effect is that the studies are sinking.

5.2 Material Sampling

In our original statement, we argue that as with examiners, we need to be able to make the claim that firearms studies cover a representative set of ammunition and firearm combinations in order to suggest that such studies are broadly generalizable. We are not the first group of statisticians to highlight this issue: the problem is mentioned in the 2009 NRC report[39], follow-up experiments have been proposed for several different previously published studies[40], and the 2016 PCAST report[41] described the necessary characteristics for studies establishing foundational validity, including

> "The studies must involve a sufficiently large number of examiners and must be based on sufficiently large collections of known and representative samples from relevant populations to reflect the range of features or combinations of features that will occur in the application." (PCAST pg. 52)

[39] Strengthening forensic science in the United States: A path forward, (National Research Council (U.S.) ed., 2009).

[40] C. Spiegelman & W. A. Tobin, *Analysis of experiments in forensic firearms/toolmarks practice offered as support for low rates of practice error and claims of inferential certainty*, 12 Law, Probability and Risk 115–133 (2013), https://academic.oup.com/lpr/article-lookup/doi/10.1093/lpr/mgs028 (last visited Oct 23, 2018).

[41] President's Council of Advisors on Science and Technology, *Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature Comparison Methods*, (2016), https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf (last visited Mar 7, 2019).

The FBI response misstates our position as much more extreme than the reality:

> The Statement claims that existing firearms error rate studies cannot reflect an accurate error rate because they fail to encompass the full range of firearms and ammunition available to the public and are thus not representative of samples encountered during casework. (FBI pg. 8)

Instead, they argue that it would be better to focus on manufacturing methods:

> No single study (or even numerous studies) can fully capture all firearms and ammunition that currently exist in the United States. However, the more relevant variable to study is the manufacturing processes used to create these firearms that impart the class and individual characteristics analyzed during an examination. (FBI pg. 8)

We largely concur, despite the attempts to paint our position as so extreme as to require that studies exist for all combinations of firearms and ammunition which currently exist in the United States. However, it is important for those conducting such studies to identify the manufacturing method and to list the types of weapons a study might be reasonably applied to on the basis of similar manufacturing. That is, the authors of a study should be responsible for outlining the reasonable scope of generalization for a study, and this should be explicitly stated in the discussion of the study's results.

BBC have similar objections to our desire to see better combinatorial studies, but for different reasons.

> "In Section 5 of Vanderplas et al. (2022, at pp. 6–7), the authors mention that existing studies cover only a limited number of firearms and ammunition types, thus preventing the possibility to generalize…" (BBC pg. 25-26; additional quotes from our affidavit are provided)

In their response, they highlight their insistence that there is no average examiner and no average combination of firearm and ammunition.

> "Second, as much as there is no"average" examiner, there is no "average" combination of firearm and ammunition. Instead, there are many firearm and ammunition categories (or types) for which a single average error rate could not meaningfully reflect examiner performance. It would be a too optimistic figure for reputedly difficult firearm and ammunition types, and too conservative one for less challenging comparison pairs. However, it would be exaggerated to require that an expert has previously seen (i.e., worked with) all possible combinations of firearms and ammunition." (BBC pg. 26)

The critique of our position by BBC represents a fundamental misunderstanding as to why we want to see a broad set of studies on manufacturing methods and ammunition types: it is not to determine an average combination of firearm and ammunition, or an average error rate, or to ensure that experts have worked with all possible combinations of firearms and ammunition. Statistics tends to be only peripherally concerned with averages: instead, we study variability and its effect on the different estimates we compute. When we indicate that part of the scientific foundation for firearm and toolmark studies is that we understand the ways in which marks might vary based on firearm manufacturing method and/or type of ammunition, it is because we want to be able to assess the external validity of the error rate studies across the wide range of conditions found in case work. While we addressed the issue of a general discipline-wide error rate as being within the range of statistics in an earlier section, this further illustrates the misconceptions that BBC have about the use of statistics. It is precisely because of the variability in difficult firearm and ammunition types vs. less challenging comparison types that we need broad studies: we recognize that variability and want to scientifically establish the consequences for error rates.

If we return momentarily to the grade-school science study we proposed in the validity section, we are essentially arguing that it is important to understand not only how plant growth changes with watering, but to ensure that those same findings hold across different temperature ranges and soil types commonly encountered in spring gardens. Without systematic manipulation of those variables across some studies that rely on the same principles of plant biology and development, we cannot ensure that our study's findings generalize well to new conditions.

Just as we want to ensure that validation studies can be generalized to the population of examiners and do not contain systematic biases that might over- or under-estimate the error rate of firearms and toolmark comparisons, we also want ensure that error rate studies are conducted on types of firearms (or manufacturing methods) and ammunition which are likely to be compared in casework. That is, our concerns about firearm manufacture and ammunition materials boil down to concerns about the *external validity* of error rate studies. At the risk of making another hypothetical statement, if error rate studies are conducted on combinations of firearms and ammunition which are known to mark well[42], then there is a risk that the error rate studies under-estimate the error rates which might be encountered in casework, where not all combinations of ammunition and manufacturing method are idealized. When there has

[42] We are not experts on the intricacies of different types of ammunition, but it is well known (and oft referenced in scientific publications in the field) that some types of ammunition do not "mark" well due to coatings or other material treatments of the ammunition surface. Examples of studies which investigate or discuss the phenomena of "marking well" include Nicole Groshon, *The effects of: Lacquered ammunition on the toolmark transfer process*, 2020, https://indigo.uic.edu/articles/thesis/The_Effects_of_Lacquered_Ammunition_on_the_Toolmark_Transfer_Process/13475034/files/25862940.pdf (last visited Jun 20, 2022);Valentina Manzalini et al., *The effect of composition and morphological features on the striation of .22LR ammunition*, 296 Forensic Science International 9–14 (2019), https://www.sciencedirect.com/science/article/pii/S0379073818310624 (last visited Jun 20, 2022); Deion P Christophe, *Approaching Objectivity in Firearms Identification: Utilizing IBIS BULLETTRAX-3D's Sensor Capturing Technology*, 2011, https://shareok.org/bitstream/handle/11244/324663/ChristopheDP2011.pdf?sequence=1 (last visited Jun 20, 2022).

not been any systematic attempt to assess the impact of these factors on error rates or on the visual information available to examiners that would be expected to influence error rates, this issue of external validity remains unresolved.

It is also worth noting that we are not the first statisticians to suggest thorough study of the discipline is necessary, nor the first to be accused of making impossible requests.

> "without understanding the proper design of experiments, modelling and sampling procedures, numerous articles in the firearms/toolmarks domain literature assert, and several judges have mistakenly observed or implied, that assessing rates of examiner error are impossible because every firearm ever made cannot be tested."[43]

There are multiple means by which such external validity might be achieved, lest we be accused of failing to offer constructive solutions to the problems we have identified[44]. First, of course, would be to conduct error rate studies that consider ammunition and/or weapon type as a variable of interest and manipulate that variable as part of the experimental design, then test whether error rates are different across different types of ammunition and manufacturing methods. This would be the most direct way to address this premise, because error rates would be directly tied to the manufacturing method and ammunition type. Unfortunately, most validation studies cover only one design and one or two types of ammunition, as shown in Table 1[45]. Those studies which are conducted over multiple types of ammunition and/or firearms do not break down responses by firearm and ammunition type.[46]

Another way to address this premise would be to conduct several studies assessing the number, quality, and/or variety of individual or accidental markings suitable for comparison across multiple types of ammunition and/or manufacturing methods. This method would not specifically address error rates, but it would be reasonable to argue that if the type and quantity of individual markings suitable for comparison was similar across ammunition and/or manufacturing methods that the error rates for such comparisons should also be similar because the fundamental information available to the examiners would be expected to be similar. Note

[43]Spiegelman and Tobin, *supra* note 48.

[44]As in BBC, pg. 8, "The dismissive attitude towards existing error rate studies, i.e., their wholesale rejection, is not helpful in that it offers no constructive advice on how the data could be used with properly acknowledged limitations."

[45]One type of ammunition and one primary type of weapon (with several known non match comparison weapons of similar manufacture) in Jaimie A Smith, *Beretta barrel fired bullet validation study*, 66 Journal of forensic sciences 547–556 (2021); one type of firearm and one type of ammunition in Baldwin et al., *supra* note 46; one type of firearm and two types of ammunition in Alfred Biasotti, *A statistical study of the individual characteristics of fired bullets*, 4 Journal of Forensic Sciences 34 (1959); one type of firearm and one type of ammunition in James E. Hamby et al., *A Worldwide Study of Bullets Fired From 10 Consecutively Rifled 9MM RUGER Pistol Barrels—Analysis of Examiner Error Rate*, 64 Journal of Forensic Sciences 551–557 (2019), https://onlinelibrary.wiley.com/doi/abs/10.1111/1556-4029.13916 (last visited Jan 29, 2020).

[46]Tasha P. Smith, G. Andrew Smith & Jeffrey B. Snipes, *A Validation Study of Bullet and Cartridge Case Comparisons Using Samples Representative of Actual Casework*, 61 Journal of Forensic Sciences 939–946 (2016), https://onlinelibrary.wiley.com/doi/abs/10.1111/1556-4029.13093 (last visited Dec 12, 2021); Keisler, M. A., Hartman, S. & Kil, A., *Isolated Pairs Research Study*, 50 AFTE Journal 56–58 (2018).

that this requires an additional degree of abstraction (ammunition/manufacturing -> markings -> error rates), but that the scientific logic still holds, even if the connection is more tenuous. An additional complication with this option is that we are not aware of an objective method for assessing the quantity of accidental information present in a fired cartridge case or bullet, nor for assessing how much individualizing information is necessary to make an informed comparison. Introducing an additional degree of subjective assessment for the marking quality would introduce additional variability that may mask the coupling between the ammunition and firearm combination and the error rates in black-box studies. However, there are certainly exploratory studies which assess the quality of markings for different types of ammunition in a specific firearm.[47] It might also be reasonable to assess the quantity of individual characteristics using an automatic system, such as NIBIN or IBIS[48] and make the argument that if a computer system can make the distinction it is reasonable for a human examiner to do so as well[49].

5.3 Consecutive Manufacturing

Another concern we originally raised in our affidavit was that of the use of consecutively manufactured firearms for error-rate studies.

> Several studies used consecutively manufactured barrels and/or slides to increase the difficulty of the comparisons, since these types of samples create the greatest potential to produce toolmark patterns and/or subclass characteristics that are similar in appearance although produced from two different sources. (FBI pg. 3)

Our concern is one of external validity. We agree that consecutively manufactured barrels may provide a higher degree of challenge in some circumstances, but this additional difficulty comes with a cost: it is harder to generalize results to the broad class of firearms of X type when you have only tested e.g. 10 consecutively manufactured barrels. Instead, the results of such a study can only be generalized to a specific point in time. This is one facet of an oft-discussed tradeoff in experimental design: you can increase experimental control, randomize subjects to treatment conditions, and take other precautions to ensure that your experiment is providing the answer to your experimental question (internal validity), but many of these control measures reduce the ability to generalize the results to wider settings because the

[47] Manzalini et al., *supra* note 50; Groshon, *supra* note 50; Brian Mayland & Caryn Tucker, *Validation of Obturation Marks in Consecutively Reamed Chambers*, 44 AFTE Journal 167–169 (2012), https://afte.org/uploads/documents/paid_for_download_products/44_2_2012_Spring.pdf (last visited Jun 27, 2022).

[48] Jan De Kinder, Frederic Tulleners & Hugues Thiebaut, *Reference ballistic imaging database performance*, 140 Forensic Science International 207–215 (2004), https://www.sciencedirect.com/science/article/pii/S0379073803005371 (last visited Jun 20, 2022); Christophe, *supra* note 50.

[49] Of course, it is much easier to test a computer algorithm's ability to make these comparisons, with the added benefit that such algorithms do not usually provide inconclusive decisions.

Table 1: Firearms studies listed by the FBI along with gun manufacturer and ammunition type, where specified. Note that studies using the same weapons have been grouped together, deviating from the otherwise chronological ordering. Proficiency tests with various firearms AND bullets (e.g. not systematically manipulated) were excluded from this table.

Study	Year	Type	Consec	Gun	Ammo
Brundage	1998	Bullet	Yes	Ruger P85 9mm	Winchester
J. Hamby et al.	2019	Bullet	Yes	Ruger P85 9mm	Winchester
Bunch & Murphy	2003	Cartridge	Yes	Glock Luger 9mm	Unspecified
DeFrance & Van Arsdale	2003	Bullet	Yes	Smith & Wesson .357 Magnum	Unspecified 158 grain jacketed soft-point
E. Smith	2005	Both	No	Ruger P89	Remington UMC 115 grain, copper-jacketed
Lyons	2009	Extractor	Yes	Colt 1911 A1, Caspian Arms Extractors	Speer Lawman .45 Auto 230 grain FMJ
Fadul	2011	Bullet	Yes	Glock EBIS	Federal 9mm
Mayland & Tucker	2012	Chamber	Yes	Kel-Tec, Hi-Point, Ruger	Winchester, Remington, Federal 9mm Luger 115 grain FMJ
Fadul et al.	2012	Slides	Yes	Ruger	Unspecified 9mm
Cazes & Goudeau	2013	Slides	Yes	Hi-Point 9mm C-9	Winchester 9mm Luger 115 grain FMJ
Stroman	2014	Cartridge	No	Smith & Wesson	Independence .40 S&W, 180 grain FMJ
Baldwin et al. (aka Ames I)	2014	Cartridge	No	Ruger	Remington 115 grain FMJ
Smith et al.	2016	Both	No	Taurus, Sig Sauer, Glock	92 UMC CC, 92 UMC Bu, 92 WIN BEB CC, 92 WIN BEB Bu, 92 Hi-Shok/Hydra-shok Bu, 92 American Eagle CC, 92 Speer GD CC, 92 Speer GD Bu
Duez et al.	2018	Cartridge	No	Colt Ruger P95 DC Taurus PT 24/7	PMC
Keisler et al.	2018	Cartridge	No	Glock 22,23,27 HK USP Compact S&W 40V, 40VE	CCI 40 S&W 180-grain gold dot
Kerkhoff et al.	2018	Cartridge	No	Glock (x39) Sig Sauer (x1)	Various
J. Smith	2021	Bullet	Yes	Beretta	Federal 9mm FMJ
C. Chapnick et al.	2021	Cartridge	No	Various 9mm Luger, 40 S&W, and 45 Auto	Unspecified
Law & Morris	2021	Cartridge	No	Various 9mm Luger	Federal American Eagle 124 grain FMJ
Bajic et al. (aka Ames II)	2021	Bullet	Some	Ruger, Beretta	Wolf Polyformance 9mm Luger 115 grain FMJ
Bajic et al. (aka Ames II)	2021	Cartridge	Some	Jimenez, Beretta	Wolf Polyformance 9mm Luger 115 grain FMJ

experimental control doesn't mirror natural conditions.[50] This paradox is also mentioned by Spiegalman & Tobin[51] in their 2013 assessment of the state of firearms validation and error rate studies.

As not all studies conducted use consecutively manufactured firearms, this is one of the less critical threats to external validity. Its inclusion here serves primarily to highlight the difference between the statistical concept of good experimental design and that of firearms and toolmark examiners, whose gaze is much more narrowly focused on the process of toolmark creation.

6 Study Design: Threats to Internal and External Validity

Our concerns about the design of firearms and toolmark error rate studies are also related to concerns about validity, but study design impacts both internal validity and external validity. Before we discuss the nuances of experimental design and appropriate, scientifically supported conclusions, we want to quickly address some broad claims about the importance of good experimental design in validation studies.

The FBI maintains that the various study designs which have been conducted since Daubert (which is a much earlier threshold than expected given the sea change that has occurred in forensics since the 2009 National Research Council and 2016 PCAST reports) provide meaningful ways to assess examiners' abilities.

> Since the *Daubert* decision in 1993, there have been 25 firearm/toolmark error rate studies conducted. They include black box studies with open set designs, studies with partially open set designs, and closed set study designs. These various experimental designs have provided meaningful ways to assess the ability of examiners to make accurate source conclusions. (FBI 2)

While we will not entirely discount the idea that there may be some amount of usable data in some of the poorly designed studies, we do feel that it is important to state in strong terms that the design flaws in many of these studies are significant enough to threaten the study's external validity. This means that they are **not meaningful for assessing the broad capability of FTEs to make accurate source conclusions**.

6.1 Closed and Open Set Studies

Study designs which are closed-set and involve multiple knowns threaten internal validity, as the study design is such that it does not allow us to estimate the number of comparisons

[50] Donald T. Campbell, *Factors relevant to the validity of experiments in social settings.*, 54 Psychological Bulletin 297–312 (1957), http://doi.apa.org/getdoi.cfm?doi=10.1037/h0040950 (last visited Jun 19, 2022).

[51] Spiegelman and Tobin, *supra* note 48.

performed by the examiner (and thus, an overall error rate cannot be calculated). In addition, these designs introduce constraints that allow conclusions based on factors unrelated to the firing process. As a result, closed-set, multiple-known studies produce a biased error rate that reflects other factors in addition to the examiners' proficiency in making evidence based conclusions.

> The community of researchers and practitioners appears to have taken this concern to heart. In a recent review of selected studies between 1998 and 2021, Monson et al. (2022, pg. 2) find that the closed set design is mainly used in studies prior to the publication of the PCAST Report (seven out of twelve summarized pre-PCAST studies). In turn, only two of six post-PCAST studies summarized by Monson et al. (2022, pg. 2) use the closed set design. (BBC pg. 24)

We acknowledge that most studies conducted since the PCAST report have used improved designs, however, we still feel the need to emphasize the issues involved in closed-set designs because some expert witnesses (and the FBI) still cite these studies and argue that they are useful when estimating examiner error rates.

The FBI uses the term a "partially open set study" to indicate a study with multiple knowns and one unknown.

> A "partially open" test design is an inter-comparison design where there are some unknowns having no matching pair. (FBI pg. 2)

This is what we would call an open-set design; the FBI is conflating two different experimental design considerations: whether or not every unknown sample has a known in the set, and whether there are multiple knowns included in the set. This distinction is important, because it speaks to how we derive the number of comparisons made by the examiner:

- In an open set with multiple known samples, if there is a match between the unknown and one of the knowns (which is not guaranteed), the examiner does not have to examine the correspondence between the unknown and any remaining, unexamined knowns. This means that we do not know how many elimination comparisons were completed by the examiner. If there is no match between the unknown and any of the knowns, then we can assume the examiner compared the unknown to all of the known samples. We can arrive at an upper bound and a lower bound for the number of comparisons performed, but we cannot precisely estimate the overall error rate, the sensitivity, or the specificity.
- In a closed set with multiple known samples, we cannot determine how many comparisons were performed for any of the unknown samples, because examiners stop looking once a match is found. Because examiners tend to assume that studies are closed-set even when not directly told that this is the case, it is possible to use logical deduction to reduce the potential for error in these studies.

- In an open set with only one known (a "kit" style set), we know that the examiner could only perform one comparison. These studies make the calculation of the error rate much easier by removing any statistical guesswork and/or ambiguity from the error rate calculation process.
- No one has attempted (nor should attempt) a closed-set study with only one known, because this would be reductive to the point of providing no information.

The number of comparisons made by the examiner is essential when calculating the error rate for the study, since the total comparisons is the denominator of that ratio. The unfortunate term "partially open" suggests that the FBI does not fully understand that the open-set issue is only part of the design problem; the inter-comparison designs which include multiple knowns are in fact a large issue as well.

Fundamentally, the problem with closed-set studies is that they under-estimate the false elimination rate (because examiners know that the unknown matches one of the knowns) and also under-estimate the rate at which examiners provide inconclusive decisions. This is a threat to the internal validity of the study (in that error rates cannot be calculated properly) and the external validity of the study (because information is present in the test which is not present in case work). The problem with inter-comparison designs (designs with multiple knowns) is that they threaten the internal validity of the study, because we cannot calculate the number of comparisons completed by the examiner.

6.2 Human-in-the-Loop Study Design and Analysis

One argument put forth by BBC suggests that we cannot validate tests which require subjective human judgement in the same way as chemical and medical laboratory tests are validated. This is fundamentally wrong.

> In such validation studies, many test items with known ground truth status are processed and the number of correct and incorrect responses are recorded, leading to standard performance metrics such as sensitivity and specificity. Results of such validation studies can then serve as an indication of the performance with which a test can be expected to operate when applied by consumers (assuming, again, they properly operate the test). Consequently, there can be discussion about whether the performance characteristics of a candidate test are "good enough" to be deployed in a particular context of application. (BBC pg. 16-17)
>
> Arguably, there is no generic and human-independent performance measure for feature comparison in forensic firearm examination, akin to performance characteristics used for traditional laboratory testing procedures. (BBC pg. 18)

First, there is nothing in the description of validation studies in general which would seem to not apply to firearms and toolmark examination, other than the idea that a consumer is the one operating the test. If we consider a "standard" chemical test such as a home pregnancy test, the examiner is analogous in this case to the test strip (which is a slightly dehumanizing comparison, but we will work within the analogy set up by BBC). The goal of any entity regulating the use of such tests, whether the court or the FDA, would be to determine whether the test is reliable in discriminating between the possible states of nature the test is designed to discriminate between: pregnant or not pregnant, same source or different source. If there is variability in the test's performance under different circumstances (or different examiners), then it is important to know that at the outset, before the test is approved for general use - that variability will factor into the overall error rate, leading to a range of possible error rates (which is something that statistical calculations are designed to handle: after all, statistics is the study of variability). So while we agree that there is variability in the performance of different examiners, we do not agree that it is useless to consider a discipline-wide error rate for the comparison of different types of marks on the basis that there is additional variability due to the human "in-the-loop". We would expect that impression-based marks would potentially need to be considered separately from striation-based marks (because the necessary features for comparison are very different), but unlike BBC, we do not consider a general summary statistic about the error rate of evaluating one type of marks to be a useless measure. In fact, their insistence that discipline-wide error rates are useless is at odds with a number of statements from researchers in the discipline that are found in error rate studies as well as in reports such as those issued by PCAST and NAS. More fundamentally, the error rate of a technique is at the heart of any scientific evaluation of that technique; this is one reason why it is listed in the criteria for admissibility under Daubert.

Even if we concede that the human-in-the-loop nature of firearms examination makes it unlike validation of a chemical test, that does not meant that error rates are invalid or that studying the performance of humans in a general sense is not important. Many medical imaging procedures also require a human to make a qualitative and even binary judgements (cancer or benign lump? appendicitis or not?) that include the presence of inconclusive results (when, e.g. the appendix cannot be identified on a scan of the abdomen),[52] but the medical community also actively studies the error rates of these diagnostics and the performance of the human examiners, calculates discipline-wide error rates and diagnostic utility rates (including inconclusives as negative outcomes), and is actively investigating the clinical use of algorithms that support human decision-making.[53]

There are other ways in which comparing pattern forensics black-box studies to medical studies is useful. Like black-box studies, medical studies are typically conducted on volunteers, however, there are significant differences in the statistical and scientific rigor in medical studies

[52] Jacob L. Jaremko et al., *Incidence and Significance of Inconclusive Results in Ultrasound for Appendicitis in Children and Teenagers*, 62 Canadian Association of Radiologists Journal 197–202 (2011), https://doi.org/10.1016/j.carj.2010.03.009 (last visited Jun 9, 2022).

[53] Nan Wu et al., *Deep Neural Networks Improve Radiologists' Performance in Breast Cancer Screening*, 39 IEEE transactions on medical imaging 1184–1194 (2020).

that are worth examining:

- Medical studies take great pains to ensure that the volunteers selected for a study are demographically representative of the population[54].
- There are strict guidelines for preregistration of study designs.[55]
- Study results for preregistered designs must be reported even if the conclusions from the study are not statistically significant. This requirement is intended to combat the "file drawer problem", an area of potential bias that we did not even start to address in our initial affidavit. The file drawer problem is a well known phenomena in many other areas of science, however, and it is reasonable to expect that forensic science is not exempt.
- Study results are reported and analyzed accounting for participant drop-out biases
- Collected data (in anonymized form) are published along with the study so that other scientists can repeat the analysis for themselves.

What is remarkable about the comparison to medical studies is that none of the conventions for appropriate scientific rigor in medicine are observed in studies of firearms and toolmark examiner error rates. Granted, study preregistration is not a convention observed in all disciplines, but if we accept the analogy to clinical trials because of the serious consequences of the results, it stands to reason that validation studies should be observing this level of experimental and scientific rigor. One of the biggest issues with forensic validation studies is that the collected data are not made available to other researchers for reanalysis - this is contrary to basic conventions of scientific ethics.

6.2.1 The Use of Objective Assessment Tools

> Although research is currently underway on computer-based methods for comparing questioned and known items, and assigning probative value to comparisons, in the current state of forensic practice such methods are not yet widely employed for case-specific evaluations, if at all. Instead, automatic comparison methods are mainly used for investigative purposes, such as the screening of large databases and retrieving specimens with similar features and ranking these specimens according to their degree of similarity with respect to a searched item. (BBC pg. 10)

Many of the problems identified with participant sampling become less problematic for external validity if objective methods are used which reduce the variability of examiner conclusions by providing quantitative information that is similar across examiners, reliable for decision-making, and the result of audit-able, explainable calculations. We firmly believe that this is the best path forward for pattern-based forensic evidence, and we have been actively involved

[54] NIH funding guidelines now require that studies proposed ensure inclusion of women and minorities in proportions that allow generalization to the relevant population under investigation (National Institutes of Health, *supra* note 31).

[55] David T. Mellor & Brian A. Nosek, *Easy preregistration will benefit any research*, 2 NATURE HUMAN BEHAVIOUR 98–98 (2018), https://www.nature.com/articles/s41562-018-0294-7 (last visited Jun 18, 2022).

in developing, implementing, and validating algorithms intended for direct item-to-item comparisons[56]. These algorithms are different from database searches such as NIBIN and IBIS that are designed to return the N closest matches from the database in that they provide a direct measure of feature similarity between two specified samples.

One issue raised by both the FBI and BBC, as well as other expert witnesses, is that researchers at the Center for Statistics and Applications in Forensic Evidence (CSAFE) has used data from error rate studies in our own research. One reason we have been able to make use of this data is that because we design algorithms, we can be sure that some of the biases which exist in validation studies do not exist in our research. This distinction is illustrative of the differences between algorithm validation studies and examiner validation studies. Consider, for instance, our use of data from closed-set studies[57] when developing an algorithm for assessing the similarity of different bullets. We obtained several test sets used in the study and, using a digital microscope, created 3D scans of the surface of the fired bullets. Then, we developed statistical methods to calculate features from those 3D scans; these features were fed into an algorithm that takes two scans, computes the features, and evaluates the similarity of the two features, eventually boiling down all of that data into a number between 0 and 1, where 0 indicates extreme dissimilarity and 1 indicates extreme similarity between the two scans. We know that our algorithm is not capable of using any of the information about the fact that the scans are from a closed-set study, because we can see exactly what features are being computed and how those features are combined to arrive at the final similarity score. That is, our algorithm is audit-able and fundamentally transparent in a way that the examiner's conclusion is not. We know exactly what information was used to train the algorithm, and how generalizable the algorithm is to data outside of the training set (for instance, its performance on a different model of firearm with similar manufacturing techniques)[58]. Because our algorithm does not depend on examiner responses to the validation study, but instead depends only on the 3D scans of bullets sent to examiners, we can use the bullet scans without compromising our algorithm's internal or external validity.

In addition, some CSAFE researchers who are not part of this discussion have used validation study data in order to demonstrate the use of statistical analysis techniques in forensics contexts. We are not the extremists that BBC and the FBI have painted us as: we will continue working within the system to improve statistical analysis methodology at the same time as we push for better study designs and the use of objective assessment methods. We see this as the most pragmatic approach to improve the discipline as a whole: while we will continue to argue that error rates derived from FTE validation studies are not sufficiently reliable for use, we will also push for the adoption of better statistical analysis methods in the academic

[56] Eric Hare et al., *Automatic matching of bullet land impressions*, 11 The Annals of Applied Statistics 2332–2356 (2017); Susan Vanderplas et al., *Comparison of three similarity scores for bullet LEA matching*, Forensic Science International 110167 (2020), http://www.sciencedirect.com/science/article/pii/S0379073820300293 (last visited Feb 10, 2020); Joe Zemmels, Heike Hofmann & Susan VanderPlas, cmcR: An implementation of the 'congruent matching cells' method (2022).

[57] Hamby et al., *supra* note 54.

[58] Vanderplas et al., *supra* note 65.

forensic evaluation literature.

6.3 Are Tests Like Casework? An Assessment of External Validity

One of BBC's arguments against the calculation of a general domain-wide error rate is that existing studies fall short of mimicking casework and may not apply to a particular case:

> [Black box] studies give only a snapshot of the performance of a selected number of examiners in conducting a particular task under more or less controlled experimental conditions. The experimental nature of these studies implies that, by definition, they fall short of mimicking casework conditions to at least some extent and may not apply to the circumstances in a particular case. (BBC pg. 18)

There is at least one study[59] that used blind proficiency testing, which mimics casework better than most studies in that 1) it is truly blind, that is, the participants are not aware that they are being tested[60], and 2) the study incorporates the verification protocols used at Houston Forensic Science Center (HFSC), which are not usually incorporated into the error rate calculations in black-box studies. In addition, this study is free from some of the participant selection biases present in other studies by virtue of the fact that examiners were essentially compelled to participate as part of continued employment, and thus sampling and selection biases were not a concern. As with most things, however, there are trade-offs: the more narrow the study's participants, the lower our ability to generalize results to a wider population. This study only covered the Houston Forensic Science Center, so it is difficult to generalize the results outside of examiners at HFSC, where different protocols would be used and examiners would be expected to have different training and mentoring opportunities.

A similar statement is found in the FBI's response:

> Another important point is that these studies capture the participants' conclusions without the benefit of the verification process and other quality control measures utilized during actual casework. These measures include independent examination of the evidence by another qualified examiner (i.e., verification) before a report may be issued. They also include administrative and technical review of an examiner's report. These quality control measures would likely lower the error rates reported in these studies even further. (FBI pg. 4)

[59] Maddisen Neuman et al., *Blind testing in firearms: Preliminary results from a blind quality control program*, 67 Journal of Forensic Sciences 964–974 (2022), https://onlinelibrary.wiley.com/doi/abs/10.1111/1556-4029.15031 (last visited Jun 18, 2022).

[60] note that this definition of "blind" is more strict than that sometimes used by forensic scientists, in which a blind test means that the person being tested doesn't know the answers (cite Bunch & Murphy).In experimental design, the notion of "blind" testing refers to participants and experimenters not knowing who was assigned to each treatment group because such knowledge might influence the test evaluation. In order for the same aim to be achieved in forensic tests, we must instead ensure that the examiner does not know that they are being tested so that we can more accurately measure how they respond to case work.

We would love to see more error rate studies conducted using blind proficiency tests; such studies clearly have better external validity in some respects, even if they often cannot be generalized outside of the laboratory where they were conducted. We recognize that not all laboratories have the resources of HFSC, and that such testing is expensive; as a result, it is still beneficial to the discipline to have error rate studies which serve as estimates of examiner error without the benefit of verification processes, because such estimates are usually derived from examiners across multiple laboratories and thus can, under the right sampling procedures, be generalized to a wider population of examiners. If the data from these proficiency tests were made available to the community in an anonymized way, it might even be possible to assess the effect of the verification process on the error rates, which would be useful information for interpreting studies without that verification process (it might be possible to estimate e.g. the magnitude of the reduction in error based on a verification process similar to that used at HFSC).

If the circumstances of a particular case are such that error rate studies are not applicable, as suggested by BBC, then that is something that should likely be brought up when the firearms and toolmark expert is testifying and during cross-examination. While it is unlikely that a specific error rate or numerical adjustment could be identified, this would at least allow the judge and/or jury to identify a starting point and a direction in which the error rate might be revised.

Our prior statement, and this statement, address the general discipline of firearms and toolmark examination. We focus on assessing the question of whether firearms and toolmark evidence has broad scientific support, with the conclusion that while there is some scientific evidence to support the idea that firearms and toolmark examination is useful for assessing questions of source, the quality of that evidence falls well short of that required for "broad scientific support" due to fundamental issues with internal and external validity in the validation studies which exist to date.

6.4 Nonresponse Bias

It is common for studies involving human subjects to involve some degree of drop-out or nonresponse. Individuals may agree to participate in a survey and then fail to actually engage (drop out) or they may leave some survey questions unanswered (item nonresponse). There are many statistical methods to handle these problems.[61]

In order to begin to address these problems, researchers first have to acknowledge them. In every study we have reviewed, the limitations due to nonresponse and drop-out bias are not

[61] There are in fact, entire areas of statistical research devoted to such methods. For some examples, see Roderick JA Little & Donald B Rubin, 793, Statistical analysis with missing data (2019) and Jae Kwang Kim & Jun Shao, Statistical methods for handling incomplete data (2014).

acknowledged. No study utilizes common statistical methods for assessing the impact of nonresponse and drop-out bias[62]. More troubling, these studies do not release any data to facilitate other researchers filling in these gaps.

As the holders of the data, the researchers conducting validation studies are the ones who bear the burden of addressing the missingness in their analyses. Choosing the correct methods depends on exploring the patterns of missingness in the data. Instead, currently, these researchers ignore the problem and proceed with inappropriate statistical analyses- despite the availability of existing appropriate methods that could be used.

The authors of BBC and the FBI responses do not refute these statements. Instead, they attempt to distract from the issue.

> This assertion is a further example of the use of a true statement (here: the existence of non-responses) for suggesting conclusions based on assumptions for which actual evidence is lacking. That is, Vanderplas et al. (2022) provide no basis to believe that all non-respondents would render erroneous answers; an error rate based on such an extreme assumption is hypothetical and not conducive of advancing a constructive discourse over what the potential of error could realistically be. In line with our discussion throughout this document, we reiterate that (i) the imperfection of existing studies and related data is not contested, (ii) imperfect data should not be dismissed entirely (provided that limitations are properly acknowledged), but interpreted within the relevant scope (e.g., limiting conclusions to those examiners who properly responded), and (iii) even if data were perfect (in strict statistical terms), the resulting domain-wide error rate would characterize an abstract question and, hence, be of limited practical usefulness. (BBC pg. 27)

As we have discussed, limitations are *not* being acknowledged. We are also not arguing imperfect data needs to be dismissed entirely. Instead, we assert the simple fact: researchers are inappropriately using methods developed for completely observed data for data which are far from completely observed. Deflecting again from this issue, the authors of BBC take umbrage with our suggestion that the nonresponse is likely leading to underestimates of the error rates.

> The Statement claims that "[g]iven what we know about why people drop out of black box studies; we would expect that studies with non-response bias underestimate the error rate." It is unclear what the Statement "knows" about why people drop out of black box studies, as it cites no data that supports this claim. (FBI pg. 11)

Research into testing and assessment in the educational setting has consistently indicated that "intuition and empirical evidence" support that "[E]xaminees are more likely to omit items

[62] Angela M Wood, Ian R White & Simon G Thompson, *Are missing outcome data adequately handled? A review of published randomized controlled trials in major medical journals*, 1 Clinical Trials 368–376 (2004), https://doi.org/10.1191/1740774504cn032oa (last visited Jun 23, 2022).

when they think their answers are incorrect than items they think their answer would be correct."[63] If an examinee is proficient enough to know when they are likely to be incorrect, then this type of behavior will lead to an underestimate of error rates if missingness is ignored.

We rely on what is known about testing more generally to suggest a direction of bias because the data from validation studies are typically not shared. To our knowledge, no ballistics validation study has released any data capable of being analyzed by a third party. However, a recent study for palmar prints by Eldridge, De Donno, and Champod[64] did release some data. While the released data does not contain sufficient information to apply methods to adjust for missingness, it does allow for the beginning of an exploration of the patterns of missingness. For example, Eldridge, De Donno, and Champod[65] identified two factors that were at associated with higher false positive error rates among examiners. These factors were being a non-active examiner and being employed by an agency outside of the United States. We explored both characteristics and their relationships with missingness. Our analyses indicated that being employed by an agency outside of the United States was also associated with a higher likelihood of examiners failing to respond to over 50% of their assigned comparisons. In other words, a group of examiners who were disproportionately likely to make false positives were also disproportionately likely to skip comparisons. Thus, for this study, there is evidence that the false positive error rate calculated ignoring the missingness is an underestimate.

7 Inconclusives

7.1 The Importance of Both Identification and Elimination

> When courts choose to consider the known or potential rate of error as a factor bearing on reliability, the key concern for admissibility is the frequency of false identifications. (FBI pg. 1-2)

The FBI is not alone in their assertion that only false identifications are important. Such claims are made by expert testimony[66] and even in the PCAST report, the criteria for foundational validity of a forensic discipline are the sensitivity rate and the false-positive rate.[67] We agree that the false positive (false identification) rate is important, but there are fundamental issues

[63] Robert J Mislevy & Pao-Kuei Wu, *Missing responses and IRT ability estimation: Omits, choice, time limits, and adaptive testing*, 1996 ETS RESEARCH REPORT SERIES i–36 (1996) pg. 16. See also, Steffi Pohl, Linda Gräfe & Norman Rose, *Dealing with omitted and not-reached items in competence tests: Evaluating approaches accounting for missing responses in item response theory models*, 74 EDUCATIONAL AND PSYCHOLOGICAL MEASUREMENT 423–452 (2014) and Shenghai Dai, *Handling missing responses in psychometrics: Methods and software*, 3 PSYCH 673–693 (2021).

[64] *Supra* note 39.

[65] *Id.*

[66] Todd Weller in People v. Ross, 68 Misc. 3d 899, 129 N.Y.S.3d 629, 2020 N.Y. Slip Op. 20153 (N.Y. Sup. Ct. 2020)

[67] PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY, *supra* note 49, pg. 159.

with the focus only on identifications when we look at the structural setup of evaluating examiner conclusions, summarized in Figure 1.

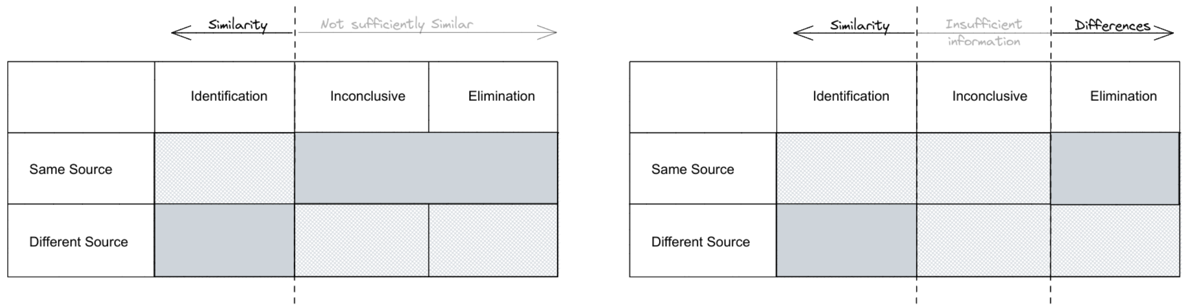

Figure 1: If examiners only spot similarities, then the classification scheme on the left is appropriate and examiners should confine themselves only to claiming to be able to make identifications, grouping inconclusives and eliminations together as having insufficient similarity to make an identification. If examiners spot similarities and differences, then it is important to evaluate the error rate of both false identifications and false eliminations, as it speaks to the fundamentals of the claims examiners make about their abilities.

If examiners are only able to spot similarities, then there should be only one threshold: either the samples under comparison are sufficiently similar, or they are not. This results in a binary classification problem - one which neatly matches the true state of the evidence: either the two items were from the same source, or they were from different sources.

If examiners can spot similarities and differences, but only focus on similarities, then they are ignoring available evidence which might be exculpatory, either because of training biases to look for similarities or because identifying differences is a harder cognitive problem. In this case, the system is set up to evaluate examiners based on whether they can identify both similarities and differences, with a middle category of inconclusive for examiners to use when there is insufficient evidence in either direction. Using such an evaluation system while focusing only on one type of error is problematic from the standpoint of objectively evaluating examiners' claims about the scientific nature of their discipline.

The FBI's discussion of the concept of the "Best Known Non Match" suggests that they are looking only at similarities:

> The ability to assess pattern agreement develops during training when an examiner evaluates the "best" agreement between two specimens known to have originated from different sources — "the Best-Known Non-Match." (FBI pg. 3)

while BBC suggest that there is not even agreement on what different examiners might consider similarities and/or differences:

> different examiners may assign different evidential values to observed features, and they may even disagree about what exactly constitute similarities and differences (in accidental characteristics) for a given pair of compared items. (BBC pg. 10)

We bring up the issue of how errors are counted in part to point out that even the basic criteria underlying subjective assessment of firearms and toolmark evidence are not agreed upon by examiners, and in part because there is a fundamental mismatch between the evaluation criteria examiners appear to use and the way the errors assessed in the community. This issue is at the heart of our paper on inconclusives[68]. While BBC identify statements made in this paper as inconsistent with statements in our affidavit, we would like to highlight the difference in context: in the Law, Probability, and Risk paper, we were examining specifically the use of inconclusives in error rate studies; in our affidavit we were examining the utility of error rate studies when evaluating the discipline of firearms and toolmark examination. The latter is a much broader question which requires consideration not only of study design, but also of sampling and general statistical procedures. We are accustomed to the nuances of data collection and analysis, including framing the question under investigation in such a way that it can be precisely answered within the bounds of the data which has been collected.

7.2 Probative Value of Inconclusives

> "… a typical item of evidence (or observation made by a scientist) may not only occur when one hypothesis (i.e., one version of a contested event) is true, but also when an alternative hypothesis is true." … "We note that what is of crucial importance for our discussion throughout this document is that, in general, for evidence to have probative value with respect to two competing hypotheses, the probability that the evidence would arise under one hypothesis must be different from the probability of that evidence to arise under the respective alternative hypothesis. In essence, we would like to have evidence that is (much) more typically encountered if one version of a contested event is true rather than some alternative version. Evidence that has this property is said to have discriminative capacity – i.e., it has (probative) value." (BBC pg. 10-11)

Using this definition, we have previously shown[69] that inconclusives have probative value - they are much more likely to occur when evidence is from different sources than when evidence is from the same source. While we acknowledge that there is considerable disagreement between experts in the area of inconclusives, we firmly believe that the treatment of inconclusives as correct decisions by FTEs and error rate studies is not correct based on the logic that underlies most scientific studies: statistical hypothesis testing.

[68]Hofmann, Vanderplas, and Carriquiry, *supra* note 26; It is customary in statistics to cite the print edition once the paper has been released; this is why in the responses the paper is given the year 2020 and in our citation it is listed as 2021. The paper was released online before the official release of the print edition.

[69]Hofmann, Vanderplas, and Carriquiry, *Id.*

In a statistical hypothesis test, we start out with a conclusion that we want to disprove, called the null hypothesis (H_0 in mathematical notation). The null hypothesis might be "Plant growth is not associated with increased moisture", or it might be "the two items originate from different sources". Then, a statistical experiment is conducted and evidence is assembled, with the assumption that the null hypothesis is true. A probability is calculated which rests on the assumption that H_0 is true; if that probability is sufficiently small, then we conclude that we are unlikely to have observed our data if H_0 is true, and that it is more likely that H_0 is false and that the alternative is true.

On the left side of Figure 1, it is possible to see how this plays out in firearm and toolmark assessment. We start by assuming that the two pieces of evidence come from different sources. As the FBI has indicated, examiners are trained to look for similarities, suggesting that as similar features accumulate, the conclusion moves from "different sources" to "same source" - that is, the accumulation of similarities between the two items causes the examiner to reject the null hypothesis and conclude that the items must have been originated from the same source. If sufficient evidence to refute H_0 does not accumulate, we cannot say anything about H_0 or the alternative, H_A. That is, we do not ever "accept" that H_0 is true (that is, an examiner would never need to conclude that the sources of the items were different); we simply do not have enough similarities to reject the hypothesis that the two items are from different sources. It would, of course, be possible to start from the opposite conclusion: we could start with a null hypothesis that the two items are from the same source, and look for differences. This is not, however, how examiners seem to arrive at their conclusions. Rather, it seems that by training and in describing how they arrive at their decisions, examiners overwhelmingly focus on similarities.

This statistical hypothesis testing logic is very similar to the framework of the criminal justice system. If the jury is convinced "beyond a reasonable doubt", then the defendant is declared to be guilty (the presumption of not guilty, H_0, is rejected in favor of the H_A of guilt). Otherwise, the defendant is declared to be "not guilty". There is no way for the defendant to be declared innocent, because the system is set up to refute the starting premise that the defendant is not guilty, with evidence presented that accumulates against that hypothesis until a certain threshold is met.

What the FBI and BBC are advocating for, that is, the utility of inconclusives, is akin to having a legal system in which individuals are judged guilty, not guilty, or unknown. While that is something that would reduce the probability that the innocent are convicted or the guilty go free, it also allows for a large grey area in what is set up to be a decisive, binary system. The judicial system would not function well if a large proportion of cases were inconclusive and did not reach some sort of decisive resolution, but forensic disciplines tolerate this situation because it decreases nominal error rates.

8 Conclusion

As we have demonstrated in this document and our previous affidavit, there are substantial threats to both the internal and external validity of currently available firearms studies. Statistically, these concerns are primarily the result of the design and analysis of firearms and toolmark error rate studies, rather than as a result of the work that examiners do on a day-to-day basis. The external validity of FTE error rate studies is threatened by participants' self-selection into the sample population, limited assessment of the impact of different combinations of ammunition and firearms, and poor assessment of the impact of nonresponse bias on the error rates reported in each study. In addition to these threats to the generalizability of results, there are also threats to the internal validity of the studies: past use of closed-set and multiple-known comparison set study designs, poor statistical practice, and the treatment of inconclusives.

We remain firm in our conclusion that the estimates established from fundamentally flawed studies with threats to both internal and external validity are not sufficiently sound to be used in high-stakes situations, including medicine, law, and engineering applications where individuals' lives, health, or freedom are at stake.

We declare under the penalty of perjury and pursuant to the laws of the state of Illinois that the statements above are true and accurate to the best of our knowledge.

Alicia Carriquiry	Heike Hofmann	Kori Khan	Susan Vanderplas

Forensic feature-comparison as applied to firearms examination: evidential value of findings and expert performance characteristics

Reply to the affidavit by Vanderplas et al. (2022) submitted in US v Kaevon Sutton (2018 CF1 009709)

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April 28, 2022

Contents

1 Preliminaries

1.1 Authors' biographic abstracts

1.1.1 Alex Biedermann, Ph.D.

I, Alex Biedermann, Ph.D., am an Associate Professor (since 2016) at the School of Criminal Justice (SCJ) of the Faculty of Law, Criminal Justice and Public Administration of the University of Lausanne (UNIL, Lausanne, Switzerland).[1] I hold a Master of Science degree in Forensic Science. My Ph.D. thesis focused on graphical models and probabilistic inference for evaluating scientific evidence in forensic science (2007).

From 2003 to 2010, I worked as a scientific advisor on forensic evidence in the Swiss Federal Department of Justice and Police (Berne, Switzerland) in cases investigated by the Office of the Attorney General of Switzerland. Subsequently, I worked as a co-developer of the worldwide first postgraduate education program (e-learning) in forensic interpretation,[2] delivered by the Foundation for Continuing Education UNIL-EPFL[3] (Lausanne, Switzerland, 2009–2015). I am currently affiliated with this program as a member of the board of academic directors.

In my position as Associate Professor at UNIL, I teach interpretation of scientific evidence and decision analysis for Master students in law (at UNIL's School of Law) and Master students in forensic science (at UNIL's SCJ), with previous visiting appointments at partner institutions in China and Australia. The teaching for Master students in forensic science includes a series of specialized lectures on the interpretation of results of firearms examinations and of gunshot residue analyses. I also co-developed UNIL's MOOC (Massive Open Online Course) *Challenging Forensic Science: How Science Should Speak to Court* (freely available on coursera.org in English, French and Italian).

I have conducted visiting research stays in Australia, Italy, the United Kingdom and the United States. I am the principal investigator of the research project NORMDECS (Normative Decision Structures of Forensic Interpretation in the Legal Process),[4] initially funded by the Swiss National Science Foundation (2016–2021), and hosted at UNIL's SCJ. This project studies fundamental questions of forensic interpretation through probability and decision theory. It aims at conceptualizing and substantiating forensic inference, both on a theoretical and practical account, as an integral part of a wider framework for coherent decision analysis in the law. The project features a highly multidisciplinary perspective by connecting core forensic science and the law with computational statistics and philosophy of science acting as supporting disciplines.

I have authored or co-authored 150 publications (peer-reviewed articles, law review articles, commentaries, chapters and books), including 3 books on probabilistic and decision theory methods for forensic evidence interpretation. I publish in English, German and French. Some of my articles have been translated into Chinese, Spanish and Italian. I served on the writing committees of the 'ENFSI Guideline for Evaluative Reporting in Forensic Science' (2015),[5] issued by the European Network of Forensic Science Institutes (ENFSI) and, more recently, the document 'The Use of Statistics in Legal Proceedings: A Primer for Courts' (2020),[6] jointly issued by The Royal Society (UK) and The Royal Society of Edinburgh.

I am a fellow of the Royal Statistical Society (RSS, since 2013), a member of the American Association for the Advancement of Science (since 2015) and a councilor of the International Association of Evidence Science (since 2017). From 2018 to 2021, I served on the RSS Section Committee 'Statistics and the Law'.

My qualifications are summarized in my resume (see Appendix A).

[1]The SCJ was founded in 1909 and was the first forensic science school in the world. It remains one of the only institutions in Europe to offer complete training in forensic science covering Bachelor, Master and Ph.D. levels, as well as continuing education. The SCJ has a longstanding international reputation of excellence for research in forensic science, education, casework and expert consultancy.

[2]Certificate of Advanced Studies in 'Statistics and the Evaluation of Forensic Evidence' (https://www.formation-continue-unil-epfl.ch/formation/statistics-evaluation-forensic-evidence-cas/), currently in 11th edition, along with a further 6 specialized courses. Since the launch of these courses in 2010, over 200 practicing forensic scientists (laboratory analysts, expert witnesses, case managers, etc.) from across the world (mainly Europe, U.S./Canada and Australia/New Zealand) have successfully completed one or more of these courses (course lengths vary between 6 and 18 months).

[3]Swiss Federal Institute of Technology Lausanne (École Polytechnique Fédérale Lausanne, EPFL)

[4]www.unil.ch/forensicdecision

[5]https://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf

[6]https://royalsociety.org/-/media/about-us/programmes/science-and-law/science-and-law-statistics-primer.pdf

1.1.2 Bruce Budowle, Ph.D.

I, Bruce Budowle, recently retired as Regents Professor in the Department of Microbiology, Immunology, and Genetics at the University of North Texas Health Science Center at Fort Worth Texas. I also served as the Director for the Center for Human Identification where I performed research and managed an operational criminal justice agency dedicated to anthropology and DNA services. I maintained an active role in research, development, validation, and implementation of forensic genomics methods to increase capabilities for human identification, microbiome research and bioinformatic solutions for genomic applications. Prior to these appointments, I was employed for 26 years at the Federal Bureau of Investigation's Laboratory Division where I was involved in the research, development, and validation of numerous DNA methods. I led the team that developed DNA typing capabilities at the FBI Laboratory in Quantico, Virginia. I ended my tenure at the FBI as Senior Scientist in the Laboratory Division.

I have extensive experience in all aspects of forensic DNA analyses, including analyses of low-level samples, mixture analyses, population genetics, statistical interpretations, STR markers, SNP markers, and mitochondrial DNA. I worked on laying some of the foundations for the current statistical analyses in forensic genetics and defining the genetic parameters of relevant population groups. I have published more than 700 articles, made more than 800 presentations (many of which were as an invited speaker at national and international meetings), and testified in well over 300 criminal cases in the areas of molecular biology, population genetics, statistics, quality assurance, and forensic biology. In addition, I have authored or co-authored books on molecular biology techniques, electrophoresis, protein detection, forensic genetics, and microbial forensics.

I was directly involved in developing quality assurance (QA) standards for the forensic DNA field in my role serving on the DNA advisory Board. I served as Chair and a member of the Scientific Working Group on DNA Methods, Chair of the DNA Commission of the International Society of Forensic Genetics, and a member of the DNA Advisory Board. I was one of the original architects of the CODIS National DNA database, which maintains DNA profiles from convicted felons, from evidence in unsolved cases, and from missing persons. Over the past two decades I also worked in counterterrorism specifically efforts involving microbial forensics and bioterrorism. I was involved directly in the scientific aspects of the anthrax letters investigation. I was one of the architects of the field of microbial forensics and served as the Chair of the Scientific Working Group on Microbial Genetics and Forensics (hosted by the FBI), whose mission was to set QA guidelines, develop criteria for biologic and user databases, set criteria for a National Repository, and developed forensic genomic applications.

I currently research in forensic genomics, particularly in dense SNP analyses for genetic genealogy. I also currently serve as a Commissioner on the Texas Forensic Science Commission and as a member or the Texas Governor's Sexual Assault Survivor's Task Force.

I led the internal team at the FBI Laboratory to investigate foundations and validity of friction ridge analyses after the wrongful identification made by the FBI Latent Print Unit in the Mayfield case. I also was the one who identified the errors in mixture interpretation of DNA evidence by the Department of Forensic Sciences (DFS) in Washington, DC and supported further investigation into the matter at the request of the United States Attorney's Office (USAO). More recently, I was part of the team requested by USAO and the Office of the Attorney General of Washington, DC that investigated and identified issues related to firearms evidence generated by the DFS.

My qualifications are summarized in my resume (see Appendix B).

1.1.3 Christophe Champod, Ph.D.

I, Christophe Champod, Ph.D., am a Full Professor of forensic science at the School of Criminal Justice (SCJ, Ecole des Sciences Criminelles in French) of the Faculty of Law, Criminal Justice and Public Administration of the University of Lausanne (UNIL, Lausanne, Switzerland). I am the Director of the SCJ and Vice-Dean of the Faculty. I am in charge of education and research on identification methods (interpretation of DNA, facial images, fingerprints, toolmarks, footwear marks and firearms).

I received my M.Sc. and Ph.D. (summa cum laude) both in Forensic Science, from the University of Lausanne, in 1990 and 1995 respectively. I remained in academia until holding the position of assistant professor in forensic science. From 1999 to 2003, I led the *Interpretation Research Group of the Forensic Science Service* (UK), before taking a full professorship position back at UNIL.

I have the privilege to work with a group of about 20 Ph.D. students. The research carried out by my group is mainly devoted to the inferential aspects associated with forensic identification techniques. I currently supervise three Ph.D. students conducting research associated with toolmarks and firearms. The first is working on the 3D modelling and statistical assessment of toolmarks left on wires by cutting pliers. The second focuses on the development of an automatic comparison system to discriminate bullets fired from AK-47. The third is investigating the use of a commercial system called *Evofinder*® to assess the weight of evidence associated with marks found on fired bullets.

I maintain an activity as an expert witness in areas of marks and biological evidence interpretation both at a national and international level. For example, I led a team of forensic specialists tasked with the detection and interpretation of potential toolmarks found on the inside of the plastic cap of secured anti-doping bottles in the context of the alleged state doping actions carried out by the Russian authorities during the Sochi Olympic games.[7]

Over the years, I published extensively (more than 120 peer-reviewed papers) in the areas of marks and impressions mainly on the weight to be attached to these marks. In 2001, I co-authored the first black box study on palmar friction ridge comparison. On the specific aspects of firearms and toolmarks, I published 3 papers in the *AFTE (Association of Firearm and Tool Mark Examiners) Journal* and 3 papers in, respectively, the journals *Forensic Science International* and *Journal of Forensic Sciences*.

I am a member of several professional bodies and scientific committees. For example, I am an affiliate member of Friction Ridge subcommittee of the Organization for Scientific Area Committees (OSAC).

For my contribution to forensic science, I received in 2015 the *Distinguished ENFSI Scientist Award*. ENFSI is the European Network of Forensic Science Institutes. In 2018, for my contribution to the good of the Profession, I received the *Henry Medal Award* from the Fingerprint Division (formerly The Fingerprint Society) of the Chartered Society of Forensic Sciences (CSFS). In 2020 I was awarded the *Douglas M. Lucas Medal* of the American Academy of Forensic Sciences for my "contributions to forensic identification."

My qualifications are summarized in my resume (see Appendix C).

1.2 Request

This statement has been prepared in reply to a request received from Sharon Donovan, Deputy Chief (Homicide Section) from the U.S. Attorney's Office, District of Columbia. Specifically, we have been requested to opine on the affidavit authored by four CSAFE (Center for Statistics and Applications in Forensic Science) members (herein referred to as Vanderplas et al. (2022)), submitted by the defense in US v Kaevon Sutton (2018 CF1 009709) in support of their request to exclude or limit the testimony of the government's firearms and toolmark expert.

1.3 Aims and scope

The aim of this document is twofold. First, we aim to provide assistance to the Judiciary, legal professionals, and lay persons in understanding essential concepts pertaining to the field of forensic feature-comparison as applied to forensic firearms examination. This primer includes (i) the assessment of the probative value of results of comparative examinations (i.e., forensic feature-comparison), and (ii) expert performance characteristics in this discipline, especially their measure through error rate studies. Second, we respond to general and recurrent critiques levelled against error rate studies and their use in legal proceedings. This response also includes a number of specific critiques expressed in the affidavit prepared by Vanderplas et al. (2022).

This document is structured as follows. Section 3 introduces the theoretical background on the probative value of results of comparative examinations performed on elements of spent ammunition (i.e., bullets and cartridge cases). Based on these background notions, Section 4 examines recurrent questions and concerns about expert performance in forensic feature-comparison as applied to forensic firearms examination, and the measurement of such performance through error rate studies. Some of

[7] A summary of the methodology used on this case has been publicly released: https://tinyurl.com/Appendix-VII-ESC-LAD-Report (last consulted April 19, 2022)

these high-level (general) critiques have been expressed in the affidavit by Vanderplas et al. (2022).

In Section 5, we consider and respond to a series of more specific, technical critiques that were proffered by Vanderplas et al. (2022), levelled against studies of examiner performance (i.e., so-called error rate studies). Discussion and conclusions are presented in Section 6.

In this document, we seek to adopt a balanced position as independent academics (see also Section 1.4) who have no interest in the specific outcomes of this case. We take balance to mean that we give our account of forensic feature-comparison in full knowledge that there are two sides represented in court. Even though our presentation of the properties of forensic feature-comparison will, at times, appear to favor one side or the other, our views of the discipline of forensic feature-comparison as a whole are not directed to "proving" the case for any particular side. Instead, our goal is to provide assistance to anyone asked to give an informed assessment about the merits and limitations of the discipline. Balance also means that we will express both, points of agreement and points of disagreement with respect to the various criticisms (of the discipline) that we will discuss. In particular, we will not refrain from making concessions on any point of criticism (of the discipline) with which we agree.

The scope of our statement is strictly delimited by the following:

- We express no opinion on whether the field of forensic feature-comparison, as applied to firearms examination, meets or should be considered to meet any specific legal requirement(s) or test(s) regarding, for example, for admissibility. Our document is intended to serve the decision makers in these tasks.
- We express no opinion on the quality, accuracy or reliability of any actual forensic feature-comparison examinations conducted in the particular case, i.e., we do not seek to approve or give credit to any such work (e.g., its level of quality control or the suitability of the chosen reporting format and language) as well as the qualification and proficiency of any examiner involved in such work. We did not review any work performed in this case.
- We express no opinion, nor do we make a recommendation on how conclusions in forensic feature-comparison should be expressed by reporting examiners in the event that such examinations will be considered admissible in this case. We solely mention the principal characteristics of the main reporting formats currently used by practitioners and how the scientific status of those formats is judged both within and outside the profession.

1.4 Conflict of interest statement

We declare that, to our knowledge, we have no financial connection or family relationship with the parties involved in this case. Specifically, we (AB and CC) declare that our roles in preparing this document have been unremunerated. All charges for preparing this document have been directly and entirely recouped by our employer (The University of Lausanne, Switzerland). BB contributed to the work in this document *pro bono*.

We also declare that we are entirely disinterested in how, ultimately, the court will decide on the admissibility of forensic feature-comparison as applied to firearms examinations. Though we (AB and CC) conduct research and teach on forensic feature-comparison as part of our academic positions, we have no direct professional dependence on the discipline of feature-comparison itself and, hence, the acceptance or otherwise of this field by the Judiciary. Moreover, we (AB and CC) hold critical positions regarding forensic feature-comparison methodology and have done so in the past, especially in relation to questions of identification (e.g., Biedermann et al., 2008; Cole and Biedermann, 2020; Champod, 1995, 2000). BB was part of the audit team commissioned by the USAO and Office of the Attorney General of Washington, DC that recently investigated the firearms issues at the Department of Forensic Sciences in Washington, DC. We see our role as experts and academicians that are critically assessing what exactly forensic science can and cannot legitimately purport to achieve in the evaluation and interpretation of scientific evidence.

1.5 How to read this document

Section 2 provides an executive summary. Section 3 provides a general introduction to the topic of forensic feature-comparison as applied to firearms examination. Attention will be drawn to the main considerations that affect the assessment of the probative value of results of comparative examinations performed on elements of spent ammunition (i.e., bullets and cartridge cases).

At the end of some of the subsections, grey boxes are inserted. They summarize the key points addressed in the respective subsections. We recommend readers to take notice of the entire Section 3 as it will help them understand the position of error rate studies in the area of forensic feature-comparison as compared to other considerations affecting the probative value of results of feature-comparison examinations.

Section 4 will build upon the notions introduced in Section 3 in order to address a series of general questions and concerns about expert performance in forensic firearms examination and the measurement of this performance using error rate studies. Some of these concerns are expressed by Vanderplas et al. (2022). This section will be structured in a question-and-answer format. Again, a series of grey boxes with summaries is included to help readers keep track of the main points discussed in the respective subsections.

Section 5 addresses and further discusses a series of specific critiques that Vanderplas et al. (2022) raise against the use of error rate studies in the field of forensic feature-comparison as applied to the field of forensic firearms examination (i.e., the comparative examination of elements of spent ammunition). A summary and conclusions are presented in Section 6.

2 Executive summary

This report is a response to positions taken by Vanderplas et al. (2022) in their affidavit submitted in US v Kaevon Sutton (2018 CF1 009709). Vanderplas et al. (2022) advocate a number of positions. The primary ones, among others, being that (i) a domain-wide error rate is needed for the practitioners of the firearms and toolmark discipline, and (ii) existing studies regarding the performance of practitioners have too many flaws to be considered sufficiently sound for use in legal proceedings (e.g., Vanderplas et al., 2022, at p. 10).

We do not support the position of a domain-wide error rate because it is an ineffective and ill-defined concept to assess expert performance in a specific case. It is not achievable, and even if it were achievable, it is dynamic and changing. Moreover, it would overvalue poor performers and undervalue good performers. Regarding the quality of existing studies, we advocate sound statistical approaches. However, we do not support the draconian position that because a study is not perfect (as most studies have limitations) that it does not add value. There is information, such as providing descriptive (i.e., summary) statistics, that may aid investigative and judicial proceedings. Moreover, multiple studies, though each with specific limitations, together can complement each other. Lastly, we point out where Vanderplas et al. (2022) are inconsistent with the positions they take and where some of the same authors have advocated alternate views in another recent publication (i.e., Hofmann et al., 2020).

We respond to the affidavit by Vanderplas et al. (2022) by providing, first, some background information on forensic feature-comparison as applied to firearms examinations. Then, we address general questions and concerns about expert performance and its measurement in forensic firearms examinations, drawing also upon relevant discussions, works and (review) reports in other forensic disciplines. Next, we provide a point-by-point reply to a series of specific, technical critiques that Vanderplas et al. (2022) have levelled against studies of examiner performance.

Overall, we respond to the affidavit by Vanderplas et al. (2022) as follows:

Points of agreement

- We agree that existing error rate studies are imperfect in several respects.
- We agree that generalization to the whole population (of examiners) is difficult, but that "any study only speaks to the error rate of the participants of that study." (Vanderplas et al., 2022, at p. 6)

Points of disagreement

- We disagree with the assertion that due to their lack of generalizability, existing data should be discarded altogether, i.e., suggesting that there is no useful information in such data.
  - All scientific studies suffer from limitations, yet they are not necessarily rendered unhelpful for advancing a discipline.
  - Discarding imperfect data would contradict the view that data can speak – given suitable acknowledgment of any limitations – to at least the actual participants of a study.
  - Discarding individual and somewhat limited studies would deprive one from seeing where individual studies can complement each other.
- We strongly disagree that generalizability and, hence, the establishment of a single domain-wide error rate should be the overarching aim:
  - While not entirely useless, because it can provide a starting point for assessments of performance, a domain-wide error rate would neither be directly informative about the performance of an individual examiner nor about the probability that an error was committed in the instant case (i.e., the case at hand).
  - Reducing considerations to only a nonspecific, domain-wide error rate would be prone to overlooking potential problems associated with the mandated laboratory and/or the individual examiner(s) having worked in a particular case.
  - A domain-wide error rate is, ultimately, a practical impossibility because there is constant variation in (i) the population of examiners (new examiners enter the field, others leave; individual proficiency evolves over time), and (ii) the types of firearms and ammunition manufactured (and subsequently present in general circulation). Thus, it is always possible to argue that existing studies are somehow imperfect, which renders the call for a domain-wide, contemporaneously valid error rate ultimately self-defeating.

Conclusions

- Given the elusive nature of the idea of a domain-wide error rate, we conclude that existing error-rate studies – despite their limitations – are not fatal to the field of forensic firearms examination as a whole.
- When considering the broad variety of pillars that make up the field of forensic feature-comparison, we contend that the isolated technical critique of the lack of generalizability of existing error rate studies is at best unhelpful and, at worst, misleading.
  - The critique is ultimately unhelpful because even if a generalized error rate could be available, it would be of limited value for a direct, case-based assessment of examiner performance. In addition, the dismissive attitude towards existing error rate studies, i.e., their wholesale rejection, is not helpful in that it offers no constructive advice on how the data could be used with properly acknowledged limitations.
  - The critique of lacking generalizability is misleading if it induces recipients of expert evidence to believe that the assessment of the suitability, capacity and merits of forensic feature-comparison as a whole would only hinge upon a generalized (i.e., domain-wide) and unspecific notion of error rate — it surely does not.

3 The probative value of results of comparative examinations of elements of spent ammunition (forensic feature-comparison)

3.1 Preliminaries: forensic feature-comparison as applied to firearms examination

This section provides a brief overview of the kinds of materials forensic firearm and toolmark examiners (FFTE) work with as well as the nature and the purpose of the examinations conducted on these materials. The examinations we refer to here pertain to the category known as forensic feature-comparison.

FFTE are commonly asked to help address the question of whether or not particular items of spent ammunition, typically bullets and cartridge cases, have been fired using a particular firearm (e.g., seized from a person of interest).[8] Such a firearm sometimes also is referred to as 'firearm in question', 'suspect firearm' or, simply, 'potential source' (of marks and traces observable on elements of ammunition).

FFTE typically work with two types of items: items of *unknown source*, also called questioned or evidentiary items (e.g., a bullet recovered from a crime scene), and items of *known source*, also called reference or control items. The latter comprise elements of ammunition test-fired under controlled laboratory conditions.

When comparing questioned and known items, FFTE focus on different types of features and marks.[9] A feature can be, for example, a design aspect of an examined item, such as the caliber of a bullet. In turn, a mark is an observable (surface) modification of an examined item. Broadly speaking, marks can be impressions or striations. Impressions can be produced when a target surface (of a tool or firearm) is pressed against (the surface of) another object with sufficient force. For example, the firing pin of a firearm that hits the base of a cartridge case can leave an impression mark. In contrast, striations result from one surface moving across the surface of another object with enough force. For example, striation marks will be produced on a bullet when it is fired through a rifled barrel.

Methodologically, FFTE follow an approach that goes from the general to the particular. That is, FFTE generally start by looking at so-called *class characteristics*. Class characteristics refer to measurable features that characterize a group of sources, such as firearms of a certain caliber and/or with a certain type of rifling (e.g., with right- or left-hand twisted grooves inside the barrel).[10] Such features pertain to well-defined, intentionally designed aspects of the manufacturing process of the firearm. When class characteristics of questioned and known specimens are found to correspond,[11] examinations may proceed further by focusing on *accidental characteristics*.[12] This term refers to marks believed to come from random imperfections or irregularities of various surfaces of the firearm, such as the inner surface of the barrel. These surface features arise accidentally during manufacture but also during the subsequent use of a firearm, cleaning and maintenance operations, corrosion, and damage. Generally, configurations of accidental marks tend to vary considerably (e.g., National Research Council, 2008) between sources (firearms) and, therefore, are widely used by FFTE to help discriminate between candidate sources.

The comparative examination of class and accidental characteristics on pairs of items (e.g., ques-

[8]For an accessible overview of this and other firearms-related forensic examinations, see e.g. the primer for courts issued recently by The Royal Society and The Royal Society of Edinburgh (2021):
https://royalsociety.org/-/media/about-us/programmes/science-and-law/royal-society-ballistics-primer.pdf

[9]Hereinafter, we will use the terms 'feature', 'mark' and 'trace' broadly as synonyms.

[10]Strictly speaking, there are also subclass characteristics, shared only by a subset of a given class of firearms.

[11]When there are obvious discrepancies between class characteristics, e.g., when the caliber of a questioned bullet is clearly larger than the caliber of the firearm of interest (the potential source), the latter can be discarded from further examinations. The same holds when, for example, the direction of twist of the grooves on a bullet and a barrel are different.

[12]In the US the term "individual" or "individualizing" characteristics is sometimes used.

tioned and known) is called *forensic feature-comparison*. Hereinafter, we will use the expressions 'forensic firearms examination' and 'forensic feature-comparison (as applied to firearms examination)' as synonyms.[13]

The fundamental purpose of forensic firearms examination is to assess the *value* of observed similarities and differences between questioned and known items (of ammunition) for helping to support whether or not compared items share a common source, i.e., they have been fired by the same firearm (Section 3.2).

There is no default or pre-established probative value for any comparison between a pair of questioned and known items. For example, the quality and the quantity of corresponding and non-corresponding features may vary from one comparison to another because some firearms are known to mark better than others.[14] In addition, elements of ammunition recovered from crime scenes may be damaged, fragmented, distorted and/or corroded to varying degrees. Last but not least, different examiners may assign different evidential values to observed features, and they may even disagree about what exactly constitute similarities and differences (in accidental characteristics) for a given pair of compared items.

Although research is currently underway on computer-based methods for comparing questioned and known items, and assigning probative value to comparisons,[15] in the current state of forensic practice such methods are not yet widely employed for case-specific evaluations, if at all. Instead, automatic comparison methods are mainly used for investigative purposes, such as the screening of large databases and retrieving specimens with similar features and ranking these specimens according to their degree of similarity with respect to a searched item.[16]

Thus, currently, computer-based systems are – at best – supporting FFTE in their search and comparison tasks. But these systems do not replace the need for a FFTE in reaching a conclusion regarding a given comparison. This current practice raises the question of how a recipient of a FFTE's report should deal with reported results of comparative examinations between questioned and known items of spent ammunition. In the next two subsections, we address two important considerations in this respect: the discriminative capacity of features observed on elements of ammunition (Section 3.2) and expert performance characteristics in forensic feature-comparison (Section 3.3).

3.2 Probative value of observations made in feature-comparison

3.2.1 Basic notions of probative value applied to firearms examination

In order for observed features on elements of ammunition to be of value for helping to assess whether or not two compared items may have been fired by the same gun, the features must have discriminative capacity. To understand the concepts of value and discriminative capacity, it is useful to start by introducing the notion of typical evidence (Robertson et al., 2016). We first explain this notion using general terms and then reconsider it in the context of marks present on elements of fired ammunition.

Typical evidence, in this context, refers to evidence that is less than perfect, i.e., it is only probative to some extent. Stated otherwise, a typical item of evidence (or observation made by a scientist) may not only occur when one hypothesis[17] (i.e., one version of a contested event) is true, but also when an

[13] More generally, marks left by a variety of tools, such as screwdrivers, bolt cutters etc., also fall into the category of forensic feature-comparison, hence the discipline termed 'forensic firearms *and toolmark* examination'.

[14] A possible reason for this is design features. For example, certain types of rifling, such as polygonal rifling, are known to leave marks that are more difficult to discern, hence posing a challenge during comparative examinations (e.g., Heard, 1997), compared to other barrel productions.

[15] See e.g. Mattijssen et al. (2020) for a study on the judgments by FFTE compared to results of a computer-based method.

[16] This application is comparable to the use of AFIS (Automatic Fingerprint Identification Systems) for sorting (known) fingerprints from persons of interest and fingermarks of unknown source.

[17] Throughout this document, we use hypothesis and proposition interchangeably to refer to statements (e.g., versions

alternative hypothesis is true.[18] We will give examples for this situation in due course. Meanwhile, we note that what is of crucial importance for our discussion throughout this document is that, in general, for evidence to have probative value with respect to two competing hypotheses, the probability that the evidence would arise under one hypothesis must be *different* from the probability of that evidence to arise under the respective alternative hypothesis (e.g., Friedman, 2017, at p. 70). In essence, we would like to have evidence that is (much) more typically encountered if one version of a contested event is true rather than some alternative version. Evidence that has this property is said to have discriminative capacity – i.e., it has (probative) value.

Let us now turn to features and marks observable on elements of spent ammunition and see how such observations can have discriminative capacity in the sense described above. Consider an example involving the observation of class characteristics on a fired bullet, such as the caliber, the number of landmarks[19] and the direction of their twist. Suppose further that (i) there is a candidate firearm thought to have been used to fire the bullet in question, and (ii) the firearm at hand is "compatible" in terms of the caliber and the rifling of the barrel (number of lands and grooves and the direction of its twist). Clearly, in such a case, the observation of these class characteristics on the questioned bullet is *more* probable[20] if the firearm at hand was used to fire the questioned bullet than if some unknown firearm was used. The reason for this position is the uncontested fact that firearms vary widely in their class characteristics.

To take these ideas further, we can say that the rarer the combination of observed class characteristics, the greater is their discriminative capacity. There is value, thus, in class characteristics in that they allow one to narrow down the potential source population (Champod, 2000). Here, potential source population means the population of firearms capable of firing the bullet in question. Stated otherwise, the rarer an observed feature combination is, the smaller is the probability of encountering those features by chance. So, as a general principle, we can say that the smaller the probability of occurrence of features by chance, the greater is their discriminative capacity and, thus, the greater is their value in helping to assess whether or not two compared items have been fired by the same gun, rather than two different guns. Conversely, if many firearms possess a given configuration of (class) characteristics, then those characteristics have less probative value for narrowing down the population of potential sources.

The above notion of discriminative capacity also applies to accidental characteristics, i.e., traces believed to come from features that are not repeatable from one firearm to another. A typical example for such traces is striation marks on a bullet caused by the rifling features of the inner surface of the barrel through which the bullet was fired. There is a long history of research in forensic science devoted to understanding the discriminative capacity – i.e., the probative value – of such traces. For example, researchers have studied the number of neighboring (consecutively corresponding) striation marks between pairs of fired bullets known to have been fired using either the same gun or different guns. While it was found that it is possible to observe a certain number of corresponding striation marks on pairs of bullets fired from different guns, bullets fired by the same gun tend to have higher numbers of corresponding (neighboring) striation marks (e.g., Biasotti, 1959).[21] Thus, striation marks have discriminative capacity in the sense defined above.

of contested events) that are either true or false, and that can be affirmed or denied (Anderson et al., 2005).

[18]This is different for *ideal* evidence which always occurs when what one is trying to prove is true, and never occurs when what one is trying to prove is not true.

[19]When a bullet is fired through a rifled barrel of suitable caliber, the lands and grooves of the inside surface of the barrel leave marks on the bullet.

[20]Actually, if the firearm at hand is the one used to fire the questioned bullet, then it is expected that class characteristics correspond.

[21]This observation is conditional on there being no intervening factor (capable to substantially affect the surface properties of the barrel) between the firing of the two bullets being compared.

Key points

- Elements of fired ammunition, i.e., bullets and cartridge cases, bear observable features that can be of value for helping to assess whether or not two compared items have been fired by the same gun, rather than different guns: such features are said to have *discriminative capacity*.
- The probative value (discriminative capacity) of observable features depends on their nature (class and accidental characteristics), their quality, their quantity, and their prevalence in the population of firearms.
- In principle, a feature (or a combination of features) has probative value for helping to assess whether two compared items have been fired by the same gun, rather than different guns, when the probability of observing the feature of interest (or configuration of multiple features) is greater among pairs of bullets fired by the same gun than among pairs of bullets fired by different guns.

3.2.2 The difference between categorical conclusions and statements of probative value

Generally, as explained in Section 3.2.1, the smaller the probability of finding corresponding marks and features is by chance, the higher is the probative value of such corresponding characteristics. Just how probable it is to find a given configuration of corresponding marks for a given pair of questioned and known elements of ammunition is, however, a recurrent matter of contention.

Forensic examiners who claim that they are capable of identifying the firearm (to the exclusion of all others) used to fire a questioned bullet or cartridge assert that they can reduce the potential source population to a single firearm – i.e., the (seized) firearm examined in that particular case. In essence, these examiners assert that the probability of observing the corresponding marks is zero in the event of the two compared items coming from different sources. Stated otherwise, they assert that it is *impossible* to observe the corresponding features by chance between two bullets fired by different weapons. This type of statement is one of the strongest that examiners could provide. Identifications expressed to this degree – also often referred to as individualization – are controversial. For example, it has been argued that such individualizations are not scientifically based because they go beyond what can be supported by empirical evidence, and thus they require (euphemistically) a "leap of faith" (Stoney, 1991, at p. 198). This limitation of categorical identification statements is also acknowledged in recent reference documents issued by the U.S. Department of Justice (2020) and the Organization of Scientific Area Committees (OSAC) for Forensic Science (2019).

Other examiners refrain from giving categorical conclusions. Instead, they restrict their reporting to an expression of probative value.[22] That is, they are willing to explain the reasons why they believe that the probability of observing corresponding features by chance is low (or very low, *but not zero*), and hence that there is high (or very high) value in the observations for helping to establish whether or not the compared items have been fired by the same weapon. Importantly, these examiners do not go as far as to suggest that the probative value is so high as to conclusively and factually establish that the firearm in question is the firearm used to fire the questioned bullet. They consider that it is more defensible and more sensible not to assert that it is impossible to observe the corresponding features by chance in a pair of questioned and known bullets from different sources.

[22] An example of an expression of probative value, adapted from Kerkhoff et al. (2017), is: "In my opinion, the observations are in the order of x times more probable if the questioned bullet was fired by the seized firearm rather than some unknown firearm. The forensic observations made on the bullets thus provide slight (moderate/strong/very strong etc.) support for the proposition that the questioned bullet was fired by the seized firearm rather than the proposition that the bullet was fired by some unknown firearm." Here, x stands for an order of magnitude that expresses the probative value. Generally, the larger the value of x, the higher the probative value of the findings. Note also that x depends on the discriminative capacity of the corresponding features.

So, while there is disagreement among FFTE about the extent to which the population of potential sources (firearms) can be reduced[23] in a given case, all FFTE rely upon the concept of discriminative capacity of features and marks described in Section 3.2.1.

Thus, what is important for our discussion in the remainder of this document is that there is intrinsic potential discriminative capacity in features and marks and that this potential represents one important aspect of forensic feature-comparison as applied to firearms examination, in addition to other important aspects, such as examiner proficiency (discussed in Section 3.3).

Key points

- There is broad agreement among FFTE that marks present on fired ammunition can have value for helping to assess whether a pair of questioned and known bullets have been fired by the same firearm, rather than two different firearms.
- There is disagreement, however, about the extent to which observable features (e.g., corresponding striations) allow one to reduce the population of potential sources (firearms).
- Part of the community of FFTE contends that, in certain cases, observable features allow one to reduce the population of potential sources to a single firearm, resulting in a categorical identification (or individualization) of that firearm as the source of the features observed on a pair of questioned and known elements of ammunition (bullets or cartridges).
- Other FFTE do not contest that there can be (high) value in observable features for helping to assess whether a pair of questioned and known bullets (or cartridges) have been fired by the same firearm, rather than two different firearms. However, these latter FFTE do not assert that the value can be so high as to result in an absolute identification.

3.3 The role of expert performance characteristics in value of evidence assessments

In the previous section, there was discussion that corresponding features observed on a pair of questioned and known items of fired ammunition can have probative value regarding the question of whether or not the compared elements have been fired by the same firearm. This notion of probative value is fundamentally rooted in the broad variability of the design features (i.e., class characteristics) of firearms as well as in the nature of accidental characteristics that vary substantially from one firearm to another.

On their own, however, physical features are of practical value only to the extent that FFTE can reliably recognize such features. This consideration is generally known as the reliability of an expert's report of observed corresponding features (Koehler, 2008). Thus, consumers of expert information need to consider both, the discriminative capacity of reportedly corresponding features (as outlined in Section 3.2) *and* the reliability of the expert's report (Koehler, 2008; Thompson et al., 2003). In the remainder of this document, we will mainly focus on the latter topic, expert reliability.

In recent years, there has been an increase in debates over the reliability of forensic examiners, i.e., their proficiency in giving accurate answers. For example, the report of the President's Council of Advisors on Science and Technology (PCAST)[24] takes one end of the spectrum of the debate and notes:

> "Without appropriate estimates of accuracy, an examiner's statement that two samples are similar – or even indistinguishable – is scientifically meaningless: it has no probative value, and considerable potential for prejudicial impact." (PCAST, 2016, at p. 6)

[23] Examiners who identify unequivocally essentially claim that they reduce the potential source population to a single firearm.

[24] Hereinafter referred to as PCAST Report.

This issue brings us to the question of how are we to know how "good" FFTE are? To what extent are FFTE capable of doing what they claim to be able to do? The concern here, simply stated, is the issue of the extent to which examiners make errors.

In more formal terms, the capacity of examiners refers to the notion of *expert performance characteristics*. In common parlance, these characteristics are often called *error rates*. This topic raises a host of interrelated questions, such as how to define performance characteristics (e.g., at the level of the discipline, the laboratory and/or the individual examiner)?; what is to be counted as an error or how to design and conduct empirical studies for measuring expert performance?; how should one make use of information about error?; as well as others (e.g., Dror, 2020).

In order to approach the notion of error in a structured way, it is helpful to start by distinguishing generally between what is and what is not contested about errors in forensic science in general. Therefore, in this section, we concentrate on the main uncontested understandings about the topic of error in forensic science. We will take a broad view on the notion of error in forensic science because considerations regarding the field as a whole also apply, without loss of generality, to individual disciplines, such as feature-comparison in forensic firearm examination. We will address contested aspects and recurrent concerns about examiner performance characteristics, and their measurement, in Sections 4 and 5.

First and foremost, it is important to recognize that in forensic science practice (casework and proficiency testing) errors occur. They do so even in what is one of the most highly regarded forensic science disciplines: DNA analysis (e.g., Kloosterman et al., 2014; Thompson, 1995). In this regard, calls for monitoring laboratory error rates can be traced back to at least the early 1990s. For example, in 1992, the National Research Council emphasized that "laboratory error rates must be continuously estimated in blind proficiency testing and must be disclosed to juries" (National Research Council, 1992, at p. 89). Interestingly, the second National Research Council Report (1996) took a different perspective and espoused re-testing to address certain types of potential error in a specific case.

Second, error is not a mere practical possibility, but can be shown – using formal developments (e.g., Thompson et al., 2003) – to logically affect the value of a reported correspondence between a pair of questioned and known items (regardless of the nature of the compared materials, e.g., DNA, fingermarks, toolmarks, etc.). In essence, one argument has been that with decreasingly small probabilities for the occurrence of corresponding features by chance alone (i.e., high discriminative capacity), the potential of error becomes an increasingly relevant consideration;[25] to the point that the value of a reported correspondence is essentially bound by the probability of error.[26] Thus, recipients of expert evidence should inquire about both, the discriminative capacity of features, i.e., their "rarity", and the potential of error. As an aside, this conceptual consideration of the impact of the potential of error on probative value is also one reason why part of the forensic science community considers that "identification" is not a defensible conclusion and is an overstatement. There should be no disagreement among experts that error occurs; the debate centers on how to make best use of such information.

Third, despite its crucial importance in value of evidence assessments, the potential of error remains an under-researched area, compared to the extent of studies devoted to quantifying the occurrence by chance of corresponding features (i.e., the discriminative capacity of features). This issue has been and continues to be addressed for forensic DNA analysis, but also should be developed more so for forensic firearms examination. For example, the PCAST report took the position that, in the latter area, there is a lack of appropriately designed studies on expert performance (PCAST, 2016, at p. 112).

[25] More generally, we contend that the potential of error is always a relevant question not just with decreasing error probabilities, especially when lay people will be making judgements.

[26] In the context forensic DNA analysis, for example, it has been noted that "the strength of the evidence is limited by the chance of an erroneous inclusion, be it due to clerical error, accidental switching of samples or whatever. (...) In the end the value of forensic or any other type [sic] evidence is totally dependent on the reliability and validity of the process by which it is generated." (Zabell, 2012, at p. 109)

As a fourth and last uncontested fact we note that, historically, forensic scientists have not always been open to admitting the existence of errors and/or the possibility of measuring their occurrence. Some scientists and commentators have actually asserted that their discipline is error-free.[27] This unsupportable stance has been challenged in a constant stream of publications over the last three decades (e.g., Thompson, 1995; Koehler, 1997; Cole, 2005; Cole and Scheck, 2018). In recent years, however, forensic science, particularly the feature-comparison discipline, has seen a move toward a better acknowledgment of the reality of examiner error. Several observations attest to this trend. In 2020, for example, researchers funded by the U.S. National Institute of Justice (2017-DN-BX-0170) published "A primer on error rates in forensic fingerprint examination" (Eldridge and Champod, 2020). In the same period, the U.S. Department of Justice published a series of documents entitled "Uniform Language for Testimony and Reports" (ULTR). These documents provide guidance for examiners in drafting reports and testifying. Specifically, the approved ULTR for the forensic firearms/toolmarks discipline (on pattern examination) states that "[a]n examiner shall not assert that examinations conducted in the forensic firearms/toolmarks discipline are infallible or have a zero error rate" (U.S. Department of Justice, 2020, at p. 3). Most recently (February 2022), a paper jointly authored by members of the FBI and the Ames Laboratories reports on the design of a "study to assess the performance of qualified firearms examiners working in accredited laboratories in the United States in terms of accuracy (error rate), repeatability, and reproducibility of decisions involving comparisons of fired bullets and cartridge cases" (Monson et al., 2022, at p. 1).[28] This research will add to over a dozen existing studies on the performance of firearms examiners reported since approximately the late 1990s.[29] However, what exactly, if anything, may be concluded about expert performance based on existing studies is a recurrent matter of concern which we address in Sections 4 and 5.

Key points

- Conclusions reported by forensic examiners bear a potential of error.
- The extent to which examiners err (especially in any specific case) is as much an important consideration as is the consideration of the discriminative capacity of corresponding features between questioned and known items of fired ammunition (bullets and cartridge cases).
- Informed forensic firearms examiners refrain from asserting that their field of practice has a zero-error rate.

4 General questions and concerns about expert performance and its measurement in forensic firearms examination

4.1 Overview of this section

After having introduced fundamental concepts of forensic feature-comparison, in particular the origin and nature of marks left by firearms on elements of ammunition (Section 3.1), and considerations affecting the probative value of examiners' observations (Sections 3.2 and 3.3), we are now in a position to conduct a more detailed examination of general questions and concerns about expert performance and its measurement in forensic firearms examinations. Some of the topics we discuss in this section have also been raised by Vanderplas et al. (2022). Where applicable, we include a reference to Vanderplas et al. (2022).

A common view among critics of forensic feature-comparison is that existing studies regarding

[27]Practical examples are reported by Cole (2005) and Saks and Koehler (2005).

[28]This publication is devoted to explaining the study design. Results from this study have not yet been published at this point.

[29]For an overview, see e.g., Monson et al. (2022, at p. 2)

the performance[30] of FFTE have too many flaws to be considered sufficiently sound for use in legal proceedings (e.g., Vanderplas et al., 2022, at p. 10).

In order to examine the pertinence and foundation of this viewpoint, and of specific arguments advanced in support thereof, it is first necessary to critically review a series of common assumptions about forensic feature-comparison as well as the strengths and limitations of studies designed to characterize the performance of human examiners (i.e., error rate studies). We will address these topics in the remainder of this section, using a question-and-answer format. A series of more specific critiques, formulated by Vanderplas et al. (2022), will be addressed later in Section 5.

The structure of the remainder of this section is as follows. Section 4.2 will start by examining the broad question that most end-users of forensic science services ask at the outset: *Is feature-comparison in forensic firearms examination a valid method (technique)?* Based on elements introduced in Section 3, we will explain why this is not a question that can be answered by reference to a single criterion only, such as a threshold value for an error rate.

Subsequent sections will address the more general claim that existing error rate studies cast doubt on examiner performance in forensic feature-comparison. We analyze this claim by breaking it down to a series of specific questions, namely: *do existing black-box type error rate studies characterize the "goodness" of the discipline of forensic feature-comparison as a whole*? (Section 4.3), *how useful is the establishment and pursuit of a (single) domain-wide error rate*? (Section 4.4), and *is it meaningful to dismiss imperfect survey data*? (Section 4.5).

The essence of our argument will be that because error rates serve, at best, only as an indirect measurement of examiner performance, the importance and practical impact of the critiques of existing error rate studies tend to be largely diffused.

4.2 Is feature-comparison in forensic firearms examination a valid method (technique)?

This question would appear to be a simple one, but this section will explain why it has no easy answer. The question is elusive because the comparative examination of spent elements of ammunition (by feature-comparison) is not akin to the operation of a standard laboratory test or technique, such as a screening test for the presence of particular biological material (e.g., blood, saliva, semen, etc.) in a specimen, or a (home use) pregnancy test. Hence, traditional ways of thinking about (diagnostic) testing and related performance assessment (through so-called validation studies) fall short of providing a suitable framework for evaluating the trustworthiness of forensic feature-comparison. To understand the reasons for this position, it is useful to recall a few design elements of conventional testing procedures and associated validation studies.

In principle, standard laboratory tests are designed to function regardless of the person who conducts the test, assuming they follow the protocol properly. That is, once brought into contact with the substance to be tested (e.g., a fluid, a powder, etc.), such tests "crank out" a result without any further human input:[31] they function as a black-box. Broadly speaking, such tests focus on a target substance (or marker), thought to be systematically associated with a particular condition (e.g., the pregnancy hormone in case of a do-it-yourself pregnancy test). For such tests, it is relatively easy to conduct validation studies prior to marketing and deployment of the test in the field. In such validation studies, many test items with known ground truth status are processed and the number of correct and incorrect responses are recorded, leading to standard performance metrics such as sensitivity[32] and

[30] Hereinafter such studies are called, for simplicity, "error rate studies".

[31] However, some minimal user intervention, such as reading a color signal, might still be necessary.

[32] The sensitivity is the proportion of true positives that a test correctly recognizes as positive (e.g., the percentage of people infected with a particular virus that a test correctly identifies as being infected).

specificity.[33] Results of such validation studies can then serve as an indication of the performance with which a test can be expected to operate when applied by consumers (assuming, again, they properly operate the test). Consequently, there can be discussion about whether the performance characteristics of a candidate test are "good enough" to be deployed in a particular context of application.

Contrary to what is largely portrayed in the forensic and legal literature,[34] the above description of standard diagnostic testing does not fit well with forensic feature-comparison methods, in particular the comparative examination of elements of fired ammunition as conducted by FFTE. One cannot easily conduct validation studies for feature-comparison in forensic firearms examination in the same way as can be done for conventional laboratory tests as mentioned above. The reason is that there is no independently operating (i.e., without user intervention) testing device that could render conclusions about pairs of questioned and known elements of ammunition.[35] Instead, a characterizing aspect of the result (output) of a forensic feature-comparison is that it involves human judgment(s). That is, ultimately, a human examiner is required to attest to (i) the similarities and differences in a given comparison, and (ii) the extent to which the observed features provide support for the proposition of same source, rather than different sources.

The above argument implies that we cannot seamlessly talk about the general validity of feature-comparison in forensic firearm examination in the same way as we can do for standard analytical tests. More specifically, there is *no* single and generic – i.e., human-independent – performance characteristic to inquire about for the discipline of forensic feature-comparison.

Notwithstanding this fundamental obstacle, efforts have been made to derive approximate standard performance characteristics (such as sensitivity and specificity) for forensic feature-comparison. The challenge is how to cope with the human examiner as part of the procedure, i.e., the black-box itself. This view is prominently highlighted in the PCAST report:

> "(...) the method must be evaluated as if it were a "black box" in the examiner's head. Evaluations of validity and reliability must therefore be based on "black-box studies," in which many examiners render decisions about many independent tests (typically, involving "questioned" samples and one or more "known" samples) and the error rates are determined" (PCAST, 2016, at pp. 5–6)

This way of looking at forensic feature-comparison is the main reason for the current and revived interest in black-box studies (i.e., error rate studies). While we support error rate studies as a legitimate and valuable area of inquiry, we caution against reducing the assessment of the discipline of forensic feature-comparison to the sole notion of error rate.

To come back to the question posed in the title of this section – the validity of the discipline – we find that the current state of development of the field offers only a partial reply. That is, in our view, the capacity of the discipline of forensic feature-comparison is a function of two main considerations. We have introduced them earlier in Section 3: on the one hand, the potential of observed features to have discriminative capacity (Section 3.2) and, on the other hand, the performance of human examiners in capturing such features and conveying their probative value (Section 3.3).

The first of these two aspects, the potential[36] discriminative capacity of traces on elements of spent ammunition, is largely uncontested, due to what is generally known about the large variability of design features introduced during manufacturing processes of firearms, as well the various mechanisms and

[33]The specificity is the proportion of true negatives that a test correctly recognizes as negative (e.g., the proportion of people *not* infected by a particular virus that a test correctly recognizes as *not* being infected by that virus).

[34]Including official reports such as the PCAST Report.

[35]As mentioned in Section 3.1, there exist computer-based comparison methods, but they are used for database searching, *not* for identification.

[36]We talk about *potential* discriminative capacity because, clearly, not all observable marks on fired elements of ammunition are of value in helping to discriminate between candidate firearms (i.e., potential sources).

phenomena that lead to configurations of surface features that leave highly variable traces on elements of fired ammunition (e.g., Bonfanti and De Kinder, 1999). We will not pursue this topic any further here other than by repeating that features on elements of fired ammunition (bullets and cartridge cases) have intrinsic probative value, conditional on being correctly assessed and interpreted by a proficient and knowledgeable examiner (Section 3.2).

The second aspect, the performance of human examiners in conducting feature-comparisons, is more nuanced to tackle because of the debates over what, if anything, one can legitimately conclude from existing error rate studies. In the forthcoming sections, we will address this controversy through a series of questions and answers that we believe are helpful to anyone asked to assess the suitability of forensic feature-comparison for use in legal proceedings.

Key points

- Forensic feature-comparison cannot be compared to conventional laboratory tests that produce outputs essentially without user intervention.
- Arguably, there is *no* generic and human-independent performance measure for feature-comparison in forensic firearm examination, akin to performance characteristics used for traditional laboratory testing procedures.
- The capacity of forensic feature-comparison is a function of two main considerations: (i) the discriminative capacity of features (marks and traces present on elements of spent ammunition) and (ii) the ability (proficiency) of examiners to correctly discern and assess the probative value of such features. Currently, point (i) is largely uncontested. Disagreements exist over point (ii).

4.3 Do existing black-box type error rate studies characterize the "goodness" of the discipline of forensic feature-comparison as a whole?

To address this question, it is important to be clear about the object of existing black-box type error rate studies:[37] such studies give only a snapshot of the performance of a selected number of examiners in conducting a particular task under more or less controlled experimental conditions. The experimental nature of these studies implies that, by definition, they fall short of mimicking casework conditions to at least some extent and may not apply to the circumstances in a particular case. For example, usually, examiners know that they are working on items submitted as part of a study or a proficiency test, which may affect the way they approach the comparison task (e.g., in terms of the care and attention devoted to the task). In addition, the study design may involve a (common) combination of firearm and ammunition which may be easier or more difficult to examine than a more unusual set of materials.

Due to their design, black-box type error-rate studies thus neither inform about the performance of the discipline of forensic feature-comparison as a whole or in an abstract sense (i.e., disconnected from an intervening human examiner).[38] Instead, such studies focus on the human component which, as we have outlined in Section 3, represents only one aspect of forensic feature-comparison.

Key point

- Error rate studies serve, at best, only as an indirect way to inform about whether selected

[37] Black-box studies are understood here as studies "in which many examiners render decisions about many independent tests (typically, involving "questioned" samples and one or more "known" samples) and the error rates are determined" (PCAST, 2016, at pp. 5–6).

[38] Recall, as explained in Section 4.2, forensic feature comparison is not comparable to a standard laboratory test that can be characterized by a general performance metric that is valid regardless of the particular examiner who applies the test.

members in the profession of forensic feature-comparison examiners are "any good" in doing what they purport to be able to do under the test conditions.

4.4 How useful is the establishment and pursuit of a (single) domain-wide error rate?

Critics of the discipline of forensic feature-comparison assert that existing error rate studies fall short of the requirement of being representative of "all qualified firearms examiners in the United States" (Vanderplas et al., 2022, at p. 5). They take the position that error rate studies should focus on representative samples obtained by random selection of participants from the relevant population or even "a full census of the population at a certain time" (Vanderplas et al., 2022, at p. 5). Doing otherwise, as they suggest, would go against what "is taught in even basic undergraduate statistics courses" (Vanderplas et al., 2022, at p. 5).

Clearly, the use of sound statistical methodology is advocated. However, one should raise the question – *should an error rate in pure statistical terms represent a minimum requirement, or even a meaningful aim?* To think through this question, suppose that we had an error rate derived from one or more studies, satisfying statistically rigorous requirements for participant selection.[39] How useful would such an error rate be? We contend that, while not being completely useless, it would be affected by clear limitations.

On the upside, we agree that a domain-wide error rate (if it were possible to achieve) could be of value for providing a starting point (termed "anchor" by Koehler (2008)) for thinking broadly about the occurrence of errors. As Koehler has concisely noted (in the context of data derived from proficiency testing):

> "(...) the industrywide error-rate estimates provide anchors for judgments about the risks of error in individual cases. This is an elementary and critical point: if the industrywide false positive error rate is 20% for technique A and 2% for technique B, then the risk of this type of error in any given case is generally higher when technique A is used rather than technique B" (Koehler, 2008, at pp. 1088–1089).

There are, however, three downsides to this position.

First, despite serving as an anchor, a domain-wide error rate cannot directly be interpreted as the probability that an error has been made in the instant case (i.e., the case at hand) because the practice of forensic feature-comparison involves different levels of difficulty and a variety of combinations of materials (i.e., combinations of types of ammunition and firearms). There is, currently, no single study, or combination of studies, capable to measure expert performance across a range of materials and levels of difficulty as encountered in casework. As an aside, note that this is a further dimension in which studies would need to achieve representativeness, in addition to the above-mentioned criterion of representativeness on the level of participant selection.

Second, the application of an anchor, i.e., representing some sort of average error rate across many examiners, is not directly informative about the performance of a given forensic examiner. Clearly, relying integrally and exclusively upon a domain-wide error rate when assessing the performance of a given examiner would be prone to overvaluing a poor (i.e., under-performing) examiner and undervaluing a proficient examiner (i.e., one with above-average capabilities). The former case would be prone to relying on potentially unsafe information whereas the latter case would tend to reduce reliance on potentially high quality evidence.

Third, individual and group proficiency evolves by technology advancement and external factors

[39] Note that participant selection is only one statistical dimension of experimental design.

such as an effective quality assurance system should identify nonconformities, perform root cause analyses, and put in place corrective actions.

These difficulties have long been recognized in some forensic feature-comparison disciplines, such as latent fingermark examination. For example, a report of the American Association for the Advancement of Science (Thompson et al., 2017), making reference to Kellman et al. (2021), noted:

> "it is unreasonable to think that the 'error rate' of latent fingerprint examination can meaningfully be reduced to a single number or even a single set of numbers. At best, it might be possible to describe, in broad terms, the rates of false identifications and false exclusions likely to arise for comparisons of a given level of difficulty." (Thompson et al., 2017, at p. 45)

Even one of the most insistent supporters of the proper acknowledgment of the phenomenon of human error in forensic casework, Dr Itiel Dror, admits that the theoretical notion of error – despite its importance – faces serious practical challenges:

> "Establishing error rates is crucial for knowing how well one is performing, determining whether improvement is needed, measuring whether interventions are effective, as well as for providing transparency. However, the flurry of activities in establishing error rates for the forensic sciences has largely overlooked some fundamental issues that make error rates *a problematic construct* and *limit the ability to obtain a meaningful error rate*. These include knowing the ground truth, establishing appropriate databases, determining what counts as an error, characterizing what is an acceptable error rate, ecological validity, and transparency within the adversarial legal system." (Dror, 2020, at p. 1034; emphasis added)

Dror goes so far as to ask whether these obstacles are so substantive that they call the whole endeavor of establishing error rates into question:

> "(...) given the time and effort it [the proper establishment of error rates] requires, as well as the inherent limitations of the very notion of error rates, is it worth it? And, how does it compare (or complement) other measures of performance (e.g., effective proficiency testing, quality assurance checks such as dip sampling and blind verification, accreditation, and ongoing training and development)[?]" (Dror, 2020, at p. 1038)

In summary, the above considerations explain that a domain-wide error rate, derived in a statistically rigorous way regarding participant selection, would at best inform about an abstract question: i.e., an average performance under a set of test conditions. We call this notion abstract because it does not directly inform about the performance of a given examiner or the probability of an event of error having occurred in the individual case. But, – we repeat – an average error rate may serve as an anchor for such assessments in a general way about use and performance.

The limitations in the practical usefulness of the idea of a domain-wide error rate discount, to a large extent, the importance of the critiques of existing error rates studies regarding representativeness at the level of participant selection. This conclusion is not an endorsement for giving poor statistical practice a pass. The point is not even statistical. Rather, it is a recognition of the fact that a perfect answer to a question is of limited helpfulness if that question itself is off the target. A perfect answer cannot remedy the shortcomings of the question asked.

Key points

- A domain-wide error rate cannot directly be used for assessing (or, interpreted as) an individual examiner's performance or the probability of an event of error having occurred in a particular case.
- At best, a domain-wide error rate can provide an anchor for reasoning about a particular

case.

- The limited operational usefulness of a domain-wide error rate weakens, to a large extent, the importance of the criticism that existing studies fall short of certain statistical requirements, such as representativeness in participant selection.

4.5 Is it meaningful to dismiss imperfect survey data?

As mentioned at the beginning of Section 4, critics of existing error rate studies in forensic feature-comparison assert that shortcomings in methodological design should prevent data from such studies from being used in practical proceedings.[40] This viewpoint seems to be predicated on the idea of looking at one study at the time, finding each of the studies deficient in some way, and then concluding that none of the studies is suitable.

We contend that proceeding in such a manner is questionable on three grounds. First, this sort of proceeding is prone to lead readers to commit one version of the "imperfection fallacy" (Koehler, 2008). Second, this way of proceeding ignores "convergent validity", a concept previously highlighted in the AAAS Report by Thompson et al. (2017, at p. 94). Third, dismissing data because of limitations in generalizability is prone to oversee the differences between descriptive and inferential statistics: that is, while data may have limitations for drawing conclusions about a (larger) population, such data may still be of value in a descriptive sense. Below, we explain each of these three drawbacks regarding that proffered by Vanderplas et al. (2022).

4.5.1 The imperfection fallacy

Controversies over how to use data have previously been encountered in discussions about the use of proficiency testing data for assessing the probability of error in casework. In this context, it is largely uncontested that data are imperfect and, hence, cannot – on their own – establish error rates (e.g., Cole, 2005; Tobin and Thompson, 2006). Yet, design imperfections should not necessarily be taken to mean that such data are irrelevant altogether. Dismissing data hastily by applying too stringent requirements has been called a fallacy:

> "A skeptic could point to one or more of the study's imperfections and draw the mistaken inference that the study is irrelevant (...). Such an inference would be an instance of what might be called the "imperfection fallacy" (i.e., a tendency to treat imperfect information as irrelevant)." (Koehler, 2008, at p. 1100)

These elements of discussion about proficiency testing data also provide guidance for dealing with results from error rate studies.

Clearly, no serious commentator would contest that data from error rate studies are imperfect to some extent and that, in practice, a perfectly flawless study is difficult to realize, especially in such a heterogenous field as forensic feature-comparison.[41] One ready way to deal with this challenge is by being transparent and stating the identified limitation(s), followed by an assessment of the impact of those limitation(s) on the conclusions to be drawn from the data. For example, when a study encountered non-responding participants (non-volunteers), attention should be drawn to the proportion of non-respondents, e.g., by asking how substantial that proportion is and to what extent it compromises generalizability.

In any case, even if generalizability is compromised, the presence of non-respondents in a study

[40] See e.g. the conclusion in Vanderplas et al. (2022, at p. 10).

[41] As noted by Judge Edelman in the case *United States v. Tibbs*, No. 2016-CF1-19431, 2019 WL 4359486 (D.C. Super. Ct. Sept. 5, 2019), "[u]ndoubtedly, experts with extensive training in research methods could likely find fault with the methodology of any study" (at p. 33).

does not prevent one from considering what a given study could, at least, say – descriptively – about the participants who have responded properly.[42]

4.5.2 Falling short of the concept of convergent validity

The second drawback of focusing on individually imperfect studies one at the time – also called "atomistic approach" (Thompson et al., 2017, at p. 94) – is to ignore the concept of "convergent validity", defined as follows:

> "the possibility that various publications, each with distinct limitations when considered by itself, can reinforce each other and collectively support conclusions that would not be warranted on the basis of a single article." (Thompson et al., 2017, at p. 94)

Recognizing that "studies will have different strengths and limitations, and that the literature as a whole will have strengths and limitations" (Thompson et al., 2017, at p. 44), there is no valid reason why one should not try to see what conclusions can be drawn from literature as a whole, especially how individually imperfect studies can complement each other.[43] We note, however, that the notion of "convergence" here should **not** be taken as tending toward (or suggesting the existence of) a single statistic (i.e., a discipline-wide error rate). Instead, the idea is that of drawing a broader picture of how different examiners perform in various experimental settings, based on data drawn from multiple relevant studies.

We believe that convergent validity is as much applicable in the field of fingerprints, discussed by Thompson et al. (2017), as it is in the discipline of forensic feature-comparison applied to firearms examination.

4.5.3 The missed distinction between descriptive and inferential statistics

A primary line of argument advanced by critics of existing error rate studies is that imperfect data, e.g., due to participant or material sampling problems (Vanderplas et al., 2022, at pp. 5–7), limit the use of such data for drawing conclusions about the wider population (i.e., profession) of forensic feature-comparison examiners. It is important to understand that this is an argument about *inferential statistics*,[44] which should be clearly distinguished from the notion of *descriptive statistics*.[45]

Specifically, drawing attention only to shortcomings in the inferential usage of data, and *to leave it at that*, is prone to concealing the descriptive dimension in which data may be used. Though widely considered as less prestigious, compared to statisticians' primary focus on inferential statistics, the factual description of data remains an important preliminary to inferential statistics. For example, one can ask – quite factually – "in this study, how many examiners have failed to report 'identification' for pairs of items known to come from the same source?", "which examiner(s) has (have) committed errors (i.e., what are the characteristics of examiners who committed errors)?", "is a majority of errors committed by a small number of examiners or do the errors distribute differently (e.g., over a larger number of examiners)?" There is no reason why such information – which is descriptive on the level of study participants who have properly responded – should be ignored in principle, regardless of how well (if at all) the data will allow one to draw conclusions about the entire profession of forensic

[42] Even critical commentators admit to the obvious point that "any study only speaks for the error rate of the participants of that study" (Vanderplas et al., 2022, at p. 6).

[43] Again, even critics appear to be open to this point when they write "it is not only important that study participants be randomly sampled from the population, but also that there are multiple studies" (Vanderplas et al., 2022, at p. 6).

[44] Broadly speaking, inferential statistics aims at providing information about the population from which a sample (data) is available (e.g., The Council of the Inns of Court and The Royal Statistical Society, 2017; The Royal Society and The Royal Society of Edinburgh, 2020)

[45] Descriptive statistics summarize and hence describe different aspects (e.g., the mean) of a given sample (e.g., The Council of the Inns of Court and The Royal Statistical Society, 2017; The Royal Society and The Royal Society of Edinburgh, 2020).

feature-comparison examiners. More importantly, taking a deeper dive in the naked numbers can reveal information that a mere average, obtained by generalization, cannot provide. Valuable data, otherwise, would be ignored.

Next, rather than just asking how many examiners have given a particular answer when comparing a particular pair of items (of same or different source), one can summarize the data and produce descriptive statistics such as the missed identification rate or the failed elimination rate, just to name two examples.

Even critics, such as Vanderplas et al. (2022), appear to acknowledge the above points. In fact, several authors of Vanderplas et al. (2022) have, in a recent paper (Hofmann et al., 2020),[46] reviewed a series of studies on examiner performance in forensic feature-comparison. They have produced different types of summary statistics (of the kind mentioned above), compared them between studies and summarized their results graphically. They observed, for example, that "examiner error rates are low for both missed elimination and missed identifications in most studies" (Hofmann et al., 2020, at p. 335). They also found that "examiners are extremely good at working with same-source evidence," but "have much more difficulty when evidence arises from different sources." (Hofmann et al., 2020, at p. 336) Underlying their approach is the idea of what may be called "zooming" into data at different levels of detail, i.e. looking descriptively at the performance of examiners when conducting known same- and different-source pairs, respectively.[47] We interpret this Hofmann et al. (2020) study as their acknowledgment of the fact that data from existing error rate studies can be used to at least some extent, given the proper acknowledgment of limitations.[48] Hofmann et al. (2020) even admit that, "[a]s discussed in Dror (2020), additional statistics that provide context to error rates can be *extremely beneficial* in court." (at p. 325; emphasis added)

Key points

- While it is widely uncontested that existing studies of expert performance in forensic feature-comparison are imperfect to varying degrees, it would be shortsighted to dismiss data from imperfect studies altogether.
- The tendency to treat imperfect information as irrelevant is known as the "imperfection fallacy" (Koehler, 2008, at p. 1100), i.e., depriving oneself of information that a study could offer when properly acknowledging and discounting for the respective limitations.
- Considering imperfect studies in isolation ignores the concept of "convergent validity" (Thompson et al., 2017, at p. 94), i.e., the possibility that different studies, though individually limited, can complement each other and support conclusions that none of the studies could have warranted individually.
- While imperfect data may be of limited use for inferential purposes (e.g., drawing conclusions beyond the sample to a wider population), it does not follow that these data could not be used for more factual and descriptive purposes (e.g., summarizing observations made on study respondents rather than making assertions about the wider population of members of the profession).

[46] Note that Vanderplas et al. (2022) refer to this paper as "Hofmann, Vanderplas, and Carriquiry (2021)". While the latter paper was officially published in 2021, it was – technically – included in Volume 19 (2020), which is why we refer to it here as "Hofmann et al. (2020)".

[47] The authors call these summaries "separate accuracy rates for comparisons of same or different-source evidence" (Hofmann et al., 2020, at p. 325)

[48] For example, Hofmann et al. (2020) note that the methodological design of some studies is such that no summary statistics can be computed.

5 What specific, technical critiques are levelled against studies of examiner performance and how to respond to those critiques? – Responses to Vanderplas et al. (2022)

Based on the general elements of discussion introduced so far, we are now in a position to review a series of specific, more technical critiques levelled against studies of the performance of forensic feature-comparison examiners. For this purpose, critiques expressed in Vanderplas et al. (2022) are addressed.

5.1 Study design: closed set vs. open set

Critique: "many common firearms and toolmark black-box study designs do not allow for estimation of the number of different-source comparisons, which ensures that it is not possible to calculate the overall error rate, the correct decision rate, or the true negative rate (the specificity)." (Vanderplas et al., 2022, at p. 4) To help overcome this problem, the commentators recommend the following: "black-box studies should be open set studies (no guarantee that an unknown item matches any provided knowns in the set) and should involve the comparison of one standard (known sample) and one or more unknown samples at a time." (Vanderplas et al., 2022, at p. 5)

Response: To address this critique, it is first necessary to explain the difference between closed set and open set studies (e.g., PCAST, 2016, at p. 106–110).

A closed set study is one in which examiners receive a set of questioned items (bullets or cartridge cases) and they are asked to compare these items to a set of reference items (bullets or cartridge cases). The latter represent the possible guns used for firing the questioned elements of ammunition. A key feature of closed set studies is that the firearm at the "source" of each questioned item is always present in the test (in the form of the reference items). In turn, an open set study is one in which not all questioned items have their "source" present among the reference items.

Generally, closed set studies are considered problematic in that they may compromise the computation of performance metrics when the number of different source comparisons is unknown. In addition, closed set studies are generally viewed as easier to accomplish because examiners can draw upon knowledge that each questioned item has a corresponding reference item. Accordingly, such studies are expected to lead to too favorable assessments of the error rate.

Given the known problems associated with closed set studies, it is widely recommended that studies should use the open set design, which was noted in the PCAST Report (2016).

The community of researchers and practitioners appears to have taken this concern to heart. In a recent review of selected studies between 1998 and 2021, Monson et al. (2022, at p. 2) find that the closed set design is mainly used in studies prior to the publication of the PCAST Report (seven out of twelve summarized pre-PCAST studies). In turn, only two of six post-PCAST studies summarized by Monson et al. (2022, at p. 2) use the closed set design. As an aside, we also note that, most recently, the field has seen what may be the first report on preliminary results of a blind testing program in forensic firearms examination (Neuman et al., 2022), implemented at the Houston Forensic Science Center since December 2015 (Guerra Thompson and Bremner Cásarez, 2020).

Regarding the impossibility to calculate the correct source decision rate, there is a marked difference between pre- and post-PCAST studies. In the list of studies summarized in Table 1 of Vanderplas et al. (2022, at p. 13), three of the four studies where the correct source decision rate is not calculable appeared prior to the PCAST Report. The single post-PCAST study for which Vanderplas et al. (2022) report that the correct source decision rate is not calculable is the one by Hamby et al. (2019), but this study is already marked as problematic because of its use of the closed set design.

In summary, we thus observe[49] that the critiques of Vanderplas et al. (2022) regarding the study design (closed set vs open set) and the impossibility to calculate correct source decision rates, while being technically correct, should be put in perspective: specifically, these critiques mainly apply more so to pre-PCAST studies, rather than the more recent post-PCAST studies.

5.2 Participant sampling problems

Critique no. 1: "if the participants are not a representative sample from the population (in this case, all qualified firearms examiners in the United States), the results of the study do not generalize to that population. This principle is taught in even basic undergraduate statistics courses; it is fundamental to our discipline. One of the easiest ways to ensure that a sample is representative is to randomly select participants from the population; a more labor-intensive option is to conduct a full census of the population at a certain time." (Vanderplas et al., 2022, at p. 5)

Response to no. 1: It is not contested that existing studies do not generalize to the population comprized of all qualified firearms examiners in the United States. It should go without saying that the imperfect nature of the data calls for caution and restraint, such as limiting conclusions to only those examiners who agreed to participate in the study and to respond properly. By the way, as noted earlier, this issue is what the commentators recommend themselves when they write that "any study only speaks for the error rate of the participants of that study." (Vanderplas et al., 2022, at p. 6)

Note also that, following our discussion in Section 4.4, the importance of the critique regarding the lack of generalizability is weakened by the fact that a domain-wide error rate, even if available, would have limited operational usefulness.

Critique no. 2: "there are many potential lurking covariates that would meaningfully affect the error rates estimated by the studies. For instance, *it is possible that* experienced examiners are more likely to volunteer to participate in these studies out of a sense of duty to the discipline: these examiners might have lower error rates due to their experience, which would lead to an estimated error rate that is lower than the error rate of the general population of all firearms examiners (including those who are inexperienced). In fact, in studies which differentiate between trainee and qualified examiners, we find a higher error rate among trainees (Duez et al. 2018)." (Vanderplas et al., 2022, at p. 5; emphasis added)

Response to no. 2: This critique is a rhetorically subtle formulation because it uses a true statement (here: higher error rate among trainees) to create a doubt for which no direct evidence is provided. That is, Vanderplas et al. (2022) give no evidence for whether experienced examiners are actually more inclined to participate than less experienced examiners. The same holds for the variables the commentators mention in this sentence: "There are many variables which might be expected to increase likelihood of volunteering for a study and also change the expected error rate: education, experience, confidence, amount of time available for study participation." (Vanderplas et al., 2022, at p. 5)

Critique no. 3: "sampling bias is one of the hardest biases to work around. Because we cannot determine how the volunteer examiners might differ from the whole population of examiners, we cannot say that it is likely that the error rate is higher or lower than what is reported from the flawed studies." (Vanderplas et al., 2022, at p. 6)

Response to no. 3: See above response to no. 1.

5.3 Material sampling problems

Critique: In Section 5 of Vanderplas et al. (2022, at pp. 6–7), the authors mention that existing studies cover only a limited number of firearms and ammunition types, thus preventing the possibility to

[49] Note, however, that the lists of articles summarized by Vanderplas et al. (2022) and Monson et al. (2022) do not exactly overlap.

generalize:

- "we lose the ability to make broad, sweeping claims about the discipline as a whole" [at p. 6]
- "We cannot generalize error rates from small consecutively manufactured firearm studies to the entire population of firearms examinations, and as a result, we do not know how to assess the error rate of the discipline as a whole on the basis of these studies." [at p. 6]
- "This makes it extremely difficult for researchers to provide a general estimate of the error rate of firearms and toolmark comparisons, as the discipline is so broad and the data under examination are affected by so many different factors: type of tool or firearm, ammunition, manufacturing process, material interactions, and so on." [at pp. 6–7]

Response: This critique goes along the critique of participant sampling problems discussed in Section 5.2 and the problem of generalizability addressed in Section 4.4. Thus, we can draw upon discussion developed in those sections.

We reiterate that, first, a single and domain-wide error rate would be of limited usefulness because an "average" examiner does not exist. An average error rate in this sense would either overvalue a poor examiner or undervalue (penalize) an above average or even outperforming examiner (Section 4.4).

Second, as much as there is no "average" examiner, there is no "average" combination of firearm and ammunition.[50] Instead, there are many firearm and ammunition categories (or types) for which a single average error rate could not meaningfully reflect examiner performance. It would be a too optimistic figure for reputedly difficult firearm and ammunition types, and too conservative one for less challenging comparison pairs. However, it would be exaggerated to require that an expert has previously seen (i.e., worked with) *all possible* combinations of firearms and ammunition. Rather, what is important for recipients of expert evidence is to see whether the examiner can demonstrate technical knowledge about the relevant category (type) of materials examined in the instant case and proficiency in examining such materials. For example, the expert will need knowledge about the design differences between conventional groove rifling (in barrels) as compared to a polygonal rifling (or even microgroove rifling) and the impact of these design features on the production of marks present on fired bullets. Clearly, the examiner does not need to have seen *all* existing barrels with conventional (or polygonal) rifling prior to explaining the kind of marks he/she would expect to see for a barrel of this particular type. Likewise, a proficient examiner can be familiar with the kind of marks present on different types of bullets, such as jacketed versus non-jacketed bullets, without having seen all existing exemplars of jacketed and non-jacketed bullets. Thus, as noted above, the point here is that the examiner should be able to demonstrate knowledge and understanding with the kind of examined items (general category of firearm and ammunition) encountered in a particular case. As a simple example, an expert who specializes mainly in modern handguns might naturally need to declare limitations with respect to his/her competence in examining antique rifles dating prior to 1900s (if the latter are beyond his/her primary field of expertise).

Third, requiring that studies should cover many or all dimensions of combinations of firearms and ammunition types is a practical impossibility, not only due to the combinatorial complexity, but also because the relevant population is never stable. New firearms and ammunitions are being manufactured regularly, while the production of certain weapons and types of ammunition is discontinued.

[50]We make the assumption here that Vanderplas et al. (2022) suggest that generalization should not only be the goal at the level of participants, but also at the level of materials subjected to feature-comparison. If this assumption misinterprets the intention of Vanderplas et al. (2022), and their suggestion instead is that error rates should be computed individually for each category of materials (i.e., combination of firearm and ammunition type), then this would amount to a practically almost impossible task (due to combinatorial complexity) and, hence, represent a self-defeating proposal.

5.4 Missing data and non-response bias

Critique: In Section 6 of Vanderplas et al. (2022, at pp. 7–8), the authors note that the quality of existing studies suffers from participants who fail to respond. Next, these commentators explain that the error rate would turn out to be higher *if* the non-respondents would have been included in the results and *if* their answers would have been consistently erroneous.

Response: This assertion is a further example of the use of a true statement (here: the existence of non-responses) for suggesting conclusions based on assumptions for which actual evidence is lacking.[51] That is, Vanderplas et al. (2022) provide no basis to believe that *all* non-respondents would render erroneous answers; an error rate based on such an extreme assumption is hypothetical and not conducive of advancing a constructive discourse over what the potential of error could realistically be.

In line with our discussion throughout this document, we reiterate that

(i) the imperfection of existing studies and related data is not contested,

(ii) imperfect data should not be dismissed entirely (provided that limitations are properly acknowledged), but interpreted within the relevant scope (e.g., limiting conclusions to those examiners who properly responded),[52] and

(iii) even if data were perfect (in strict statistical terms), the resulting domain-wide error rate would characterize an abstract question and, hence, be of limited practical usefulness.

5.5 Types of marks and study difficulty

Critique: In Section 7 of Vanderplas et al. (2022, at pp. 8–9), the authors note that "there are many different types of marks used for firearms and toolmark examination, and it would not be reasonable to assume they all have the same error rates" [at p. 8] and that "[t]he difficulty level across different studies is not necessarily comparable" [at p. 9]. As a consequence, according to the commentators, error rates will differ as a function of these variables (i.e., types of marks and levels of difficulty).

Response: We agree with the above statements by Vanderplas et al. (2022) which notably seem at odds with their advocacy for a domain-wide error rate. They confirm our position that the attempt to derive a domain-wide error rate is neither practically possible[53] nor particularly useful. We reiterate that what is important is that the examiner is able to demonstrate *knowledge and understanding with the kinds and types of materials examined in a particular case* (see also our discussion in Section 5.3).

5.6 Inconclusives

Critique: "Scientifically, an inconclusive result has to be automatically incorrect: a comparison is either from a same-source or a different-source." (Vanderplas et al., 2022, at p. 9)

Response: One of us has recently discussed at length elsewhere why this assertion falls short of a meaningful account of the problem (Biedermann and Kotsoglou, 2021).

To start with, it is important to acknowledge that no reasonable scientist ignores that "inconclusives" can represent a problem. Indeed, suppose an extreme situation in which an examiner would report "inconclusives" only. Such an examiner would – obviously – never commit a false identification or a false exclusion and hence would have a zero-error rate. However, such a reporting strategy would be noted in a transparent or quality system, and the examiner would reveal him-/herself as entirely unhelpful (i.e., she/he would never give a supportive conclusion).

[51] A previous example of this kind was discussed in our reply to critique no. 2 in Section 5.2).

[52] Further, one should properly distinguish between descriptive and inferential uses of data (see also discussion in Section 4.5.3).

[53] The main reason for this is combinatorial complexity when considering multiple dimensions in which examiners, firearms/ammunition as well as marks and study difficulty may vary.

Conversely, no reasonable scientist would assert that "inconclusives" should be completely ignored. Instead, "inconclusives" should be monitored for what they are: the rate of "inconclusives" provides a measure of the assertiveness of (or, the level of caution exerted by) an examiner. But inquiries into inconclusive results should dive deeper. It is also important to examine the circumstances under which "inconclusives" are given. For example, it makes a difference whether an examiner renders an "inconclusive" in a very difficult case (e.g., where the marks are poor and/or of limited informative value)[54] or an easy case (e.g., with good/high quality marks with many discriminative features). In the first case, an "inconclusive" might be a suitable (i.e., scientifically defensible) conclusion,[55] whereas in the latter case an "inconclusive" might reflect overcautiousness by falling short of what a majority of proficient examiners would assign as probative value.

Thus, labelling "inconclusives" generically as errors is of little help in practice. A meaningful discussion about expert performance requires clarity about the kind of error. For example, in our experience, recipients of expert evidence typically have a primary interest in the proportion of false positive errors. It is clearly unsuitable then to conceal the inconclusive statistic (if it were treated solely as error [sic]) by transforming it into an unspecific notion of error that comprises several different types of potential error.[56]

In our view, the key to dealing with "inclonclusives" is transparency. "Inconclusives" fall into a response category in its own right that can and should be summarized in a separate statistic that is useful for monitoring various aspects of a study (e.g., examiners' level of responsiveness). "Inconclusives" should not be dismissed; they should be used within the scope in which they can be meaningfully informative.

Overall, our view is in line with standpoints expressed elsewhere in the legal literature, which emphasizes balance and clarity in the use of "inconclusives":

> "Similarly, when an examiner offers an "inconclusive" opinion (...) there is a sense in which he has erred. After all, he did not get the answer right, and the consequences of this failure may be serious (e.g., missed opportunity to exonerate a suspect). However, in the more usual sense of the meaning of error, *an inconclusive is not an error. It is a pass.* An inconclusive means that the examiner offers no judgment about whether two prints do or do not share a common source. Therefore, for the purpose of computing the errors and error rates (...), I set inconclusives aside." (Koehler, 2008, at pp. 1080–1081; emphasis added)

Finally, we note that by labelling "inconclusives" by default as errors, Vanderplas et al. (2022) take a more extreme position than what some of the same authors have conveyed elsewhere. Specifically, in Hofmann et al. (2020), they explain that there are ways to summarize data that "do not require inconclusive results to be explicitly handled as errors or correct decisions" (at p. 325) and that this represents an "advantage" (at p. 325).

5.7 Further observations on the affidavit by Vanderplas et al. (2022)

Hereafter, we note a few additional and more general observations on the affidavit by Vanderplas et al. (2022):

- Overall, Vanderplas et al. (2022) present a narrow view because it is almost exclusively tailored towards the (statistical) argument of generalizability (i.e., the lack thereof), resulting from a

[54] Another example could be so-called "close non-matches" (Koehler and Liu, 2021).
[55] See e.g. Biedermann et al. (2019) for a decision-theoretic justification of this argument.
[56] This view is also echoed by the Judiciary. For example, Judge Edelman, though acknowledging that "inconclusives" represent "an error of some kind", questioned the idea of jointly considering different types of errors: "such a characterization *fails to make logical sense*: while under laboratory conditions such inconclusives are surely some type of error, it does not follow that inconclusives are functionally the same as a false conclusion by an examiner who attributes a cartridge casing to a gun that did not fire it." (*United States v. Tibbs*, supra note 41, at pp. 40–41)

variety of methodological study design problems.

- We do not contest that, technically speaking, the various methodological aspects that Vanderplas et al. (2022) critically espouse have the potential to adversely affect generalizability. But for reasons we have discussed in Section 4.5, we do not share their ultimately extreme position that the currently existing data, though imperfect, "are not sufficiently sound to be used in criminal proceedings." (Vanderplas et al., 2022, at p. 10) For example, data can be used in a descriptive sense with respect to those examiners who volunteered and who have properly responded, without making claims about whether or not these data generalize to the profession of feature-comparison examiners as a whole.

- The dismissive, categorically extreme position of Vanderplas et al. (2022) is inconsistent with respect to a more nuanced prior position that some of these same authors have taken elsewhere, i.e., in the paper by Hofmann et al. (2020). In Hofmann et al. (2020), the authors have described ways (in technical parlance called "statistics") whereby data from different studies can be meaningfully summarized and compared. They stated that "additional statistics that provide context to error rates can be extremely beneficial in court." (Vanderplas et al., 2022, at p. 325)

- We find Vanderplas et al. (2022) imbalanced in the sense that the authors lean towards a "worst case scenario" (at p. 10). For example, they conjecture about what the error rate *would be* under the assumption that all non-respondents would have replied and that *all* of their responses would have been erroneous (at p. 10). This conjecture is problematic because the authors provide no actual, supportive evidence of the assumptions underlying their worst-case scenario. Quite to the contrary, the authors actually diffuse the veil of the worst-case scenario themselves when they write:
  - "there is no possibility of assessing the true impact of non-response bias in these studies when the authors do not make their data available (...)." (Vanderplas et al., 2022, at p. 10)
  - "we cannot say that it is likely that the error rate is higher or lower than what is reported from the flawed studies." (Vanderplas et al., 2022, at p. 6)

6 Summary and conclusions

6.1 Summary of the points of agreement and disagreement with the affidavit by Vanderplas et al. (2022)

In their statement, Vanderplas et al. (2022) argue along the following lines:

- They start by defining the goal to be *generalizability*: "As scientists, we want to derive knowledge that is generalizable to the population." (at p. 6)
- Next, they observe that existing error rate studies are imperfect in various respects, such as representativeness in participant recruitment, material sampling as well as types of marks and study difficulty.
- They conclude by asserting that these imperfections "cast doubt on the ability to generalize error rates from these studies to the wider population of all examiners" (at p. 10) and, more broadly, that "error rates established from [such] studies (...) are not sufficiently sound to be used in criminal proceedings." (at p. 10)
- Subsidiarily, they argue that within the limited scope that the existing studies do offer data, the design problems of those studies "suggest that the true error rates in casework may be significantly higher" (Vanderplas et al., 2022, at p. 10) than what is commonly said or believed.

Overall, we respond to this position statement as follows:

Points of agreement

- We agree that existing error rate studies are imperfect in several respects.
- We agree that generalization to the whole population (of examiners) is difficult, but that "any study only speaks to the error rate of the participants of that study." (Vanderplas et al., 2022, at p. 6)

Points of disagreement

- We disagree with the assertion that due to their lack of generalizability, existing data should be discarded altogether, i.e., suggesting that there is no useful information in such data.
  - Arguing in the way Vanderplas et al. (2022) do would amount to a sort of imperfection fallacy (Koehler, 2008); on this point, see our discussion in Section 4.5. All scientific studies suffer from limitations, yet they are not necessarily rendered unhelpful for advancing a discipline.
  - Discarding imperfect data would contradict the view that data can speak – given suitable acknowledgment of any limitations – to at least the actual participants of a study, a point to which even Vanderplas et al. (2022) agree; see quote above in points of agreement and our discussion in Section 4.5.3 of the position taken by some of the authors of Vanderplas et al. (2022) in a different paper (i.e., Hofmann et al., 2020). In essence, the point here is that data with limitations for broad and all-encompassing inferential use can still be of use for descriptive purposes.
  - Discarding individual and somewhat limited studies would deprive one from exploiting the notion of "convergent validity" (Thompson et al., 2017, at p. 94), i.e., seeing where individual studies can complement each other (see also discussion in Section 4.5). Technically, Vanderplas et al. (2022) appear to agree on this point, too, when they write that "it is not only important that study participants be randomly sampled from the population, but also that there are *multiple studies*." (at p. 6; emphasis added)
- We strongly disagree that generalizability and, hence, the establishment of a single domain-wide error rate should be the overarching aim:
  - While not entirely useless, because it can serve as a starting point for assessments on the level of individual cases (Koehler, 2008), a domain-wide error rate would neither be directly informative about the performance of an individual examiner nor about the probability that an error was committed in the instant case (i.e., the case at hand).
  - Reducing considerations to only a nonspecific, domain-wide error rate would be prone to overlooking potential problems associated with the mandated laboratory and/or the individual examiner(s) having worked in a particular case. For examples of such cases in firearms examination see Garrett (2022).
  - A domain-wide error rate is, ultimately, a practical impossibility because there is constant variation in (i) the population of examiners (new examiners enter the field, others leave; individual proficiency evolves over time), and (ii) the types of firearms and ammunition manufactured (and subsequently present in general circulation). Thus, it is always possible to argue that existing studies are somehow imperfect, which renders the call for a domain-wide, contemporaneously valid error rate ultimately self-defeating.

Given the elusive nature of the idea of a domain-wide error rate, we conclude that existing error-rate studies – despite their limitations – are not fatal to the field of forensic firearms examination as a whole. Indeed, they can add value. The reason, in part, for this positive position is that the notion of error rate is not the only dimension that characterizes the discipline of forensic feature-comparison (e.g., Dror, 2020).

6.2 Conclusions

Inquiring about the quality of error rate studies in forensic feature-comparison is an important undertaking. However, focusing attention *only* on the notion of error rate is not conducive of achieving a suitable assessment of the forensic discipline. As explained in Section 3, examiner performance is merely one component among others that one should inquire about when dealing with a forensic feature-comparison report. A further component is the existing – and widely uncontested – scientific knowledge about the intrinsic potential probative value (i.e., discriminative capacity) of class and accidental characteristics present on elements of fired ammunition.

But even if one were to restrict attention to the notion of error rate, it is important to keep in mind that it is not the only measure of examiners' overall performance.[57] Strictly speaking, error rates can serve, at best, as an indirect measurement of examiner performance. However, even if an error rate of some sort would be available, it would still be necessary to scrutinize the trustworthiness of the examiner on a case-based level. As recommended by the PCAST Report, the examiner should be required to demonstrate that he/she "has undergone rigorous proficiency testing on a large number of test problems to evaluate his or her capability and performance, and discloses the results of the proficiency testing" (at p. 113).

We thus conclude that the limited practical usefulness and necessarily restricted scope of a general error rate weakens, considerably, the critiques of the quality (and hence generalizability) of existing error rate studies. Stated otherwise, the critique – however statistically well-grounded – in the sense that existing studies do not allow one to generalize to the whole population of examiners is of reduced importance if generalizabilty itself is of limited usefulness.[58] On this latter point, as discussed in Section 4.4, we agree with the position of the AAAS Report by Thompson et al. (2017) that noted that "it is unreasonable to think that the 'error rate' (...) can meaningfully be reduced to a single number or even a single set of numbers." (at p. 45)[59]

While we agree that existing error rate studies can be criticized on some grounds, we reject the view that data from such studies should be discarded altogether, and that nothing can be said about examiner performance. Excessive insistence on flawlessness in study design is ultimately self-defeating and would deprive one from what data could support as a conclusion given a suitable acknowledgment of limitations. Error rate studies do not need to meet a best possible design criterion in order to be useful.[60] For example, studies can still be exploited with respect to those examiners who have actually participated and responded, which may give some idea of the general performance with a test or a set of tests used in the study. One observation, for instance, is that trained firearms examiners may exhibit a better performance than trainees (Duez et al., 2018), a point that even critics admit (e.g., Hofmann et al., 2020, at p. 328). Finally, dismissing individually imperfect data sets will also

[57] Another common performance indicator, not discussed here, is proficiency testing (e.g., Dror, 2020; Koehler, 2008).

[58] As noted in Section 5.3, an average error rate is not directly usable because it would either overvalue a poor examiner or undervalue (penalize) an above average or even outperforming examiner.

[59] On this viewpoint, see also our discussion in Section 4.2, explaining why forensic feature-comparison is not akin to a standard laboratory (or field) test for which a validation study with the classic performance metrics (error rates, sensitivity and specificity) could easily be conducted.

[60] Similarly, Judge Edelman has noted that *"Daubert* does not necessarily require the proponent of a theory or methodology to present only studies with the best possible design." (*United States v. Tibbs*, supra note 41, at p. 33)

deprive one from the potential of studies to complement each other and, hence, from the possibility of "convergent validation", emphasized in the AAAS Report by Thompson et al. (2017).

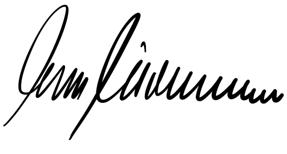
In conclusion, when considering the broad variety of pillars that make up the field of forensic feature-comparison, we contend that the isolated technical critique of the lack of generalizability of existing error rate studies is at best unhelpful and, at worst, misleading.

The critique is ultimately unhelpful because even if a generalized error rate could be available, it would be of limited value for a direct, case-based assessment of examiner performance. In addition, the dismissive attitude towards existing error rate studies, i.e., their wholesale rejection, is not helpful in that it offers no constructive advice on how the data could be used with properly acknowledged limitations (e.g., within a perspective of convergent validation).

The critique of lacking generalizability is misleading if it induces recipients of expert evidence to believe that the assessment of the suitability, capacity and merits of forensic feature-comparison as a whole would only hinge upon a generalized (i.e., domain-wide) and unspecific notion of error rate — it surely does not.

6.3 Statement of truth

We declare that the foregoing statement is true and correct to the best of our knowledge.


Alex Biedermann


Bruce Budowle


Christophe Champod

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The Council of the Inns of Court and The Royal Statistical Society (2017). Statistics and probability for advocates: Understanding the use of statistical evidence in courts and tribunals. London.

The Royal Society and The Royal Society of Edinburgh (2020). The use of statistics in legal proceedings: A primer for courts. Edinburgh.

The Royal Society and The Royal Society of Edinburgh (2021). Understanding ballistics: A primer for courts. Edinburgh.

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A Resume of Alex Biedermann

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Curriculum vitae

Alex Biedermann

Associate Professor

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http://ch.linkedin.com/in/abiedermann/en

EDUCATION

Ph.D. in Forensic science 03/2003 – 03/2007
Title: Bayesian networks and the evaluation of scientific evidence in forensic science (*summa cum laude*)
University of Lausanne (UNIL), Faculty of Law, Criminal Justice and Public Administration, School of Criminal Justice (thesis defense: 27.03.2007; date of certificate: 04.09.2007)

M.Sc. (formely called "Licence") in Forensic science 10/1997 – 07/1998, 10/1999 – 07/2002
Faculty of Law, Criminal Justice and Public Administration (UNIL) (date of certificate: 07/2002)

B.Sc. in Chemistry (exchange program, 2 semesters/1 year) 10/1998 – 07/1999
Faculty of Chemistry and Pharmacy, University of Innsbruck, Austria

CURRENT POSITIONS

Associate Professor (with tenure) 02/2016 – present
Faculty of Law, Criminal Justice and Public Administration (UNIL)

Scientific consultant 01/2022 – 12/2024
Consultant for the NIJ research project no. 15PNIJ-21-GG-04192-RESS (National Institute of Justice, U.S. Department of Justice, Office of Justice Programs 2021 Research and Development in Forensic Science for Criminal Justice Purposes; Principal investigator: Dr. David Stoney).

PREVIOUS POSITIONS AND PROFESSIONAL EXPERIENCE

Associate Professor (part-time, fixed term, 50%) 01/2016 – 12/2021
Faculty of Law, Criminal Justice and Public Administration (UNIL), Research professorship as principal investigator of the Swiss National Science Foundation (SNSF) Starting Grant Project (equivalent to an ERC Starting Grant) 'Normative decision structures of forensic interpretation in the legal process' (NORMDECS)[1] (see also section 'Funding ID')

Lecturer (Maître assistant) (part-time, 50%) 09/2010 – 01/2016
Faculty of Law, Criminal Justice and Public Administration (UNIL)

[1] www.unil.ch/forensicdecision

Scientific collaborator (part-time, 50%) 01/2009 – 12/2015
Fondation pour la Formation Continue UNIL-EPFL (FORMC),[2] University of Lausanne and Ecole Polytechnique Fédérale Lausanne (EPFL, Swiss Federal Institute of Technology in Lausanne): development and tutoring of postgraduate e-learning courses in forensic statistics (see also section 'Teaching')

Senior lecturer (part-time, 20%) 09/2010 – 07/2011 (12 months)
Faculty of Law, Criminal Justice and Public Administration (UNIL), during sabbatical leave of Prof. F. Taroni

External scientific collaborator 09/2007 – 08/2010
Faculty of Law, Criminal Justice and Public Administration (UNIL)

Scientific collaborator (100% until 2009, 70% afterwards) 04/2003 – 08/2010
Swiss Federal Department of Justice and Police (Berne, Switzerland): provided forensic science services for the Office of the Attorney General of Switzerland

Researcher (100%) 08/2002 – 01/2003 (6 months)
Faculty of Law, Criminal Justice and Public Administration (UNIL) and Department of Mathematics (EPFL): joint research project on forensic case analyses using graphical models

FELLOWSHIPS AND VISITING RESEARCH STAYS

University of Zürich 01.02. – 30.04.2021 (3 months)
Faculty of Law, Zürich
Chair for Criminal Law and Criminal Procedure, including Commercial and Administrative Criminal Law
Visiting scholar with Prof. Marc Thommen

Federal Judicial Center 09.03. – 20.03.2020 (2 weeks)
Research Unit, Washington, D.C.
Visiting Foreign Judicial Fellow (visit interrupted due to covid pandemic)

The University of Adelaide 19.08. – 13.09.2019 (1 month)
Adelaide Law School, Litigation Law Unit, Adelaide, South Australia
Visiting research stay, Guest lecturer in the course 'Evidence and Advocacy'

Northwestern University 01.07. – 28.07.2019 (1 month)
Pritzker School of Law, Chicago, IL
Visiting research stay with Prof. Ronald J. Allen

University of California Irvine 02.01. – 30.01.2019 (1 month)
Department of Criminology, Law and Society, Irvine, CA
Visiting research stay with Prof. Simon A. Cole

University of Michigan 16.07. – 24.08.2018 (1.5 months)
Law School, Center for International and Comparative Law, Ann Arbor, MI
Visiting research stay with Prof. Richard Friedman, supported by a 'Michigan Grotius Research Scholarship'

The University of Adelaide 09.02. – 12.03.2018 (1 month)
Adelaide Law School, Litigation Law Unit, Adelaide, South Australia
Visiting research stay, supported by a University of Adelaide 'Aim for the Stars' Grant

[2]Formation Continue UNIL-EPFL is a foundation that groups together the continuing education activities of UNIL and EPFL.

University of California Berkeley 17.06. – 15.07.2016 (1 month)
School of Public Health, Berkeley, CA
Visiting research stay with Prof. George Sensabaugh

The University of Nottingham 05. – 12.02.2016 (1 week)
School of Law, Nottingham (UK)
Visiting research stay at the Criminal Justice Research Centre with Prof. Paul Roberts

The University of Adelaide 07/2015 (1 month)
Adelaide Law School, Litigation Law Unit, Adelaide, South Australia
Research stay for the comparative analysis of legal cases involving scientific evidence
Supported by a Research Mobility Grant of the Fondation de l'Université de Lausanne (The University of Lausanne Foundation)

Università Ca' Foscari Venezia 03/2013, 08/2013 – 02/2014 (8 months)
Department of Economics (Statistics), Venice (Italy)
Research project 'Potential of error in forensic DNA analyses: comparative study of evaluative approaches using graphical probability models'
Exchange program supported by the Société Académique Vaudoise (Research mobility grant)

Università IUAV di Venezia 07/2012 (1 month)
Faculty of Arts and Design, Cognitive Science Research Unit, Venice (Italy)
Research project 'Interpretations of probability and the 'problem' of individualization in forensic science'
Exchange program supported by the Fondation de l'Université de Lausanne

Università IUAV di Venezia 11/2011 – 01/2012 (3 months)
Faculty of Arts and Design, Cognitive Science Research Unit, Venice (Italy)
Research project 'Decision-theoretic analysis of forensic sampling criteria using Bayesian decision networks'
Exchange program supported by the Swiss National Science Foundation

Università Ca' Foscari Venezia 07/2008 (1 month)
Department of Economics (Statistics), Venice (Italy)
Research project 'Bayesian statistical analysis of rare count data for forensic science applications using computational procedures and graphical probability models'
Exchange program jointly supported by the Swiss National Science Foundation and the Italian National Research Council

AWARDS

NIFS Award: Best Literature Review (Highly Commended) 2019
Award received from the National Institute of Forensic Science (NIFS, Australia and New Zealand) for the paper 'Evaluation of forensic genetics findings given activity level propositions: a review' (by Duncan Taylor, Bas Kokshoorn and Alex Biedermann, Forensic Science International: Genetics (Elsevier), 36 (2018), 34–49).

NIFS Award: Best Paper in a Refereed Journal (Highly Commended) 2018
Award received from the National Institute of Forensic Science (NIFS, Australia and New Zealand) for the paper 'A template for constructing Bayesian networks in forensic biology cases when considering activity level propositions' (by Duncan Taylor, Alex Biedermann, Tacha Hicks and Christophe Champod, Forensic Science International: Genetics (Elsevier), 33 (2018), 136–146).

Best Paper Award 2017
Award received from the Editorial Board of the Journal of Forensic Science and Medicine for the paper 'The role of the subjectivist position in the probabilization of forensic science' (Journal of Forensic Science and Medicine, 1 (2015), 140–148).

Prix de la Banque Cantonale Vaudoise (BCV) 2007
Award received from the Banque Cantonale Vaudoise[3] (BCV), Switzerland, for the quality of the Ph.D. thesis

Prix de l'Association des Diplômés en Sciences Criminelles (ADSC) de l'Université de Lausanne 2002
Award received from the 'Association of Graduates of the School of Criminal Justice' (UNIL, www.adsc.ch), for the quality of the M.Sc. studies

LANGUAGES

German: Mother tongue; English, French: Professional skills; Italian: Basic knowledge

FUNDING ID

Since obtaining my Ph.D. in 2007, I was awarded 13 grants as main applicant (funding agencies: Italian National Research Council, Fondation de l'UNIL, UNIL, Academic Society of the Canton of Vaud, Swiss National Science Foundation/SNSF, University of Michigan Law School). In addition, in the last decade, I also acted as co-applicant for 8 SNSF research grants. These awarded funds exceed 2.3 million CHF (Swiss Francs).[4]

Projects as main applicant

10BP12_208532/1: Swiss National Science Foundation Book Open Access Funding 12/2021
Funding for the Open Access publication of the research monograph "Bayes factors for forensic decision analyses with R" (co-authored with S. Bozza and F. Taroni), edited by Springer Nature (New York) as part of the series "Springer Texts in Statistics".
15'000 CHF

Fondation pour l'Université de Lausanne 03 – 04/2021 (1.5 months)
Research mobility grant for the project '(Un-)interpretability of scientific evidence'
2'000 CHF

Société Académique Vaudoise 02 – 04/2021 (3 months)
Research mobility grant for the project '(Un-)interpretability of scientific evidence'
2'000 CHF

BSSGI0_155809: Swiss National Science Foundation Starting Grant 2014 01/2016 – 12/2021 (72 m.)
SNSF 'Starting Grant' Research project 'Normative decision structures of forensic interpretation in the legal process (NORMDECS)'[5] (equivalent to an ERC Starting Grant)
1'293'456 CHF (+ 100'000 CHF matching funds obtained from the Faculty of Law, Criminal Justice and Public Administration, UNIL)

[3]The BCV is a Swiss cantonal bank (www.bcv.ch).
[4]A detailed history of my SNSF funding record is available on the SNSF Data Portal: https://data.snf.ch/grants/person/55553
[5]https://wp.unil.ch/forensicdecision/

10001A_156290: Swiss National Science Foundation 03/2015 – 10/2016 (18 months)
Research project ‘Probabilistic inference schemes in forensic handwriting examination: a diagrammatic approach to support evaluation and reporting’
87’220 CHF

FIP 2014: Think Cloud – Pré-évaluation de Cas Assistée 03 – 12/2014 (10 months)
Fonds d’innovation pédagogique de l’Université de Lausanne (Teaching Innovation Fund of the University of Lausanne)
45’000 CHF

Société Académique Vaudoise 03/‘13, 08/2013 – 02/2014 (8 months)
Research mobility grant for the project ‘Potential of error in forensic DNA analyses : comparative study of evaluative approaches using graphical probability models’
3’500 CHF

Fondation de l’Université de Lausanne 07/2012 (1 month)
Research project ‘Interpretations of probability and the ‘problem’ of individualization in forensic science’
1’300 CHF

IZ32Z0_143013: Swiss National Science Foundation 10/2012 (2 days)
International Exploratory Workshop ‘Inference and decision modeling in forensic science’
6’510 CHF

FIP 2012: éICAR – étude Interdisciplinaire de Cas par Annotation de Rapport 2012 (12 months)
Fonds d’innovation pédagogique de l’Université de Lausanne (Teaching Innovation Fund of the University of Lausanne)
29’900 CHF

IZK0Z1_139483: Swiss National Science Foundation 11/2011 – 01/2012 (3 months)
Research project (Short International Visit) ‘Decision-theoretic analysis of forensic sampling criteria using Bayesian decision networks’
9’300 CHF

IZAI10_121282: Swiss National Science Foundation 07/2008 (1 month)
Research project (Short International Visit) ‘Bayesian statistical analysis of rare count data for forensic science applications using computational procedures and graphical probability models’
1’500 CHF

Total amount of funding awarded as main applicant: $>$ 1’590’000 CHF

Projects as associated applicant

100014_150276: Swiss National Science Foundation 02/2014 (24 months)
Research project ‘Ontology for normative combinations of evidence in forensic science: an approach using graphical probabilistic analyses’
100’841.65 CHF

105315_144557: Swiss National Science Foundation 11/2012 (24 months)
Research project ‘Current challenges of forensic DNA mixture analysis: a probabilistic approach to evaluate results of a novel DNA marker system’
117’312.00 CHF

100014_135340: Swiss National Science Foundation 05/2011 (12 months)
Research project 'Rational decisions in forensic science: case studies and applications'
57'288.00 CHF

100014_124615: Swiss National Science Foundation 04/2009 (1 month)
Research project 'Utilisation des Object-Oriented-Bayesian Networks dans la combinaison des indices scientifiques'
49'685 CHF

100014_122601: Swiss National Science Foundation 02/2009 (24 months)
Research project 'How to make rational decisions: Bayesian networks and decision theory in forensic science applications'
96'967.00 CHF

K-11K1_116620: Swiss National Science Foundation 09/2008 (24 months)
Research project 'Progress in handwriting analysis: towards shape quantification of characters and probabilistic assessment of their evidential value'
263'127.00 CHF

105214_120750: Swiss National Science Foundation 07/2008 (27 months)
Research project 'Analysis of recurrent complications in the evaluation of Low Copy Number (LCN) DNA profiling results in forensic science: a graphical probability approach'
95'967.00 CHF

100015_111736: Swiss National Science Foundation 08/2006 (30 months)
Research project 'Bayesian networks and the analysis of combinations of items of evidence'
94'302.00 CHF

Total amount of funding awarded as co-applicant: ∼ 870'000 CHF

Other grants/scholarships

University of Michigan, 'Michigan Grotius Research Scholarship' 07–08/2018 (1.5 months)
Law School, Center for International and Comparative Law, Ann Arbor, MI (obtained as main applicant)

University of Adelaide, 'Aim for the Stars' Grant 02/2018 (1 month)
Principal applicant: Mr. David Caruso, University of Adelaide Law School; Beneficiary: Alex Biedermann
Visiting research stay at University of Adelaide Law School, Litigation Law Unit
AUD 5'750.00

SUPERVISION OF GRADUATE STUDENTS AND PARTICIPATION IN PHD-COMMITTEES

Teaching module 'Complex/transdisciplinary cases' 09/2010 – present
Faculty of Law, Criminal Justice and Public Administration (UNIL)
15-25 M.Sc. students in forensic science per year

Participation in 11 Ph.D.-committees (6 completed) 09/2007 – present
Faculty of Law, Criminal Justice and Public Administration (UNIL)

Tutoring 01/2003 – present
Faculty of Law, Criminal Justice and Public Administration (UNIL)

approx. 50 M.Sc. students in forensic science per year, tutorials and practical exercise sessions on probabilistic evaluation

TEACHING

University

Associate Professor, Faculty of Law, Criminal Justice and Public Administration (UNIL) 01/2016 – today

- Course 'Interprétation de l'indice scientifique et prise de décision' (Interpretation of scientific evidence and decision-making), for M.Sc. students in forensic science, 14 weeks (2h/w), 6 ECTS,[6] 09/2016 – today
- Course 'Interprétation et prise de décision' (Interpretation and decision making), for students of the MLaw in Judicial Careers, 14 weeks (2h/w), 5 ECTS, 09/2019 – today
- Seminar 'MOOC (Massive Open Online Course): La science forensique au tribunal: témoin digne de foi?' (MOOC 'Challenging Forensic Science: How science should speak to court'), 18h/semester, for students of the MLaw in Judicial Careers, 2 ECTS, 01/2019 – today
- Practical module 'Cas pratiques transversaux' (Transversal case studies), for M.Sc. students in forensic science, 14 weeks, 10 ECTS, 09/2021 – today
- Course 'Identification d'armes à feu à partir d'éléments de munition' (Firearms identification based on elements of ammunition), for M.Sc. students in forensic science, 14 weeks (2h/w), 3 ECTS, 01/2016 – today
- Practical module 'Cas complexes/transversaux' (Complex/transdisciplinary cases), for M.Sc. students in forensic science, 14 weeks (1 day/w), 10 ECTS, 09/2016 – today

Invited lecturing (ad-hoc)

Invited Professor, China University of Political Science and Law (CUPL), Beijing, China 12/2021
Invited by the National Collaborative Innovation Center of Judicial Civilization (Key Laboratory of Evidence Science of the Ministry of Education at CUPL and the 111th Program of Evidence Science Innovation and Intelligence Base)
Course (delivered online) 'Introduction to the evaluation of scientific evidence and decision analysis' (32 h, for graduate students in 'Evidence science')

Invited Professor, Swiss Graduate School of Public Administration, University of Lausanne 29.10.2020
Guest lecture (3 h) 'Decision-making: theoretical perspectives and practical applications' ('La prise de décision: courants théoriques et applications pratiques') as part of the Certificate of Advanced Studies 'Law and Public Action' ('Droit et Action Publique')

Invited Professor, University College London, Centre for the Forensic Sciences, London (UK) 23.01.2020
Guest presentation as part of the seminar series of the Centre for the Forensic Sciences

Invited Professor, Adelaide Law School, Litigation Law Unit, Adelaide, South Australia 08–09/2019
Guest lectures (3 h, for undergraduate law students) 'Elements of interpreting scientific evidence' given as part of the LLB course 'Evidence and advocacy'

Invited Professor, China University of Political Science and Law, Beijing, China 09/2018
Course 'Introduction to the evaluation of scientific evidence and decision analysis' (32 h, for graduate students in 'Evidence science')

[6] European Credit Transfer and Accumulation System (ECTS) credits are used in higher education across the European Union and other collaborating European countries for comparing volume of learning and workload.

Invited Professor, Adelaide Law School, Litigation Law Unit, Adelaide, Australia 02–03/2018
Guest lectures (6 h, for undergraduate law students) 'Elements of interpreting scientific evidence' given as part of the intensive course 'Miscarriages of Justice'

Invited lecturer, Adelaide Law School, Litigation Law Unit, Adelaide, Australia 07/2015
Guest lecture 'Incriminating forensic evidence: what strategy for the defendant?' given in the intensive course 'Miscarriages of Justice'

Senior lecturer, Faculty of Law (UNIL) 08/2010 – 07/2011
Courses 'Interpretation I' (B.Sc. students in Forensic science, MLaw students) and 'Interpretation II' (M.Sc. students in Forensic science), during sabbatical leave of Prof. F. Taroni

Continuing education (e-learning)

Massive Open Online Courses (MOOCs) focusing on the public understanding of forensic science
MOOC 'Challenging forensic science: How science should speak to court' launched 11/2018
MOOC 'La science forensique au tribunal: digne de foi?' launched 04/2019
On Coursera (www.coursera.org): Faculty of Law, Criminal Justice and Public Administration, UNIL; also available in Italian

Specialised postgraduate e-learning courses in forensic interpretation 01/2009 – today
Developer and tutor in a unique long-distance education project (e-learning) on forensic interpretation, offered by the Foundation for Continuing Education of UNIL and EPFL :

- 'Statistics and the evaluation of forensic evidence', Certificate of Advanced Studies (in 11th edition, 18 months each, awarded 20 ECTS)
- 'Essentials of DNA interpretation' (in 10th edition, 6 months each, awarded 5 ECTS)
- 'Essentials of Bayesian networks in forensic science' (in 5th edition, 6 months each, awarded 5 ECTS)
- 'Essentials of forensic interpretation' (in 7th edition, 6 months each, awarded 5 ECTS)
- 'DNA interpretation given activity level propositions' (in 3rd edition, 9 months, awarded 5 ECTS)
- 'Advanced interpretation of transfer material given activity level propositions' (in 1st edition, 12 months, awarded 5 ECTS)

Training courses, workshops and round-tables (participation as organiser, co-organiser and/or instructor)

Webinar 'Computational methods for decision support in the law' 16.12.2020
Royal Statistical Society 'Statistics and the Law Section', London (co-organised with Dr. Anjali Mazumder, The Alan Turing Institute). Half a day, number of participants: approx. 50.

Webinar 'Interpretation and communication of expert evidence in digital imaging' 29.09.2020
The Chartered Society of Forensic Sciences (UK) (co-organised with Prof. Graham Jackson, Abertay University, UK). Number of participants: 10

Seminar 'Digital evidence in investigative and evaluative proceedings' 04.05.2020
Royal Statistical Society 'Statistics and the Law Section', London, co-organised with Dr. Amy Wilson, University of Edinburgh, School of Mathematics, and Dr. Anjali Mazumder, Alan Turing Institute, London. Half a day, number of participants: approx. 50

Case assessment and interpretation workshop 18. – 19.06.2019
Evaluative Reporting Symposium, Ontario Centre of Forensic Sciences, Toronto (co-organised with Prof. Graham Jackson, Abertay University, UK). Two days, number of participants: approx. 80

Seminar 'The statistics of drug testing in sport' 18.04.2019
Royal Statistical Society 'Statistics and the Law Section', London (co-organised with Dr. Amy Wilson, University of Edinburgh, UK, and Prof. Julia Mortera, Università Roma Tre). Half a day, number of participants: approx. 30

Conference round table 'Identification' 06.09.2018
18th ENFSI Fingerprint Working Group Annual Meeting, University of Lausanne (co-organised with Prof. Christophe Champod). Number of participants: approx. 100

Workshop 'Fingerprints and probabilities' 04.09.2018
18th ENFSI Fingerprint Working Group Annual Meeting, University of Lausanne (in collaboration with Prof. Christophe Champod, Dr. Glenn Langenburg and Marco De Donno). Number of participants: approx. 30

Workshop 'Fingerprints and probabilities' 27.08.2018
8th European Academy of Forensic Science Conference, Lyon (in collaboration with Prof. Christophe Champod, Dr. Glenn Langenburg and Marco De Donno). Number of participants: approx. 30

Pre-symposium Workshop 'Expert evidence in the legal process in an international and comparative perspective' 25.06.2018
3rd International Symposium on Sino-Swiss Evidence Science ('Pursuing Truth from Different Perspectives), Hangzhou, China, China University of Political Science and Law and Guanghua Law School (Zhejiang University). Number of participants: approx. 60.

Advanced Case Assessment and Interpretation Workshop 26. – 27.03.2018
For members of the Swedish National Forensic Centre, University of Lausanne

Research workshop 'Interpretation of probabilistic test results and inductive reasoning' 27.–28.04.2017
Workshop organised at the University of Lausanne as part of the research project NORMDECS. Total number of participants: 7 (of which 4 externally invited scholars)

Pre-symposium Workshop 'Forensic science reporting: scope, diversity and potential for improvement' 06.09.2016
2nd International Symposium on Sino-Swiss Evidence Science ('Exploring Scientific Evidence and Judicial Proof in an International Perspective'), University of Lausanne

Session on the ENFSI Guideline for Evaluative Reporting 17.06.2016
Information session given to the EUROJUST College of National Members (Agency of the European Union dealing with judicial co-operation in criminal matters), The Hague (Netherlands)

Advanced Case Assessment and Interpretation Workshop 18. – 19.04.2016
For members of the Swedish National Forensic Centre, University of Lausanne

Advanced forensic interpretation workshop for scientific researchers and caseworkers of the Netherlands Forensic Institute, University of Lausanne 22. – 23.03.2016

Workshop 'L'évaluation et l'expression des résultats de la police scientifique: une approche scientifique' (A scientific approach to evaluating and reporting forensic science results) 03.02 and 09.03.2016
University of Lausanne (two half a days)

Workshop 'Introduction to inference and decision analysis using Bayesian networks' 07.10.2015
University of Lausanne, Doctoral School Program

Workshop 'A guideline for reporting evaluative evidence in Court' 09.11.2015
7th European Academy of Forensic Science Conference, Prague

Pre-symposium workshop 'A Standard (guideline) for reporting evaluative evidence in court' 19.01.2015
1st International Symposium on Sino-Swiss Evidence Science
Hainan University, Law School, Haikou, Hainan, China

Lecture 'Neue Entwicklungen der Kriminalistik (DNA, Mikrospuren) und Probleme von Wahrscheinlichkeitsaussagen' (New developments in forensic science (DNA, trace evidence) and problems with probabilistic expressions), Conference '*StrafR!* Der Beweis', organised by Prof. M. Killias and lic. iur. B. Gut, University of Zürich 09.09.2014

Workshop 'Introduction to inference and decision analysis using Bayesian networks' 26.06.2014
23rd International Meeting on Forensic Medicine Alpe-Adria-Pannonia
University Center of Legal Medicine Lausanne–Geneva

Advanced case assessment and interpretation workshop 13. – 14.05.2013
For members of the Swedish National Forensic Centre, University of Lausanne

Workshop 'Ce que la justice fait dire aux moyens de preuve dits scientifiques (et ce que ceux-ci ne disent pas vraiment)' 29.08.2012
For members of the judiciary of the Canton of Berne, University of Lausanne

Workshop 'Introduction to Bayesian networks in forensic science' 23.08.2012
6th European Academy of Forensic Science Conference, The Hague

Workshop 'Bayesian networks in forensic science: applications' 30.05. – 01.06.2012
For members of the Swedish National Forensic Centre, Linköping

Workshop 'Bayesian networks in forensic science' 18.07.2011
8th International Conference on Forensic Inference and Statistics, University of Washington, School of Public Health, Department of Biostatistics, Seattle

Workshop 'Introduction aux modèles graphiques probabilistes: l'utilisation des Réseaux Bayesiens en science forensique' 19. – 21.01.2009
For members of law enforcement agencies in Switzerland, University of Lausanne

Workshop 'The use of Bayesian networks in forensic science' 20.08.2008
7th International Conference on Forensic Inference and Statistics, University of Lausanne

HOSTING OF VISITING SCHOLARS

Since 2016, I have hosted 13 visiting researchers and professors at UNIL (Faculty of Law, Criminal Justice and Public Administration). Total duration of visiting time: 88 months. Origin of visitors: Australia, China, Italy, Switzerland, U.K., U.S.

ORGANIZATION OF SCIENTIFIC MEETINGS

4th International Symposium on Sino-Swiss Evidence Science, University of Lausanne 2022 (forthcoming)
Member of the local scientific and organising committee

3rd International Symposium on Sino-Swiss Evidence Science, Hangzhou (China) 25. – 29.06.2018
Member of the scientific and organising committee

2nd International Symposium on Sino-Swiss Evidence Science, University of Lausanne 05. – 09.09.2016
Member of the scientific and organising committee

Inference and Decision Modelling in Forensic Science (International Exploratory Workshop) 25. – 26.10.2012
Responsible organiser, meeting financed by the Swiss National Science Foundation, hosted at the University of Lausanne, 2 days, 11 invited participants

7th International Conference on Forensic Inference and Statistics 20. – 23.08.2008
Member of the organising committee and co-organiser of a workshop, hosted at the University of Lausanne, 4 days, 150 participants

SERVICE TO THE PROFESSION

Panel discussant

Decision-support in Litigation 06.12.2019
Royal Statistical Society 'Statistics and Law Committee', The University of Edinburgh, Bayes Centre, Edinburgh Centre for Statistics

IPTES 2018, Impression, Pattern and Trace Evidence Symposium, Arlington, VA (USA) 24.01.2018
Discussant of the panel 'Statistical approaches to forensic interpretation'

DFRWS Europe 2016, 3rd Annual Digital Forensics Research Conference, Lausanne 01.04.2016
Discussant of the panel 'Conclusions scales or likelihood ratios in digital forensic science'

Section Chair

7th International Conference on Evidence Law and Forensic Science, Freiburg (Germany) 31.07. – 02.08.2019
Chair of the section 'Forensic science: Topics impacting many or all of forensic science'

2nd International Symposium on Sino-Swiss Evidence Science, Lausanne 05. – 09.09.2016
Chair of the section 'Current issues in scientific evidence and proof'

Section Co-Chair

5th International Conference on Evidence Law and Forensic Science, Adelaide 22. – 23.07.2015
Co-Chair of the section 'Miscarriages of justice: lessons of proof and practice'

Scientific advisor

11th International Conference on Forensic Inference and Statistics, Lund (SE) 2023 (forthcoming)
Member of the scientific committee

10th International Conference on Forensic Inference and Statistics, Minneapolis, MN 05. – 08.09.2017
Member of the scientific committee

6th International Conference on Evidence Law and Forensic Science, Baltimore, MD 14. – 16.08.2017
Member of the expert review panel for the forensic science full paper submissions

ISFG (International Society of Forensic Genetics) 31.01.2017 – 10.11.2017
Advisor for the ISFG DNA Commission for the development of a recommendation entitled 'Evaluation of evidence'.

9th International Conference on Forensic Inference and Statistics, Leiden (NL) 19. – 22.08.2014
Member of the scientific advisory board

Editorial responsibilities

Frontiers (http://www.frontiersin.org), Review Editor 2014 – today

Frontiers in Genetics 08/2016 – 08/2020
Topic Editor (Guest Associate Editor) of the Research Topic 'The dialogue between forensic scientists, statisticians and lawyers about complex scientific issues for court'

Frontiers in Statistical Genetics and Methodology 11/2012 – 12/2013
Guest Associate Editor for the issue 'DNA, statistics and the law : a cross-disciplinary approach to forensic inference'

Editorial assistance

Revue Internationale de Criminologie et de Police Technique et Scientifique 09/2010 – 2020
Article and book reviews for the section 'Notes de police scientifique' (Notes on Forensic Science) (28 contributions)

Reviewer for peer reviewed journals

AFTE Journal, Association of Firearm and Toolmark Examiners (number of assignments: 1)	2015
Annals of Applied Statistics, Institute of Mathematical Statistics (1)	2012
Artificial Intelligence and Law, Springer (3)	2013 – today
Augmented Human Research, Springer (1)	2020
Australian Journal of Forensic Science, Taylor & Francis Group (1)	2013
Emerging Topics in Life Sciences (Biochemical Society), Portland Press (1)	2021
Forensic Science International , Elsevier Science (78)	2010 – today
Forensic Science International: Digital Investigation (formerly: Digital Invest.), Elsevier (4)	2019 – today
Forensic Science International: Genetics, Elsevier Science (6)	2013 – today
Homicide Studies, SAGE (1)	2015
International Journal of Evidence and Proof, SAGE (3)	2016 – today
Journal of Forensic and Legal Medicine, Elsevier (1)	2014
Journal of Forensic Sciences, Wiley (2)	2015 – today
Law, Probability & Risk, Oxford University Press (9)	2007 – today
Palgrave Communications, Springer Nature (1)	2020
Psychonomic Bulletin & Review, Springer (1)	2020
Revue Internationale de Criminologie et de Police Techique et Scientifique (1)	2012
Science & Justice, Elsevier Science (5)	2013 – today
Theoretical Criminology, SAGE (1)	2019

Reviewer for book proposals

Cambridge University Press (number of assignments: 1)	2019
Hart Publishers (1)	2020
John Wiley & Sons (1)	2010

Reviewer for research proposals and research reports

Since 2017, I have completed 17 reviews for the following entities: Czech Science Foundation, National Science

Centre Poland, Netherlands Organisation for Scientific Research, Royal Statistical Society's Working Group on Statistics and the Law, University of Lausanne Teaching Innovation Fund, U.S. National Institute of Justice.

Reviewer for University teaching programs

Panel member for the external assessment of the Master in Forensic Science degree programme of the University of Amsterdam 13.–14.03.2017 and 2022/23 (forthcoming)

Scientific working group membership

Member of the ENFSI project group 'Development and implementation of an ENFSI standard for reporting evaluative forensic science' 03/2012 – 12/2014

MEMBERSHIP AND ACTIVITIES IN SCIENTIFIC SOCIETIES

The International Association of Evidence Science (IAES) (theiaes.cupl.edu.cn) 2017 – today
Member of the Council

American Association for the Advancement of Science (AAAS) (www.aaas.org), Member 2015 – today

Royal Statistical Society (www.rss.org.uk), Fellow 2013 – today

Member of the group 'Publications Network of Advisors', 01/2020 – 12/2021

Member of the Section Committee 'Statistics and the Law', 01/2018 – 12/2021

Société Académique Vaudoise (Academic Society of the Canton of Vaud, www.s-a-v.org) 2013 – today
Lifetime member

Association of Graduates of the School of Criminal Justice (UNIL, www.adsc.ch) 2002 – today
Member

Lausanne, April 2022

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Publications

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http://ch.linkedin.com/in/abiedermann/en

My *h*-index on Scopus is 24 and the total number of citations for papers is 1717.[7]

MONOGRAPHS

150. Bozza S., Taroni F., Biedermann A., *Bayes factors for forensic decision analyses with R*, Springer (forthcoming 2022).
149. Taroni F., Biedermann A., Bozza S., Garbolino P., Aitken C.G.G. 2014, *Bayesian networks for probabilistic inference and decision analysis in forensic science*, Statistics in Practice, 2nd Ed., Chichester: John Wiley & Sons, Ltd., 443 p. + xxiv.
148. Taroni F., Bozza S., Biedermann A., Garbolino P., Aitken C.G.G. 2010, *Data analysis in forensic science: a Bayesian decision perspective*, Statistics in Practice, Chichester: John Wiley & Sons, Ltd., 367 p. + xvii.
147. Taroni F., Aitken C.G.G., Garbolino P., Biedermann A. 2006, *Bayesian networks and probabilistic inference in forensic science*, Statistics in Practice, Chichester: John Wiley & Sons, Ltd., 354 p. + xviii.

CHAPTERS

146. Taroni F., Bozza S., Biedermann A. 2021, The logic of inference and decision for scientific evidence, in: *Philosophical Foundations of Evidence Law*, Dahlman C., Stein A., Tuzet G. (Eds.), Oxford: Oxford University Press, 251–266.
145. Taroni F., Bozza S., Biedermann A. 2020, Decision theory, in: *Handbook of Forensic Statistics*, Banks D. L., Kafadar K., Kaye D.H., Tackett M. (Eds.), Chapman & Hall/CRC Handbooks of Modern Statistical Methods, 103–130.
144. Vuille J., Biedermann A., Taroni F. 2015, Accounting for the potential of error in the evaluation of the weight of scientific evidence, in: *Understanding Wrongful Conviction. The Protection of the Innocent Across Europe and America*, collana editoriale 'Giustizia penale europea', Luparia L.(Ed.), Milano: Wolters Kluwer, 39–55.
143. Mazzella W.D., Biedermann A. 2014, Interpretation: printed document examination and evidence, in: *Wiley Encyclopedia of Forensic Science*, Jamieson A., Moenssens A. (Eds.), Chichester: John Wiley & Sons (online publication).

[7] All counts are taken from Scopus on March 23rd 2022 (Period 2004–2022). On the same date, Google scholar states a *h*-index of 29 and a total citation count of 3104.

142. Biedermann A., Taroni F. 2014, Evaluation probabiliste, in: *Traces d'armes à feu, Expertise des armes et des éléments de munitions dans l'investigation criminelle*, 2nd Ed., Gallusser A. (Ed.), Lausanne: Presses Polytechniques Universitaires Romandes, 375–440.[8]

141. Taroni F., Biedermann A. 2014, Probability and inference in forensic science, in: *Encyclopaedia of Criminology and Criminal Justice*, Bruinsma G.J.N., Weisburd D.L. (Eds.), New York: Springer Science + Business Media, 3947–3957.

140. Vuille J., Biedermann A., Taroni F. 2013, L'arbre qui cache la forêt, Correspondances fortuites et erreurs lors des analyses ADN, in : *Criminology, Criminal Policy and Criminal Law in an International Perspective, Essays in honour of Martin Killias on the occasion of his 65th birthday*, Kuhn A. et al. (Eds.), Bern: Stämpfli Verlag, 1095–1110.

139. Aitken C.G.G., Taroni F., Biedermann A. 2013, Statistical interpretation of evidence: Bayesian analysis, in: *Encyclopedia of Forensic Sciences*, Second Edition, Siegel J.A., Saukko P.J. (Eds.), Waltham: Academic Press, vol. 3, 292–297. – Reprinted in:

    - *Forensic Anthropology*, First Edition, 2017, Houck M. (Ed.), San Diego: Academic Press/Elsevier, 325–331.
    - *Forensic Chemistry*, First Edition, 2015, Houck M. (Ed.), San Diego: Academic Press/Elsevier, 331–336.
    - *Forensic Biology*, First Edition, 2015, Houck M. (Ed.), San Diego: Academic Press/Elsevier, 155–161.
    - *Professional Issues in Forensic Science*, First Edition, 2015, Houck M. (Ed.), San Diego: Academic Press/Elsevier, 119–125.

138. Taroni F., Biedermann A. 2013, Bayesian networks, in: *Encyclopedia of Forensic Sciences*, 2nd Ed., Siegel J.A., Saukko P.J. (Eds.), Waltham: Academic Press, vol. 1, 351–356. – Reprinted in:

    - *Forensic Biology*, First Edition, 2015, Houck M. (Ed.), San Diego: Academic Press/Elsevier, 221–227.

137. Vuille J., Biedermann A., Taroni F. 2013, The importance of having a logical framework for expert conclusions in forensic DNA profiling: illustrations from the Amanda Knox case, in: *Wrongful Convictions and Miscarriages of Justice: Causes and Remedies in North American and European Criminal Justice Systems*, Huff R.C., Killias M. (Eds.), New York: Routledge Chapman & Hall, 137–159.

136. Taroni F., Biedermann A. 2010, La valeur probante de l'indice ADN: juristes et scientifiques face à l'incertitude et aux probabilités, in: *300 ans d'enseignement du droit à Lausanne*, Peter H. (Ed.), Zürich: Edition Schulthess, 337–374.

135. Taroni F., Biedermann A. 2008, Inference problems in forensic science, in: *Bayesian Belief Networks: a Practical Guide to Applications*, Pourret O., Naïm P., Marcot B.G. (Eds.), Chichester: John Wiley & Sons, Ltd., 113–126.

[8] This monograph was nominated as a finalist for the *27e édition du Prix Roberval 2014 Enseignement Supérieur* (The Roberval Prize, prixroberval.utc.fr). The Roberval Prize is an international competition to encourage the production of works (in French) devoted to the explanation of technology.

E-BOOKS

134. Pope S., Biedermann A. (Eds.) 2020, The dialogue between forensic scientists, statisticians and lawyers about complex scientific issues for court, Frontiers in Genetics (Statistical Genetics and Methodology), Lausanne: Frontiers Media SA, doi: 10.3389/978-2-88966-049-0, 62 p. (11 articles, 22 authors).
133. Biedermann A., Vuille J., Taroni F. (Eds.) 2014, DNA, statistics and the law: a cross-disciplinary approach to forensic inference, Frontiers in Genetics (Statistical Genetics and Methodology), Lausanne: Frontiers Media SA, doi: 10.3389/978-2-88919-250-2, 39 p. (11 articles, 18 authors).

PH.D. THESIS

132. Biedermann A. 2007, Bayesian networks and the evaluation of scientific evidence in forensic science, Université de Lausanne, Faculté de droit, des sciences criminelles et d'administration publique, Ecole des sciences criminelles, no. XXXV.

LAW REVIEW AND PEER–REVIEWED ARTICLES

131. Biedermann A., Koehler J. J. 2022, Influence diagrams for complex litigation, Jurimetrics: The Journal of Law, Science, and Technology (American Bar Association), 62, 131–171.
130. Biedermann A., Kotsoglou K. N. 2022, (Un-)Interpretability in expert evidence: an inquiry into the frontiers of evidential assessment, Quaestio facti (Revista Internacional sobre Razonamiento Probatorio Quaestio facti. International Journal on Evidential Legal Reasoning), 3, 481–515.
129. Biedermann A. 2022, The strange persistence of (source) "identification" claims in forensic literature through descriptivism, diagnosticism and machinism, Forensic Science International: Synergy, 4, 100222.
128. Biedermann A., Caruso D., Kotsoglou K. 2021, Decision theory, relative plausibility and the criminal standard of proof, Criminal Law and Philosophy, 15, 131–157.
127. Biedermann A., Kotsoglou K., 2021, Forensic science and the principle of excluded middle: "Inconclusive decisions" and the structure of error rate studies, Forensic Science International: Synergy, 3, 100147.
126. Kotsoglou K., Biedermann A., Vuille J. 2020, DNA und Beweiswürdigung – Der statistische Rubikon und die Dogmatik der Identitätsfeststellung, Zeitschrift für die gesamte Straftrechtswissenschaft, 132, 891–937.
125. Biedermann A., Kotsoglou K. 2020, Digital evidence exceptionalism? A review and discussion of conceptual hurdles in digital evidence transformation, Forensic Science International: Synergy, 2, 262–274.
124. Lau T., Biedermann A. 2020, Assessing AI output in legal decision-making with nearest neighbors, Penn State Law Review, 124, 609–655.
123. Cole S.A., Biedermann A. 2020, How can a forensic result be a "decision"? A critical analysis of ongoing reforms of forensic reporting formats for federal examiners, Houston Law Review, 57, 551–592.
122. Biedermann A., Bozza S., Taroni F. 2020, Normative decision analysis in forensic science, Artificial Intelligence and Law, 28, 7–25.
121. Biedermann A., Bozza S., Taroni F., Vuille J. 2020, Computational normative decision support structures of forensic interpretation in the legal process, SCRIPTed: A Journal of Law, Technology and Society, 17, 83–124.
120. Vuille J., Biedermann A. 2019, Une preuve scientifique suffit-elle pour fonder une condamnation pénale?,

Revue de droit suisse, 138, 491–512.

119. Caruso D., Biedermann A., Vuille J., Gilby D. 2019, Sterben in support of a decisional paradigm for assisted dying, Criminal Law Journal, 43, 254–273.

118. Biedermann A., Bozza S., Taroni F., Vuille J. 2019, Are inconclusive decisions in forensic science as deficient as they are said to be?, Frontiers in Psychology (Cognition), 10, Article 520, 1–9.

117. Vuille J., Biedermann A. 2019, Correspondances partielles d'ADN et identifications erronées, Forumpoenale, 1, 58–64.

116. Biedermann A., Vuille J. 2018, The decisional nature of probability and plausibility assessments in juridical evidence and proof, International Commentary on Evidence, 16, 1–30.

115. Biedermann A., Bozza S., Taroni F., Garbolino P. 2018, A formal approach to qualifying and quantifying the 'goodness' of forensic identification decisions, Law, Probability and Risk, 17, 295–310.

114. Biedermann A., Vuille J. 2018, Understanding the logic of forensic identification decisions (without numbers), sui-generis, 397–413.

113. Biedermann A., Kotsoglou N. 2018, Decisional dimensions in expert witness testimony – A structural analysis, Frontiers in Psychology (Cognition), Research topic 'Judgment and Decision Making Under Uncertainty: Descriptive, Normative, and Prescriptive Perspectives', 9, Article 2073, 1–15.

112. Taroni F., Garbolino P., Biedermann A., Aitken C., Bozza S. 2018, Reconciliation of subjective probabilities and frequencies in forensic science, Law, Probability and Risk, 17, 243–262.

111. Taroni F., Biedermann A., Vuille J., Bozza S. 2018, Statistical adhockeries are no criteria for legal decisions – The case of the expert medical report on the assessment of urine specimens collected among athletes having participated to the Vancouver and Sochi Winter Olympic Games, Frontiers in Sociology (Research topic 'The interface between forensic scientists and statisticians when calculating likelihood ratios for low template and complex DNA results'), Frontiers in Sociology, 3, 1–3.

110. Aitken C., Nordgaard A., Taroni F., Biedermann A. 2018, Commentary: Likelihood ratio as weight of forensic evidence: A closer look, Frontiers in Genetics, 9, 1–2.

109. Taylor D., Kokshoorn B., Biedermann A. 2018, Evaluation of forensic genetics findings given activity level propositions: A review, Forensic Science International: Genetics, 36, 34–49.[9]

108. Biedermann A., Taroni F., Bozza S., Augsburger M., Aitken C. 2018, Critical analysis of forensic cut-offs and legal thresholds: a coherent approach to inference and decision, Forensic Science International, 288, 72–80.

107. Thompson W.C., Vuille J., Taroni F., Biedermann A. 2018, After uniqueness: the evolution of forensic science opinions, Judicature, 102, 18–27. Translated as:
    - Thompson W.C., Vuille J., Taroni F., Biedermann A. 2018, 独特性之后：法庭科学意见的演进 (After uniqueness: the evolution of forensic science opinions), Evidence Science, 26, 503–513.

106. Biedermann A., Bozza S., Taroni F. 2018, Analysing and exemplifying forensic conclusion criteria in terms of Bayesian decision theory, Science & Justice, 58, 159–165.

105. Taylor D., Biedermann A., Hicks T., Champod C. 2018, A template for constructing Bayesian networks in forensic biology cases when considering activity level propositions, Forensic Science International:

[9]This article has received the NIFS (National Institute of Forensic Science, Australia and New Zealand) Award 'Best Literature Review' (Highly Commended) 2019. By July 2021 (3 years after publication) this paper has been cited 50 times.

Genetics, 33, 136–146.[10]

104. Biedermann A., Bozza S., Taroni F., Aitken C. 2017, The meaning of justified subjectivism and its role in the reconciliation of recent disagreements over forensic probabilism, Science & Justice, Special Issue on Measuring and Reporting the Precision of Forensic Likelihood Ratios, 57, 477–483.

103. Gaborini L., Biedermann A., Taroni F. 2017, Towards a Bayesian evaluation of features in questioned handwritten signatures, Science & Justice, 57, 209–220.

102. Moreillon L., Vuille J., Biedermann A., Champod C. 2017, Les nouvelles lignes directrices du European Network of Forensic Science Institutes en matière d'évaluation et de communication des résultats d'analyses et d'expertises scientifiques, forumpoenale, 10, 105–110.

101. Taylor D., Biedermann A., Samie L., Pun K.-M., Hicks T., Champod C. 2017, Helping to distinguish primary from secondary transfer events for trace DNA, Forensic Science International: Genetics, 28, 155–177.

100. Biedermann A., Champod C., Willis S. 2017, Development of European standards for evaluative reporting in forensic science: The gap between intentions and perceptions, The International Journal of Evidence & Proof, Special Issue on Proof in Modern Litigation: Selected Essays of the 5th International Conference on Evidence Law and Forensic Science, 21, 14–29.

99. Biedermann A., Bozza S., Taroni F., Aitken C. 2017, The consequences of understanding expert probability reporting as a decision, Science & Justice, Special Issue on Measuring and Reporting the Precision of Forensic Likelihood Ratios, 57, 80–85.

98. Biedermann A., Champod C., Jackson G., Gill P., Taylor D., Butler J., Morling N., Hicks T., Vuille J., Taroni F. 2016, Evaluation of forensic DNA traces when propositions of interest relate to activities: analysis and discussion of recurrent concerns, Frontiers in Genetics, Statistical Genetics and Methodology (Research topic 'The interface between forensic scientists and statisticians when calculating likelihood ratios for low template and complex DNA results'), 7, 215, 1–12.

97. Biedermann A., Bozza S., Taroni F., Aitken C. 2016, Reframing the debate: a question of probability, not of likelihood ratio, Special Issue on Measuring and Reporting the Precision of Forensic Likelihood Ratios, Science & Justice, 56, 392–396.

96. Marquis R., Biedermann A., Cadola L., Champod C., Gueissaz L., Massonnet G., Mazzella WD, Taroni F, Hicks T. 2016, Discussion on how to implement a verbal scale in a forensic laboratory: Benefits, pitfalls and suggestions to avoid misunderstandings, Science & Justice, 56, 364–370.

95. Biedermann A., Bozza S., Taroni F., Fürbach M., Li B., Mazzella W.D. 2016, Analysis and evaluation of magnetism of black toners on documents printed by electrophotographic systems, Forensic Science International, 267, 157–165.

94. Biedermann A., Bozza S., Taroni F. 2016, The decisionalization of individualization, Forensic Science International, 266, 29–38. Translated as:
   - Biedermann A., Bozza S., Taroni F. 2020, L'individualizzazione come decisione, Philosophical Readings, 20, 335–347.
   - Biedermann A., Bozza S., Taroni F. 2016, La naturaleza decisoria de las conclusiones de los expertos en ciencia forense (The decisionalization of individualization), Teoría y derecho, 20, 262–284.
   - Biedermann A., Bozza S., Taroni F., Li B., Zhao D. 2016, "同一认定" 中的意见决策论 (The decisional-

[10]This paper has received the NIFS (National Institute of Forensic Science, Australia and New Zealand) Award 'Best Paper in a Refereed Journal' (Highly Commended) 2018.

ization of individualization), Evidence Science, 24, 627–641.

93. Biedermann A., Vuille J. 2016, Digital evidence, ‘absence’ of data and ambiguous patterns of reasoning, Digital Investigation (DFRWS 2016 Europe – Proceedings of the Third Annual DFRWS Europe), 16, S86-S95.

92. Taroni F., Bozza S., Biedermann A., Aitken C.G.G. 2016, Rejoinder, Law, Probability and Risk, 15, 31–34.

91. Taroni F., Bozza S., Biedermann A., Aitken C.G.G. 2016, Dismissal of the illusion of uncertainty in the assessment of a likelihood ratio, Law, Probability and Risk, 15, 1–16.

90. Biedermann A., Hicks T. 2016, The importance of critically examining the level of propositions when evaluating forensic DNA results, Frontiers in Genetics, Genomic Assay Technology (Research topic ‘The interface between forensic scientists and statisticians when calculating likelihood ratios for low template and complex DNA results’), 7, 8.

89. Taroni F., Biedermann A., Bozza S. 2016, Statistical hypothesis testing and common misinterpretations: Should we abandon *p*-value in forensic science applications?, Forensic Science International, 259, e32–e36.

88. Taroni F., Biedermann A. 2015, Uncertainty in forensic science: experts, probabilities and Bayes’ theorem, Statistica Applicata – Italian Journal of Applied Statistics, 27, 129-144

87. Hicks T., Biedermann A., de Koeijer J.A., Taroni F., Champod C., Evett I.W. 2015, The importance of distinguishing information from evidence/observations when formulating propositions, Science & Justice, 55, 520–525.

86. Biedermann A. 2015, The role of the subjectivist position in the probabilization of forensic science, Journal of Forensic Science and Medicine, 1, 140–148.[11]

85. Biedermann A., Vuille J., Taroni F., Champod C. 2015, The requirement for reporting standards in forensic science, Law, Probability and Risk, 14, 169–173.

84. Biedermann A., Bozza S., Taroni F. 2015, Prediction in forensic science: a critical examination of current understandings, Frontiers in Psychology, Quantitative Psychology and Measurement (Research topic ‘Judgment and decision under uncertainty: Theory and measurement’), 6, 737.

83. Taroni F., Marquis R., Schmittbuhl M., Biedermann A., Thiéry A., Bozza S. 2014, Bayes factor for investigative assessment of selected handwriting features, Forensic Science International, 242, 266–273.

82. Biedermann A., Voisard R., Scoundrianos A., Furrer J., Taroni F., Champod C. 2014, Supporting interdisciplinary case studies: development and implementation of a joint learning environment for students in forensic science and criminal law, Australian Journal of Forensic Sciences, 46, 317–329.

81. Biedermann A., Taroni F., Aitken C.G.G. 2014, Liberties and constraints of the normative approach to evaluation and decision in forensic science: a discussion towards overcoming some common misconceptions, Law, Probability and Risk, 13, 181–191.

80. Cereda G., Biedermann A., Hall D., Taroni F. 2014, An investigation of the potential of DIP-STR markers for DNA mixture analyses, Forensic Science International: Genetics, 11, 229–240.

79. Biedermann A., Vuille J. 2014, Exorbitante Zahlenwerte in der forensischen Befundbewertung, Kriminalistik, 169–173.

[11] This paper received the Best Paper Award 2017 from the Editorial Board of the Journal of Forensic Science and Medicine (JFSM). The paper was selected among the more than 170 papers published by the JFSM since its launch in 2015, based on the number of citations received during the first two years after publication.

78. Taroni F., Biedermann A., Bozza S., Vuille J., Augsburger M. 2014, Toxic substances in blood: an analysis of current recommendations under a Bayesian (decision) approach, Law, Probability and Risk, 13, 27–45.

77. Gittelson S., Biedermann A., Bozza S., Taroni F. 2014, Decision analysis for the genotype designation in low-template-DNA profiles, Forensic Science International: Genetics, 9, 118–133.

76. Cereda G., Biedermann A., Hall D., Taroni F. 2014, Object-oriented Bayesian networks for evaluating DIP-STR profiling results from unbalanced DNA mixtures, Forensic Science International: Genetics, 8, 159–169.

75. Thompson W.C., Vuille J., Biedermann A., Taroni F. 2013, The role of prior probability in forensic assessments, Frontiers in Genetics (Statistical Genetics and Methodology), 4, 220, 1–3.

74. Biedermann A., Vuille J., Taroni F. 2013, Apprécier le risque d'erreur lors d'une analyse ADN : de la nécessité d'être concret, Aktuelle juristische Praxis (AJP)/Pratique juridique actuelle (PJA), 1217–1223.

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Lectures and Presentations

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KEYNOTE AND INVITED PRESENTATIONS

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21. Gittelson S., Biedermann A., Taroni F., Analysing complex inference problems in forensic science using Bayesian networks: the example of the two-trace transfer problem, European Academy of Forensic Science Conference, Glasgow, 08.–11.09.2009.

20. Biedermann A., Taroni F., Bozza S., Mazzella W.D., Evaluating results of black toner analyses in forensic document examination using Bayesian networks, International Conference on Forensic Inference and Statistics, Lausanne, 21.–23.08.2008.

19. Biedermann A., Taroni F., Graphical probability models and the evaluation of scientific evidence, European Academy of Forensic Science Triennal Meeting, Helsinki, 13.–16.06.2006.

18. Taroni F., Bozza S., Biedermann A., Aitken C.G.G., Evidence pre-assessment and decision making in forensic science, European Academy of Forensic Science Triennal Meeting, Helsinki, 13.–16.06.2006.

17. Taroni F., Dobler A., Bernard M., Biedermann A., Bayesian networks and the evaluation of DNA evidence in victim identification cases, European Academy of Forensic Science Triennal Meeting, Helsinki, 13.–16.06.2006.

16. Biedermann A., Taroni F., Evaluation of scientific evidence in a graphical probability environment, Transdisciplinary Seminars on Law, Probability and Risk, Criminal Investigation and Evidence Evaluation II, Edinburgh, 02.–03.12.2005.

15. Taroni F., Bozza S., Biedermann A., Aitken C.G.G., Forensic scientists and decision making, Transdisciplinary Seminars on Law, Probability and Risk, Criminal Investigation and Evidence Evaluation II, Edinburgh, 02.–03.12.2005.
14. Biedermann A., Taroni F., Bayesian networks and the assessment of scientific evidence: the use of qualitative probabilistic networks and sensitivity analyses, 14th International Forensic Science Symposium (Interpol), Lyon, 19.–22.10.2004.
13. Gallusser A., Biedermann A., Specht Y., Esseiva P., Anglada F., Supporting complex criminal investigations by information derived from the systematic profiling of illicit drugs,14th International Forensic Science Symposium (Interpol), Lyon, 19.–22.10.2004.
12. Taroni F., Biedermann A., Bayesian networks for inference in forensic science, Transdisciplinary Seminars on Law, Probability and Risk, Criminal Investigation and Evidence Evaluation, Edinburgh, 07.–09.05.2004.
11. Biedermann A., Taroni F., Semadeni C., Davison A.C., Reasoning under uncertainty in forensic fire cause analysis (Part I): an approach using Bayesian networks, European Academy of Forensic Science Triennal Meeting, Istanbul, 22.–27.09.2003.
10. Biedermann A., Taroni F., Semadeni C., Davison A.C., Reasoning under uncertainty in forensic fire cause analysis (Part II): a practical example of the use of Bayesian networks, European Academy of Forensic Science Triennal Meeting, Istanbul, 22.–27.09.2003.
9. Biedermann A., Taroni F., Semadeni C., Davison A.C., Reasoning under uncertainty in fire cause analysis: an approach using Bayesian networks, S.CO. 2003, Modelli complessi e metodi computazionali intensivi per la stima e la previsione, Treviso, 04.–06.09.2003.
8. Biedermann A., Taroni F., Buloncelli F., Transfer and persistence of glass fragments: a study of the relation between fragments found on different parts of the breaker, Annual Meeting of the International Association of Forensic Science, Montpellier, 02.–07.09.2002.
7. Massonnet G., Monard-Sermier F., Huguenot K., Biedermann A., Vayne F., Fillon C., A survey of glass fragments in automotive cars: population study and secondary transfer from a contaminated person into cars, Annual Meeting of the International Association of Forensic Science, Montpellier, 02.–07.09.2002.
6. Mailvaganam B., Biedermann A., Sink-float method for glass density comparison using sodium polytungstate, 48th Annual Meeting of the Canadian Society of Forensic Science, Toronto, 06.–11.11.2001.

INVITED SEMINARS

5. Biedermann A., The ongoing decisional transformation of forensic individualisation, University College London, Centre for the Forensic Sciences, 23.01.2020.
4. Biedermann A., Bozza S., Taroni F., Normative decision analysis at the intersection between forensic science and the law, University of California, Irvine, Center for Statistics and Applications in Forensic Evidence (csafe), Department of Criminology, Law and Society, and Department of Statistics, Irvine, California, 22.01.2019.
3. Biedermann A., The evolution of forensic science reporting, CPD Presentation (Continuing Professional Development) for members of the Office of the Director of Public Prosecutions (DPP) and Forensic Science South Australia (FSSA), Adelaide, South Australia, 06.03.2018.
2. Biedermann A., NORMDECS: Normative decision structures of forensic interpretation in the legal pro-

cess, Stanford Law School, CodeX (The Stanford Center for Legal Informatics) Group meeting (presented remotely), 26.01.2017.

1. Biedermann A., Vuille J., Scientific evidence as criminal proof: a Swiss homicide case-study, University of Nottingham, School of Law, Criminal Justice Research Centre, Criminal Justice Discussion Group, Nottingham, 10.02.2016.

OTHER PRESENTATIONS

Biedermann A., ThinkCloud: Pré-évaluation de cas assistée ('ThinkCloud: assisted case pre-assessment'), 4ème Journée de l'Innovation Pédagogique – 'Le feedback comme levier d'apprentissage' (4th Teaching Innovation Day – Feedback as a learning lever), University of Lausanne, 28.11.2017.

Lausanne, April 2022

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B Resume of Bruce Budowle

The resume starts on the next page. The rest of this page is intentionally left blank.

NAME: Bruce Budowle

TITLE: Regents Professor (Retired), Consultant

b.budowle@att.net

EDUCATION:

King College Bristol, Tennessee		B.A. - 1975 (Biology)
Virginia Polytechnic Institute and State University Blacksburg, Virginia	Ph.D. - 1979 (Genetics)	

DISSERTATION: Phase Change in Hedera helix L.

RESEARCH AND/OR PROFESSIONAL EXPERIENCE:

1974	Undergraduate Research Scientist, King College, Bristol, Tennessee
1976 - 1979	Graduate Teaching Assistantship in Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia
1979 - 1982	Postdoctoral Fellow in Immunogenetics, Awarded by the National Cancer Institute, University of Alabama in Birmingham, Alabama
1982	Consultant to Department of Criminal Justice University of Alabama in Birmingham
1983 - 1985	Consultant to Beckman Instruments, Inc. Palo Alto, California
1983 - 1994	Research Chemist, Forensic Science Research and Training Center, Laboratory Division, FBI Academy, Quantico, Virginia
1994 - 1997	Chief, Forensic Science Research Unit, Laboratory Division, FBI Academy, Quantico, Virginia
1985 - 2008	Adjunct Professor, School of Continuing Education, University of Virginia, FBI Academy Campus
1987 - 1988	Council Member, International Electrophoresis Society
1987 - 1988	Vice President, America's Branch of the Electrophoresis Society
1988 - 1990	Vice President, International Electrophoresis Society
1989 - 1991	Council Member, American Electrophoresis Society
1989 - 1998	Associate Editor, Applied and Theoretical Electrophoresis
1990 - present	Editorial Board, BioTechniques

1990 - 1991	Visiting Instructor, Rush Presbyterian - St. Luke's Medical Center.
1990 - present	Editorial/Advisory Board, International Journal of Legal Medicine
1991 - 2005	Chairman of the DNA Commission of the International Society of Forensic Haemogenetics
1994	Defense Science Board, Mitochondrial DNA, AFDIL
1994 - 1998	Editor, Crime Laboratory Digest
1995 - 2000	Chairman of The Scientific Working Group on DNA Analysis Methods
1995 - 2000	DNA Advisory Board, DNA Identification Act, Federal Bureau of Investigation
1995 - 2005	Editorial Board, Genetic Analysis: Biomolecular Engineering
1998 - 2001	The Research and Development Working Group, National Commission on the Future of DNA Evidence, National Institute of Justice
1998 - 2009	Senior Scientist - Biology, Laboratory Division, Federal Bureau of Investigation
1999 - 2009	Editorial Board, Forensic Science Communications
1999 - present	Editorial Board, Legal Medicine (Japanese Society of Legal Medicine)
1999 - 2003	Research Professor, Institute for Biosciences, Bioinformatics, and Biotechnology, George Mason University, Manassas, Virginia
1999 - 2003	Affiliate Professor, Department of Biology, George Mason University, Fairfax, Virginia
2000	Outside Reviewer for German Proficiency Testing System (GEDNAP)
2001-2002	Celera DNA Advisory Board, Mitochondrial DNA/WTC
2001-2003	Kinship and Data Analysis Panel for WTC Victim Identification
2002	Steering Committee, Colloquium on Microbial Forensics, American Society of Microbiology
2002 - 2004	Chair of Scientific Working Group Microbial Genetics and Forensics
2002	Co-organizer of Microbial Forensics Meeting, The Banbury Center, Cold Spring Harbor Laboratory
2002 - 2008	Adjunct Faculty, Department of Pathology, University of

	North Texas Health Science Center, Ft. Worth, Texas
2003 - 2008	National Biodefense Analysis and Countermeasures Center Advisory Group
2002 - 2007	National Interagency Genomics Science Coordinating Committee, National Science Foundation
2003	Disease Informatics Senior Coordinating Committee, National Science Foundation
2004	Co-organizer of Second Microbial Forensics Meeting, Identifying Gaps, sponsored by the Department of Homeland Security, The Banbury Center, Cold Spring Harbor Laboratory
2004 - 2007	Editorial Board, Forensic Science International
2004	Participant in Expert Meeting on Microbial Forensics, National Academy of Sciences, Washington, D.C., June 22-25, 2004
2004	Participant in Biosecurity Threats in the 21st Century: Re-examining how we define the "problem" and mitigate the effects, National Academy of Sciences, Minneapolis, MN, July 15, 2004
2004	Invited Lecturer, Post Graduate Course in Forensic Genetics, Finish Graduate School in Population Genetics and department of Forensic Medicine, University of Helsinki, Finland, September 20-21, 2004
2004	Member of Steering Committee on the Animal Forensics Working Group of the International Society of Animal Genetics
2004 – 2009	Member of Scientific Working Group for the NIAID-funded Bioinformatics Resource Center (BRC) at The Institute for Genomic Research (TIGR)
2005	Co-organizer of Third Microbial Forensics Meeting, sponsored by the Department of Homeland Security, Evidence Collection, Storage, and Extraction, The Banbury Center, Cold Spring Harbor Laboratory
2006	Participant in Advancing the International Biosecurity Dialogue: Clarifying Definitions, National Academy of Sciences, Washington, D.C., January 27, 2006
2006	Participant in Genomics and Global Pathogens, The American Academy of Microbiology, Washington, D.C., September 27-28, 2006
2006	Lecturer in Science Exposition and Ethics Course, Watson School of Biological Science, Cold Spring Harbor, New York, November 29, 2006
2006	International Fellow, Institute of Environmental Science and Research, New Zealand, December 1-13, 2006

2006 - 2008	Steering Committee Member, Scientific Working Group on Chemical, Biological, Nuclear and Radiological Analyses
2007	Member of National Planning Committee for Workshop on Plant Pathogen Forensics: Filling the Gaps, sponsored by Oklahoma State University, Oklahoma City, Oklahoma, January 11-13, 2007
2007 - present	Editorial Board, Forensic Science International Genetics
2007	Co-organizer of Fourth Microbial Forensics Meeting, Enduring Research Pathways, sponsored by the Department of Homeland Security, The Banbury Center, Cold Spring Harbor Laboratory
2008	Invited Outside Reviewer on DNA Technology for National Research Institute of Police Science, National Police Agency, Chiba, Japan, January 15-16, 2008
2008	Visiting Fellow, Faculty of Health Science and Medicine, Bond University, Gold Coast, Australia, June 23-July 5, 2008
2008 – 2009	Visiting Professor, Faculty of Health Science and Medicine, Bond University, Gold Coast, Australia
2008 – 2009	Member, Expert Working Group on Human Factors in Latent Print Analysis, NIST and NIJ
2009 – 2013	Professor, Department of Forensics and Investigative Genetics, University of North Texas Health Science Center, Ft. Worth, Texas
2009 – 2013	Executive Director, Institute of Applied Genetics, University of North Texas Health Science Center, Ft. Worth, Texas
2009	Invited Speaker, Overview of Microbial Forensics and the Concepts of Validation, Committee on Review of the Scientific Approaches used during the FBI's Investigation of the 2001 *Bacillus anthracis* Mailings, First Meeting, National Academy of Sciences, July 30-31, 2009
2009	Invited Speaker, Low Copy Number Typing Issues, Mixture Interpretation Issues, Committee on Science, Technology and Law, National Academy of Sciences, October 19, 2009
2009 - 2011	Co-Editor-in-Chief, BMC Investigative Genetics
2010	Member of Steering Committee for Forensic Death Investigation Symposium, National Institute of Justice, Scottsdale, AZ, June 7-9, 2010
2010	Consultant to Cyprus Institute of Neurology and Genetics Laboratory of Forensic Genetics UN Missing Persons Identification Program, Cyprus, September 20-24, 2010
2010 - present	Adjunct Faculty, Department of Biological Sciences, University of North Texas, Denton, TX

2010	Co-organizer of Fifth Microbial Forensics Meeting, Microbial Forensics in the Era of Genomics, sponsored by the Department of Homeland Security, The Banbury Center, Cold Spring Harbor Laboratory, November 7-10, 2010
2011	Co-organizer of Lyme Disease Diagnostics in the Proteomics-Genomics Era, The Banbury Center, Cold Spring Harbor Laboratory, April 10-13, 2011
2011	Visiting Professor, Department of Forensic Medicine, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand, June 2011.
2011	Member of Organizing Committee, Microbial Evolution and Cutting Edge Tools for Outbreak Investigations, Center for Disease Control and Prevention, Atlanta, GA, September 14-16, 2011.
2011 - present	Editorial Board, American Journal of Forensic Medicine and Pathology
2012	Member of planning committee for the Forum on Microbial Threats Workshop: The science and applications of microbial genomics: predicting, detecting, and tracking novelty in the microbial world, Institute of Medicine, Board on Global Health, National Academy of Sciences, June 12-13 2012.
2012- 2017	Member of the Technical Advisory Group to the Board of the Houston Forensic Science Center, LGC, Inc.
2013-2016	Member of the International Expert Committee for the Biology Division of Health Sciences Authority, Singapore
2013- present	Appointment with Center of Excellence in Genomic Medicine Research (CEGMR), King Abdulaziz University, Jeddah, Saudi Arabia.
2013-2014	Member of Committee for the Science Needs for Microbial Forensics: Developing an Initial International Science Roadmap, Institute of Medicine, Board on Global Health, National Academy of Sciences.
2013-2015	Visiting Professor, Science Without Borders, Universidade Federal Do Rio De Janeiro, Centro De Ciências Da Saúde, Instituto De Biofísica Carlos Chagas Filho
2014-2015	Member of Committee on PCR Standards for the BioWatch Program, Board of Life Sciences, Division on Earth and Life Sciences, Board of Health Sciences Policy, Institute of Medicine, Board on Global Health, National Research Council, National Academy of Sciences.
2014 – present	Associate Editorial Board of Biosafety and Biosecurity of Frontiers in Bioengineering and Biotechnology
2016 – present	Director of the Center for Human Identification, University of North Texas Health Science Center, Ft. Worth, Texas

2016 – 2022	Professor, Department of Microbiology, Immunology, and Genetics, University of North Texas Health Science Center, Ft. Worth, Texas
2016	GAO Meeting on Gaps in Capabilities for Attributing the Source of a Biological Attack, Washington, DC, April 20-21, 2016.
2016	Tackling Low Cost Nucleic Acid Test for the Developing World: Catalyzing Innovation in Sample Preparation, Scientific Advisory Board, Bill & Melinda Gates Foundation, Seattle, WA, May 25, 2016.
2016 - present	Member of the Texas Forensic Science Commission.
2017 - 2019	Vice-Chair, Department of Microbiology, Immunology and Genetics, University of North Texas Health Science Center, Ft. Worth, Texas.
2020 - present	Member of the Sexual Assault Survivors' task force, Office of the Gevernor.
2020	Interim Chair, Department of Microbiology, Immunology and Genetics, University of North Texas Health Science Center, Ft. Worth, Texas.
2020 - present	Editorial Board, Genes
2021 - present	Member of the Texas Evidence Collection Protocol Advisory Board, Office of the Attorney General, Texas A&M University College of Nursing, Texas A&M Health Center of Excellence in Forensic Nursing.
2022	Regents Professor, Department of Microbiology, Immunology and Genetics, University of North Texas Health Science Center, Ft. Worth, Texas.

MEMBERSHIPS IN PROFESSIONAL AND SCHOLARLY ORGANIZATIONS:

International Society for Forensic Genetics

HONORS AND OTHER SPECIAL COMMENTS:

1) Pi Alpha Sigma (1972)
2) Undergraduate Research Award (1974)
3) Graduate State Tuition Scholarship (1976 - 1979)
4) Phi Kappa Phi (1976)
5) Sigma Xi (1978)
6) American Academy of Forensic Sciences Recognition Award (1981)
7) Attorney General's Award for Exceptional Service (1991)
8) Jefferson Award, University of Virginia (1991)
9) Forensic Scientist of the Year, MAAFS (1996)
10) Honorary Member of the Finnish Society of Forensic Medicine (1998)
11) Director's Award for Excellence in Investigative Support (2000)
12) Paul L. Kirk Award, Criminalistics Section, American Academy of Forensic Sciences (2001)
13) University of Alabama at Birmingham's 2004 Ireland Distinguished Visiting

Scholar
14) Honorary Member of the Mediterranean Academy of Forensic Sciences (2004)
15) Health Care Hero Award, Dallas Business Journal (2010)
16) GSA Outstanding Faculty Award 2016, GSBS, UNTHSC

RESEARCH INTERESTS:

Forensic Science
Genetic Marker Systems
Technique Development
Molecular Biology
Population Genetics
Human Genetics
Microbial Forensics
Pharmacogenomics

PUBLICATIONS:

1. Budowle, B., Go, R. C. P. and Acton, R. T.: Isoelectric focusing of hair proteins. In: Electrophoresis '81 (Allen, R. C. and Arnaud, P., eds.) Walter de Gruyter, Berlin, pp. 585-590, 1981.

2. Budowle, B., Go, R. C. P., Barger, B. O. and Acton, R. T.: Properdin factor B polymorphism in black Americans. J. Immunogenetics 8:519-521, 1981.

3. Budowle, B. and Acton, R. T.: A technique for the detection of variable electrophoretic patterns of hair proteins. Electrophoresis 2:333-334, 1981.

4. Budowle, B., Acton, R. T. and Barger, B. O.: A method for the dialysis of micro-samples. Anal. Biochem. 118:399-400, 1981.

5. Budowle, B., Reitnauer, P. J., Barger, B. O., Go, R. C. P., Roseman, J. M. and Acton, R. T.: Properdin factor B in type 1 (insulin-dependent) diabetic patients. Diabetologia 22(6):483-485, 1982.

6. Acton, R. T., Balch, C. M., Budowle, B., Go, R. C. P., Roseman, J. M., Soong, S-J., and Barger, B. O.: Immunogenetics of melanoma. In: Melanoma Antigens and Antibodies (Reisfeld, R. A. and Ferrone, S., eds.) Plenum Publishing Corporation, New York, pp. 1-21, 1982.

7. Reitnauer, P. J., Go, R. C. P., Acton R. T., Murphy, C. C., Budowle, B., Barger, B. O. and Roseman, J. M.: Evidence for genetic admixture as a determinant in the occurrence of IDDM in U.S. Blacks. Diabetes 31:532-537, 1982.

8. Budowle, B., Barger, B. O., Balch, C. M., Go, R. C. P., Roseman, J. M. and Acton, R. T.: Associations of Properdin factor B with melanoma. Cancer Genetics and Cytogenetics 5:247-251, 1982.

9.Budowle, B., Acton, R. T., Barger, B. O., Blackstock, R., Crist, W., Go, R. C. P., Humphrey, G., Ragab, A., Roper, M., Vietti, T. and Dearth, J.: Properdin factor B and acute lymphocytic leukemia (ALL). Cancer 50: 2369-2371, 1982.

10. Acton, R. T., Balch, C. M., Barger, B. O., Budowle, B., Go, R. C. P., Soong, S-J., and Roseman, J. M.: The occurrence of melanoma and its relationship with host, lifestyle and environmental factors. In: Melanoma-1 (Constanzi, J. J., ed.), Martinus Nijhoff Publishers, The Hague, pp. 151-182, 1983.

11. Budowle, B., Go, R. C. P., Roseman, J. M., Barger, B. O. and Acton, R. T.: C4 phenotypes in Caucasians from the southeastern United States. In: Electrophoresis '82 (Stathakos, D., ed.), Walter de Gruyter, Berlin, pp. 715-723, 1982.

12. Budowle, B., Roseman, J. M., Go, R. C. P., Crist, W. and Dearth, J.: Complement phenotypes for prediction of risk and prognosis for acute lymphocytic leukemia (ALL). In: Cancer: Etiology and Prevention (Crispen, R. G., ed.) Elsevier Biomedical, New York, pp. 109-123, 1983.

13. Budowle, B., Roseman, J. M., Go, R. C. P., Louv, W. C., Barger, B. O. and Acton, R. T.: Phenotypes of the fourth complement component (C4) in black Americans from the southeastern United States. J. Immunogenetics 10 (3):199-204, 1983.

14. Budowle, B., Louv, W. C., Barger, B. O., Go, R. C. P., Roseman, J. M. and Acton, R. T.: Age at onset of insulin-dependent diabetes mellitus associated with BfF1. Immunogenetics 17:437-440, 1983.

15. Budowle, B., Dearth, J., Bowman, P., Melvin, S., Crist, W., Go, R., Kim, T., Iyer, R. J., Roseman, J., Barger, B., and Acton, R.: Genetic predisposition to acute lymphocytic leukemia in American Blacks. Cancer 55:2880-2882, 1985.

16. Budowle, B., Roseman, J. M., Go, R. C. P., Barger, B. and, Acton, R. T.: The complement component C4 in black Americans with type 1 (insulin-dependent) diabetes mellitus. Diabetologia 26:166-168, 1984.

17. Budowle, B.: A method to increase the volume of sample applied to isoelectric focusing (IEF) gels. Forens. Sci. Int. 24(4):273-277, 1984.

18. Budowle, B.: A reproducible method for dialysis of multiple small volume samples. BioTechniques 1(4):176-177, 1983.

19. Budowle, B.: Increasing the sensitivity of detection of group-specific component in agarose gels by double-staining with coomassie brilliant blue R250 and silver. J. Forens. Sci. 29(4):1183-1186, 1984.

20. Budowle, B. and Gambel, A.: An alternative gel system for group III gels. Crime Lab Digest 11 (1):12-13, 1984.

21. Budowle, B.: Increasing the sensitivity of protein detection of a silver stain for agarose gels. Electrophoresis 5(3):174-175, 1984.

22. Budowle, B.: Phosphoglucomutase-1 subtyping of human bloodstains on ultrathin-layer polyacrylamide gels. Electrophoresis 5(3):165-167, 1984.

23. Budowle, B.: An ultrathin-layer polyacrylamide gel isoelectric focusing method for transferrin subtyping. Electrophoresis 6(2):97-99, 1985.

24. Budowle, B.: Rapid electrofocusing of erythrocyte acid phosphatase. Electrophoresis 5(4):254-255, 1984.

25. Budowle, B.: Typing esterase D by isoelectric focusing. Electrophoresis 5(5):314-316, 1984.

26. Budowle, B. and Davidson, L.: Electrophoresis: The theory and evolution of electrophoretic methods. Crime Lab Digest 11 (3): 45-50, 1984.

27. Budowle, B. and Chow, G. H.: Discontinuous polyacrylamide gel electrophoresis for typing haptoglobin in bloodstains. J. Forens. Sci. 30(3):893-897, 1985.

28. Budowle, B. and Scott, E.: Transferrin subtyping of human bloodstains. Forens. Sci. Int. 28:269-275, 1985.

29. Budowle, B.: An agarose gel method for typing phosphoglucomutase-1, esterase D or glyoxalase I. J. Forens. Sci. 30(4):1216-1220, 1985.

30. Budowle, B., Sundaram, S. and Wenk, R.: Population data on the forensic genetic markers: phosphoglucomutase-1, esterase D, erythrocyte acid phosphatase and glyoxalase I. Forens. Sci. Int. 28:77-81, 1985.

31. Budowle, B.: A rapid method for subtyping phosphoglucomutase-1. BioTechniques 3(2):92-93, 1985.

32. Murch, R. and Budowle, B.: Applications of isoelectric focusing in forensic serology. J. Forens. Sci. 31(3):869-880, 1986.

33. Budowle, B.: Subtyping group-specific component or esterase D using the same ultrathin-layer polyacrylamide gel format. Electrophoresis 7:141-144, 1986.

34. Budowle, B. and Murch, R.: A high resolution, rapid procedure for alpha 1-antitrypsin typing. Electrophoresis 6(10):523-525, 1985.

35. Budowle, B.: Principles of isoelectric focusing. In: Proceedings of the International Symposium on the Forensic Application of Electrophoresis, Government Printing Office, Washington, D. C., pp. 121-126, 1984.

36. Budowle, B. and Davidson, L.: Selecting genetic markers for analysis of forcibly removed hairs. In: Proceedings of the International Symposium on Forensic Hair Comparisons. Government Printing Office, Washington, D.C., pp. 89-93, 1985.

37. Budowle, B. and Eberhardt, P.: Ultrathin-layer polyacrylamide gel isoelectric focusing for the identification of hemoglobin variants. Hemoglobin 10(2):161-172, 1986.

38. Budowle, B., Murch, R. S., Davidson, L. C., Gambel, A. M. and Kearney, J. J.: Subtyping phosphoglucomutase-1 in semen stains and bloodstains: A report on the method. J. Forens. Sci. 31(4):1341-1348, 1986.

39. Budowle, B.: A method for subtyping group-specific component in bloodstains. Forens. Sci. Int. 33(3):187-196, 1987.

40. Gambel, A., Budowle, B., and Terrell, L.: Glyoxalase I typing and phosphoglucomutase-1 subtyping of a single hair. J. Forens. Sci. 32(5):1175-1181, 1987.

41. Budowle, B.: Making ultrathin-layer polyacrylamide gel isoelectric focusing a reproducible methodology. In: Proceedings of the 1986 Meeting of the Americas Branch of the Electrophoresis Society. National Bureau of Standards, pp. 1-12, 1986.

42. Budowle, B. and Murch, R. S.: Applications of isoelectric focusing in forensic serology. II. In: New Directions in Electrophoretic Methods (Jorgenson, J. and Phillips, M., eds.), ACS Symposium Series 335, pp. 143-157, 1987.

43. Budowle, B. and Mudd, J. L.: An aluminum template for casting agarose gels. J. Forens. Sci. 32(3):784-787, 1987.

44. Budowle, B. and Gambel, A.: Negative gold staining for electrophoretic protein profile interpretations. Acta Histochemica et Cytochemica 19(5):647-654, 1986.

45. Allen, R. C., Budowle, B., Lack, P. M. and Graves, G.: Rehydrated polyacrylamide gels: A comparison with conventionally cast gels. In: Electrophoresis 86 (Dunn, M., ed.), VCH, Weinheim, pp. 462-473, 1986.

46. Allen, R. C., Budowle, B., Saravis, C. A. and Lack, P. M.: Enzyme and antibody detection following isoelectric focusing on ultrathin-layer rehydrated polyacrylamide gels. Acta Histochemica et Cytochemica 19(5):637-645, 1986.

47. Alexander, L. A., Reeder, D. J. and Budowle, B.: A method for routinely producing high resolution black and white journal quality photographs of electrophoretic gels. J. Forens. Sci. 32(5):1331-1341, 1987.

48. Budowle, B.: Improved separation of the common transferrin variants in gels containing pH 5-7 ampholines and HEPES. Electrophoresis 8(4):210-212, 1987.

49. Budowle, B. and Allen, R.C.: Electrophoresis Reliability. I. The contaminant issue. J. Forens. Sci. 32(6):1537-1550, 1987.

50. Budowle, B. and Gambel, A. M.: An alternative effective substrate for erythrocyte acid phosphatase phenotype determinations. J. Forens. Sci. 33(4):915-920, 1988.

51. Budowle, B. and Gambel, A. M.: A hybrid ampholyte focusing technique for esterase D subtyping of evidentiary material. J. Forens. Sci. 33(3):738-743, 1988.

52. Budowle, B., Huddleston, J. F., Go, R. C. P., Barger, B. O., and Acton, R. T.: Association of HLA-linked Factor B with gestational diabetes mellitus in Black women. Amer. J. Obstet. Gyn. 159(4):805-806, 1988.

53. Budowle, B., Deadman, H. A., Murch, R. S. and Baechtel, F. S.: An introduction to the methods of DNA analysis under investigation in the FBI Laboratory. Crime Laboratory Digest 15(1):8-21, 1988.

54. Budowle, B., Adams, D.E., Comey, C.C., and Merril, C.R.: Mitochondrial DNA: A possible genetic material suitable for forensic analysis. In: Advances in Forensic Science (Lee, H.C. and Gaensslen, R.E., eds.), Year Book Medical Publishers, Chicago, pp. 76-97, 1990.

55. Budowle, B., Adams, D.E., and Allen, R.C.: Fragment length polymorphisms for forensic science applications. In: Methods in Nucleic Acids (Karam, J., Chao, L., and Warr, G., eds.), CRC Press, Boca Raton, Florida, pp. 181-202, 1991.

56. Budowle, B.: The RFLP technique. Crime Laboratory Digest 15(4):97-98, 1988.

57. Budowle, B. and Baechtel, F.S.: Modifications to improve the effectiveness of restriction fragment length polymorphism typing. Appl. Theor. Electrophoresis 1:181-187, 1990.

58. Allen, R.C., Graves, G. and Budowle, B.: Polymerase chain reaction amplification products separated on rehydratable polyacrylamide gels and stained with silver. BioTechniques 7(7):736-744, 1989.

59. Budowle, B., Waye, J.S., Shutler, G.G., and Baechtel, F.S.: Hae III - a suitable restriction endonuclease for restriction fragment length polymorphism analysis of biological evidence samples. J. Forens. Sci. 35(3): 530-536, 1990.

60. Waye, J.S., Presley, L., Budowle, B., Shutler, G.G., and Fourney, R.M.: A simple method for quantifying human genomic DNA in forensic specimen extracts. BioTechniques 7(8):852-855, 1989.

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787. Budowle, B.: The power of DNA Typing, Forensics as a Method to Improve Law Enforcement Capabilities, FBINAA Latin-America Caribbean Retrainer, San Salvador, El Salvador, 2019.

788. Budowle, B.: Topics in DNA analysis: complex mixture and secondary transfers, Forensic Science and Criminal Law Conference, Vancouver, Canada, 2019.

789. Budowle, B.: The USA journey to DNA databases and their global importance to fighting crime, The Future of DNA Databases in the Philippines, Philippines National Police, Manila, Philippines, 2019.

790. Budowle, B.: Forensic genomics innovations and their impact on public safety, Human Identification Solutions Conference, Kobe, Japan, 2019.

791. Budowle, B.: DNA and mixture interpretation, NY State Appelate Judges Seminar, Wading River, NY, 2019.

792. Budowle, B.: The USA journey to DNA databases and their global importance to fighting crime, International Symposium on Forensic DNA, Buenos Aires, Argentina, 2019.

793. Budowle, B.: The science and creation of a national DNA database, Forum on Genetic Registration Law, Justice and Human Rights Commission, San Salvador, El Salvdor, 2019.

794. Novroski, N., Woerner, A.E., Wendt, F.R., Buś, M.M., Coble, M.D., and Budowle, B.: Highly heterozygous STR markers for enhanced DNA mixture deconvolution, 30th International Symposium on Human Identification, Palm Springs, CA, 2019.

795. Kieser, R.W., Buś, M.M., King, J., Van der Liet, W., Thelen, J., and Budowle, B.: Reverse Complement PCR: A novel one-step PCR yystem for typing highly degraded DNA for human identification, 30th International Symposium on Human Identification, Palm Springs, CA, 2019.

796. Sherier, A.J., Schmedes, S.E., Woerner, A.E., Novroski, N.M.M., Wendt, F.R., King, J.L., and Budowle, B.: Human skin microbiome: selecting informative SNPs for human identification, 30th International Symposium on Human Identification, Palm Springs, CA, 2019.

797. Woerner, A.E., Hewitt, C., Freitas, M.A., Zhang, L., Baniasad, M., Schulte, K.Q., Smith, A.R., Albright, N.C., LeSassier, D.S., Weber, K., Manley, T.E., Allen, L.W., Powals, M.E., Ludolph, B.C., and Budowle, B.: From peptides to random match probabilities, 30th International Symposium on Human Identification, Palm Springs, CA, 2019.

798. Cihlar, J.C., Peters, D., Capt, C., Strobl, C., Parson, W., and Budowle, B.: Massively parallel sequencing of the mitochondrial genome in casework-type samples, 30th International Symposium on Human Identification, Palm Springs, CA, 2019.

799. Buś, M.M., Schellberg, T., and Budowle, B.: Human trafficking – a complex challenge for forensic science, 30th International Symposium on Human Identification, Palm Springs, CA, 2019.

800. Cihlar, J.C., Strobl, C., Peters, D., Capt, C., Parson, W., and Budowle, B.: The implementation process: a massively parallel sequencing workflow for mitochondrial DNA analysis, Green Mountain DNA Conference, Burlington, VT, 2019.

801. Buś, M.M., Schellberg, T., and Budowle, B.: Human Trafficking – multinational challenge for forensic science, 28th Congress of the International Society of Forensic Genetics, Prague, Czech Republic, 2019.

802. Strobl, C., Churchill Cihlar, J., Lagacé, R., Wootton, S., Roth, C., Huber, N., Schnaller, L., Zimmermann, B., Huber, G., Hong, S.L., Moura-Neto, R., Silva, R., Alshamali, F., Souto, L., Anslinger, K., Egyed, B., Jankova-Ajanovska, R., Casas-Vargas, A., Usaquén, W., Silva, D., Barletta-Carrillo, C., Tineo, D.H., Vullo, C., Würzner, R., Xavier, C., Gusmão, L., Niederstätter, H., Bodner, M., Budowle, B., and Parson, W.: Validation of the Precision ID Whole Genome Panel in a worldwide lineage study, 28th Congress of the International Society of Forensic Genetics, Prague, Czech Republic, 2019.

803. Berger, B., M., Parson, W., and Budowle, B.: Sequence data of 31 autosomal STR loci from 498 Spanish individuals, 28th Congress of the International Society of Forensic Genetics, Prague, Czech Republic, 2019.

804. Budowle, B.: Molecular advances in human identification – increasing capabilities to analyze human remains, 4th Bone Workshop and Conference 2019, Prague, Czech Republic, 2019.

805. Budowle, B.: Dense DNA data for missing persons identification, Emerging Issues of Privacy, Trust, and Societal Benefit from Consumer Genomics, Banbury Center, Cold Spring Harbor Laboratory, NY, 2019.

806. Budowle, B.: Genomic solutions for complex forensic casework samples, 2nd Human Identification Users Meeting, Bogota, Colombia, 2019.

807. Budowle, B.: Analysis of mitochondrial DNA using MPS technology, 2nd Human Identification Users Meeting, Bogota, Colombia, 2019.

808. Smuts, A., Muenzler, M., King, J., and Budowle, B.: Presumptive test compatibility with efficient DNA collection swabs, American Academy of Forensic Sciences, Anaheim, CA, 2020.

809. Budowle, B.: Forensic genealogy applications, 31st International Symposium on Human Identification, Virtual Meeting, 2020.

810. Budowle, B.: A project to combat human trafficking in Latin America, XI International Congress of Legal Medicine and Forensic Sciences: Challenges for Forensic Sciences during the Pandemic by COVID-19, Virtual Meeting, 2020.

811. Budowle, B. and Buś, M.M.: Combating human trafficking with DNA analysis, DNA databases, legislation, policy, privacy protection, and public outreach, 7th Annual Human Identification Solutions Conference (HIDS), Virtual Meeting, 2021.

812. Budowle, B.: Advances in forensic DNA technologies, Canadian Society of Forensic Science Meeting, Virtual Meeting, 2021.

813. Cihlar, J.C., Kapema, K.B., King, J.L., and Budowle, B.: Cross-Platform Workflow for the Promega PowerSeq 46GY System, 32nd International Symposium on Human Identification, Orlando, FL, 2021.

814. Sherier, A., Woerner, A.E., and Budowle, B.: Ancestry Informative Markers in the Skin Microbiome for Human Identification, 32nd International Symposium on Human Identification, Orlando, FL, 2021.

815. Ge, J., Crysup, B., Peters, D., Huang, M., and Budowle, B.: Interpretation of Y Chromosome STRs for Missing Persons Cases, 32nd International Symposium on Human Identification, Orlando, FL, 2021.

816. Budowle, B., Nagraj, V.P., S cholz, M., Jessa, S., Acevedo, C., Ge, J., King, J.L., Smuts, A., Woerner, A.E., and Turner, S.D.: Validation of kinship software for application of forensic genetic genealogy for missing persons identifications, 32nd International Symposium on Human Identification, Orlando, FL, 2021.

817. Buś, M.M., de Jong, E., King, J.L., van der Vliet, W., Theelen, J., Muenzler, M., Wang, X., and Budowle, B.: Reverse Complement PCR (RC-PCR) system for analyses of highly degraded DNA samples, 32nd International Symposium on Human Identification, Orlando, FL, 2021.

818. Cihlar, J.C., Kapema, K.B., Lagacé, R., Budowle, B.: Validation of the Applied Biosystems RapidHIT ID Instrument and ACE GlobalFiler Express Sample Cartridge, 32nd International Symposium on Human Identification, Orlando, FL, 2021.

819. Woerner, A.E., Mandape, S., Crysup, B., and Budowle, B.: Probabilistic genotyping and whole genome kinship estimation, 32nd International Symposium on Human Identification, Orlando, FL, 2021.

820. Budowle, B.: Kinship and data analyisis panel (WTC 9/11/2001), 32nd International Symposium on Human Identification, Orlando, FL, 2021.

821. Budowle, B.: Advanced DNA technologies to support criminal investigations, NEXTlab2021 - 4th Scientific Conference on Forensics Biology, Uniejów, Poland, 2021.

822. Budowle, B.: Extended kinship and databases to augment human identification capabilities, NEXTlab2021 - 4th Scientific Conference on Forensics Biology, Uniejów, Poland, 2021.

823. Budowle, B.: How to interpret DNA mixtures, NEXTlab2021 - 4th Scientific Conference on Forensics Biology, Uniejów, Poland, 2021.

824. Buś, M. and Budowle, B.: Human trafficking, NEXTlab2021 - 4th Scientific Conference on Forensics Biology, Uniejów, Poland, 2021.

825. Budowle, B.: Advanced DNA technologies to support criminal investigations, 13th AFSN Annual Meeting and Symposium, Virtual Meeting, 2021.

826. Budowle, B.: Humanitarian database strategies for identifying missing persons, 13th AFSN Annual Meeting and Symposium, Virtual Meeting, 2021.

827. Budowle, B.: Forensic molecular biology and genomics innovations and their impact on society, Molecular Diganostics 2021 Conference, Moscow, Russia (virtually presented), 2021.

828. Budowle, B.: DNA technology and recent advances that improve humanitarian programs (missing persons and unidentified bodies), ICRC and DNAforAfrica, Virtual Meeting, 2021.

829. Ge, J., King, J., Mandape, S., and Budowle, B.: Enhanced mixture interpretation with macrohaplotypes based on long-read DNA sequencing, American Academy of Forensic Sciences, Seattle, WA, 2022.

FUNDING

PI; Improved Tools and Interpretation Guidelines for Examining Limited Low Copy Number DNA Obtained from Degraded Single Source Samples: Bones, Teeth, and Hairs; Awarded by the National Institute of Justice; Award Number: 2009-DN-BX-K188; 10/01/2009 – 9/30/2011; Total: $935,992.00.

Co-PI; Development of an Expert System for Automated Forensic mtDNA Data Analysis; Awarded by the National Institute of Justice; Award Number: 2009-DN-BX-K171; 10/01/2009 - 03/31/2011; Total: $353,857.00.

Co-PI; Establishing the quantitative basis for sufficiency: threshold and metrics for friction ridge pattern detail quality and foundation for a standard; Awarded by Virginia Tech subcontract; the National Institute of Justice; Award Number: 2009-DN-BX-K229; 10/01/2009 - 09/30/2011; Total: $854,907.00; Subcontract: $123,120.00.

PI; Addressing Quality and Quantity; the Role of DNA Repair and Whole Genome Amplification in Forensically Relevant Samples; Awarded by the National Institute of Justice; Award Number: 2010-DN-BX-K227; 10/01/2010 – 09/30/2012. Total: $363,613.00

PI; Identity, Lineage, and Phenotypic SNP Identification, Assay Development, and Data Interpretation; Awarded by the 2010 Intelligence Community Postdoctoral Research Fellowship Program; Award Number: 2010*0937130*000; 09/01/2010 – 08/31/2010; Total: $239,076.00.

PI; Indel Study; Awarded by Life Technologies; Project ID RP0060; 10/18/2010 –04/01/2011; Total: $30,000.00.

PI; Research Collaboration; Awarded by Promega Corporation; 10/01/2010 – 09/30/2012; Total: $142,006.28

Co-PI; Comprehensive Training Program in Forensic DNA Interpretation and Statistics; Awarded by National Institute of Justice; Award number: NIJ-2010-93494, 2010-DN-BX-K239; 10/01/10-09/30/12; Total: $999,481.00.

PI; Microbial Forensics Technical and Scientific Process; Awarded by Signature Science; Award number: 2012-030-0002; 02/01/2012-01/31/2013; Total: $131,164.98.

Co-PI; Testing, Evaluation and Demonstration of New Technologies; Awarded by RTI International subcontract; Awarded by the National Institute of Justice; Award number: 2011-DN-BX-K564; 10/01/2011 – 09/30/2012; Total: $375,000.00.

PI; Development of Reference Sample DNA Profiling for Databases Using Next Generation Sequencing Technologies; Awarded by the National Institute of Justice; Award Number: 2012-DN-BX-K033; 10/01/2012 – 6/30/2014; Total: $747,797.00.

PI; NIJ Ph.D. Graduate Research Fellowship Program FY 2012; Awarded by the National Institute of Justice; Award Number: Award 2012-IJ-CX-0016; 10/01/2012 – 09/30/2013; Total: $24,988.00.

PI; Validation of Rapid DNA Typing System; Awarded by Department of Defense; Contract Number: HQ0034-13-P-0002; 1/28/2013 – 01/27/2014; Total: $32,659.80.

PI; Microbial Forensics Technical and Scientific Process; Awarded by Signature Science; Renewal of Award number: 2012-030-0002; 02/01/2013-01/31/2014; Total: $131,164.98.

Co-PI; Testing, Development of Improved Insertion-Deletion Assays for Human and Ancestral Identifications from Degraded Samples; Awarded by the National Institute of Justice; Award number: 2013-DN-BX-K036; 10/01/2013 – 09/30/2015; Total: $336,282.96.

PI; Microbial Forensics Technical and Scientific Process; Awarded by Signature Science; Renewal of Award number: 2012-030-0002; 02/01/2014-01/31/2015; Total: $131,164.98.

PI; Deadwood Project, Historic Preservation Archives Department Deadwood, South Dakota; 09/01/2014-12/31/2014; Total: $3000.00.

PI; Familial Searching; Awarded by RTI International subcontract; 09/05/2014-12/31/2014; Total: $ $71,550.77.

PI; Novel Collection Device for Enhanced DNA Recovery and Release from Biological Stain Samples; Awarded by the National Institute of Justice; Award Number: 2014-DN-llX-K031; 01/01/2015 – 12/31/2016; Total: $487,884.00.

PI; Human Microbiome Species and Genes for Human Identification; Awarded by the National Institute of Justice; Award Number: 2015-NE-BX-K006; 01/01/2016 – 12/31/2017; Total: $589,701.00.

PI; Enhancing Mixture Interpretation with Highly Informative STRs; Awarded by the National Institute of Justice; Award Number: 2015-DN-BX-K067; 01/01/2016 – 12/31/2017; Total: $585,415.00.

Co-PI; Enhanced Sample Preparation and Data Interpretation Strategies for Massively Parallel Sequencing for Human Identification in Missing Persons and DVI Casework; Awarded by the National Institute of Justice; Award Number: 2015-DN-BX-K067; 01/01/2016 – 12/31/2017; $294,805.59.

PI; DNA Capacity Enhancement and Backlog Reduction Program, FY15, Awarded by the National Institute of Justice; Award Number: 2015-DN-BX-0057, 01/01/2016 – 12/32/2017; $507,165.00.

PI; Using DNA Technology to Identify the Missing, FY15, Awarded by the National Institute of Justice; Award Number: 2015-DN-BX-K070; 01/01/2016 to 12/31/2017; $2,238,750.00.

PI; Management and Support of the National and Missing and Unidentified Persons System (NamUs), FY15, Awarded by the National Institute of Justice; Award Number: 2011-MU-BX-K063; 10/01/2016 to 09/30/2017; $5,866,325.85.

PI; DNA Analysis of Sexual Assault Evidence, Interagency Agreement Texas Department of Public Safety; 09/01/2016 – 12/31/2016; $192,990.00.

PI; Typing Highly Degraded DNA Using Circularized Molecules and Target Enrichment; Awarded by the National Institute of Justice; Award Number: 2016-DN-BX-0154; 01/01/2017 – 12/31/2018; $682,474.00.

PI; Application for Funding to Support the National Missing and Unidentified Persons System (NamUs); Awarded by the National Institute of Justice; Award Number: 2016-MU-BX-K007; 10/01/2016 – 09/30/2017; $4,700,000.00.

PI; FY 2016 DNA Capacity Enhancement and Backlog Reduction Program; Awarded by the National Institute of Justice; Award Number: 2016-DN-BX-0114; 01/01/2017 – 12/31/2018; $473,465.00.

PI; Evaluation and Implementation of High Throughput Second Generation Sequencing for Mitochondrial DNA Testing in Missing Persons and Forensic Casework at the UNT Center for Human Identification; Awarded by the National Institute of Justice; Award Number: 2016-DN-BX-K001; 01/01/2017 – 12/31/2018; $727,072.00.

PI; FY17 Graduate Research Fellowship in Science, Technology, Engineering, and Mathematics; Awarded by the National Institute of Justice; Award Number: Award 2017-IJ-CX-0010; 08/01/2017 – 07/31/2019; Total: $89,194.00.

PI; Reducing Human Trafficking Through Forensics in Central America; Awarded by the U.S. Department of State; Award Number: S-INLEC-17-GR-1013; 09/20/2017 – 09/20/2018; $3,301,122.48.

PI; Development of a Mitochondrial Mixture Database and Interpretation Tool; Awarded by the National Institute of Justice; Award Number: 2017-DN-BX-0134; 01/01/2018 – 12/31/2019; Total: $556,910.00.

PI; Application for Funding to Support the National Missing and Unidentified Persons System (NamUs); Awarded by the National Institute of Justice; Award Number: 2016-MU-BX-K007 (continuation); 10/01/2017 – 09/30/2018; $7,455,832.00.

PI; Research Project; A Sustainable Approach to High Confidence Metagenomics Analysis of Complex Samples; Awarded by Signature Science; 05/30/17-05/07/18; Total: $24,932.82.

PI; FY 2017 DNA Capacity Enhancement and Backlog Reduction Program; Awarded by the National Institute of Justice; Award Number: 2016-DN-BX-0114; 01/01/2018 – 12/31/2019; $494,555.00.

PI; Victims of Crime Act; Awarded by the National Institute of Justice; 10/01/16-09/30/18; $999,999.00.

PI; Office of Violence Against Women; Awarded by the National Institute of Justice; 10/01/16-09/30/18; $187,860.00.

PI; FY 2018 Forensic DNA Laboratory Efficiency Improvement and Capacity Enhancement Program: Backlog Reduction of Missing Persons' Samples; Awarded by the National Institute of Justice; Award Number: 2018-DN-BX-0198; 01/01/2019-12/31/2020; Total: $ 2,260,781.00.

PI; DNA Analysis of Sexual Assault Evidence, Interagency Agreement Texas Department of Public Safety; Sponsor number: 405-17-P012859; 01/01/2017 – 12/31/2019; $1,800,000.00.

PI; Application for Funding to Support the National Missing and Unidentified Persons System (NamUs); Awarded by the National Institute of Justice; Award Number: 2016-MU-BX-K007 (continuation); 10/01/2018 – 09/30/2019; $5,000,000.00.

Co-I; Research Project; Awarded by Signature Science; Sponsor number: S1110; 07/02/2018-07/01/2019; Total: $80,986.02.

Co-I; Better algorithms and chemistry for mixture interpretation; Awarded by the National Institute of Justice; Award Number: 2018-DU-BX-0177; 01/01/2019-12/31/2020; $694,525.00.

PI; Application for Funding to Support the National Missing and Unidentified Persons System (NamUs); Awarded by the National Institute of Justice; Award Number: 2016-MU-BX-K007 (continuation); 10/01/2019 – 09/30/2020; $5,500,000.00.

PI; Reducing Human Trafficking Through Forensics in Central America; Awarded by the U.S. Department of State; Award Number: S-INLEC-19-GR-0383; 10/01/2019 – 09/20/2020; $3,500,00.00.

PI; FY 2019 DNA Capacity Enhancement and Backlog Reduction; Awarded by the National Institute of Justice; Award Number: 2019-DN-BX-0087; 01/01/2020 – 12/31/2021; $477,688.00.

PI; Development of Dense DNA Data for Enhanced Missing Persons Identification; Awarded by the National Institute of Justice; Award Number: 2019-DU-BX-0046; 01/01/2020 – 12/31/2021; Total: $743,927.00.

PI; Reducing Human Trafficking Through Forensics in Central America; Awarded by the U.S. Department of State; Award Number: S-INLEC-20-GR-3160; 07/15/2020 – 07/15/2021; $3,500,00.00.

Co-I; Interpretation of Y chromosome STRs for missing persons cases; Awarded by the National Institute of Justice; Award Number: 2020-DQ-BX-0018; 01/01/2021 – 12/31/2021; Total: $198,362.00.

Co-I; Efficient and Effective SNP System for Analysis of Highly Degraded DNA Samples; Awarded by the National Institute of Justice; Award Number: 2020-DQ-BX-0005; 01/01/2021 – 12/31/2022; Total: $444,723.00.

PI; National Missing and Unidentified Persons System; Awarded by the National Institute of Justice; Award Number: 016-MU-BX-K007 (suppl 4); 10/01/2020 – 09/30/2021; Total: $4,288,461.

PI; Best Practices for Cold Case Investigations in American Indian and Alaska Native Jurisdictions; Awarded by the Community Oriented Policing Services; Award Number: 2020HEWXK001; 01/01/2021 – 12/31/2022; Total: $399,902.00.

PI; National Missing and Unidentified Persons System; Awarded by the National Institute of Justice; Award Number: 016-MU-BX-K007 (suppl 5); 02/01/2021 – 09/30/2021; Total: $ $3,341,165.

PI; Reducing Human Trafficking Through Forensics in Central America; Awarded by the U.S. Department of State; Award Number: S-INLEC-19-GR-0383; 9/21/2020 – 03/31/2023; $7,000,00.00.

PI; Reducing Human Trafficking Through Forensics in Central America; Awarded by the U.S. Department of State; Award Number: S-INLEC-20-GR-3160; 07/16/2021 – 08/31/2023; $9,999,222.16.

GRADUATED STUDENTS

Masters

Shamika Kelley, Masters, Thesis Practicum: Assessment of DNA transfer events involving routine human behavior, May 2010.

David Warshauer, Masters, Thesis Practicum: An evaluation of saliva-based DNA transfer, August 2011.

Alyssa Koehn, Masters Thesis: Identification of unknown PCR products generated during STR analysis of bone samples, May 2013.

Andrea Moore, Masters Thesis: STR typing of reference samples with rapid DNA technology, May 2014.

Lisa Skandalis, Masters Thesis: Population variances in the whole mitochondrial genome impacting capture for human identification, May 2015.

Allison Conway, Masters Thesis: A validation of STRmix for forensic casework, May 2017.

Natalie Colon, Masters Thesis: Variation in mitochondrial DNA heteroplasmy from blood, buccal, and hair samples, May 2020.

Gemma Campos, Masters Thesis: Validation study of the RapidHIT ID System for human identification, May 2020.

Doctoral

Pamela Marshall, Doctoral Dissertation: Improved tools for the robust analysis of low copy number and challenged DNA samples, May 2014.

David Warshauer, Doctoral Dissertation: Development of a comprehensive massively parallel sequencing panel of single nucleotide polymorphism and short tandem repeat markers for human identification, August 2015.

Xiangpei Zeng, Doctoral Dissertation: Selection of Highly Informative Markers for Apportionment of Ancestry and Population Affiliation, May 2016.

Sarah Schmedes, Doctoral Dissertation: Genetic Profiling of Skin Microbiomes for Forensic Human Identification, September 2017.

Frank Wendt, Doctoral Dissertation: Pharmacogenetics of Select Genes in the Opiate Metabolism and Response Pathways, July 2018.

Nicole Novroski, Doctoral Dissertation: Highly Informative Short Tandem Repeat Markers for Enhanced DNA Mixture Deconvolution, July 2018.

Carey Davis, Doctoral Dissertation: Increased Resolution Screening of the Pharmacogenetic Gene *CYP2D6* with Microarray Technology, July 2019.

Racel Kieser, Doctoral Dissertation: Typing Highly Degraded DNA Using Target Enrichment, May 2020.

Monika Stoljarova, Doctoral Dissertation: Massively Parallele Sequencing of Human Mitochondrial Genome for Forensic Analyses. Institute of Chemistry and Biotechnology, Tallinn University of Technology, June 2020.

Allsion Sherier, Doctoral Dissertation: Improving Human Identification Using the Human Skin Microbiome, January 2022.

POST-DOCTORAL FELLOWS

Meredith Turnbough 2010-2011

Bobby Larue 2010-2012

Seung Bum Seo 2012-2014

Jennifer Churchill 2014-2018

Angela Ambers 2015-2018

Maiko Takahashi 2015-2018

Xiangpei Zeng 2016-2017

August Woerner 2016-2017

Magdalena Buś 2018-2019

C Resume of Christophe Champod

The resume starts on the next page. The rest of this page is intentionally left blank.

CURRICULUM VITAE

Updated: February 2022

SURNAME: CHAMPOD

FIRST NAME: Christophe

DATE OF BIRTH: 12th August 1968

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Media http://avisdexperts.ch/experts/christophe_champod

PRESENT POSITION

From June 2003, **full professor of forensic science** at the Ecole des Sciences Criminelles (ESC) of the Faculty of law, criminal justice and public administration of the University of Lausanne. From August 2021, he is the **Director of the ESC and Vice-Dean of the Faculty**. Before that, he acted as vice-director of the ESC from 2004 to 2014 and from 2014 to 2021, he was the operational director of the ISO 17025 accredited laboratory of the ESC.

His research and teaching activities are centered on identification methods, mainly faces, fingerprints, footwear marks, toolmarks, DNA and other biometric systems.

Casework duties include fingerprints, footwear marks and marks examinations and interpretation issues (DNA, face recognition, earprint, toolmarks and fibres).

CV of 30 pages in total

Lausanne, February 28th 2022

EDUCATION

2008	AFIS Services Bern: “Searching palm prints (2 days)”. Trainers: R. Gander and G. Leuenberger.
2006	Passed the equivalence test for the Swiss Level 2 fingerprint expert status. Renewals for Level 2 and Level 3 fingerprint expert status were not continued due to my involvement in the Swiss Fingerprint Working Group as the coordinator of the training for Level 3 for the French course and lead assessor for the practical test for national Level 2 course.
2001	Forensic Identification Training Seminars, LLC: “Advanced Ridgeology Comparison Techniques” (5 days), trainer: Pat Wertheim.
2000	Forensic Science Service: three training workshops (3 days each) on *Case Assessment and Interpretation* (G. Jackson and S. McCrossan), *STR interpretation* (I Evett, L. Foreman and S. Pope) and *Drugs interpretation* (G. Booth).
1991-1995	University of Lausanne, Institut de Police Scientifique et de Criminologie (IPSC), Law Faculty; **Ph.D. *summa cum laude* in forensic science** under the direction of Prof. P.-A. Margot. The jury was chaired by Prof. M. Killias (University of Lausanne, Switzerland), with Dr. C. J. Lennard (Australian Federal Police) and Dr. D. A. Stoney (McCrone Institute, Chicago) as external experts. The thesis dealt with computer-assisted analysis of minutiae occurrences in fingerprints.
1992-1993	University of Lausanne, Institut de Police Scientifique et de Criminologie (IPSC), Law Faculty; course on the security of information systems.
1991-1992	Swiss Federal Institute of Technology, Lausanne; courses on probability and statistics.
1986-1990	University of Lausanne, Institut de Police Scientifique et de Criminologie (IPSC); **Master’s degree in Forensic Science and Criminology (with honors)**. Main subjects studied included: Chemistry, Physics, Mathematics, Forensic Techniques (analysis of glass, soil, paints, fibres, paper, inks, questioned documents, forged currency, etc.). Research projects over the two last years were on the application of FTIR microspectrometry and DRIFTS in forensic science.
1983-1986	High School in Neuchâtel; **Baccalaureate** (High School Certificate) with a major in Science (type C).

LANGUAGES AND INFORMATION TECHNOLOGIES

Native French, fluent English (oral and written) and German (reading).
Expert competence in office software, image processing and statistical programming (ImageJ and R).

AWARDS

In 2020, for his service to forensic science and, in particular, to forensic identification techniques, received the Douglas M. Lucas medal of the American Academy of Forensic Sciences.

In 2020, for the paper with Taylor D., C. Champod & L. Samie, Using Bayesian Networks to track DNA movement through complex transfer scenarios, Forensic Science International: Genetics, 2019, 42, 69-80, the award “Best Paper: Capability Enhancement and Innovation” of the Australian National Institute Forensic Science (NIFS).

In 2018, for the paper Taylor D., A. Biedermann, T. Hicks and C. Champod, A template for constructing Bayesian networks in forensic biology cases when considering activity level propositions, Forensic Science International: Genetics, 2018, 33: 136-146, the award “Highly Commended” in a refereed paper of the Australian National Institute Forensic Science (NIFS).

In 2017, for his outstanding contribution to the good of the Profession, received the Henry Medal Award from the Fingerprint Division (formerly The Fingerprint Society) of the Chartered Society of Forensic Sciences (CSFS).

In 2016, for the paper Taylor, D., Abarno D., Hicks T & C. Champod, Evaluating Forensic Biology Results given Source Level Propositions, Forensic Science International: Genetics, 2016, 21; 54-67, the award “Highly Commended” in a refereed paper of the Australian National Institute Forensic Science (NIFS).

In 2015, for his contribution to forensic science, received the *Distinguished ENFSI Scientist award*. ENFSI is the European Network of Forensic Science Institutes.

In 2009, for the paper Buckleton, J., C. Triggs, F. Taroni, C. Champod, and G. Wevers, Experimental Design for Acquiring Relevant Data to Address the Issue of Comparing Consecutively Manufactured Tools and Firearms, *Science and Justice*, 2008, 48: 178-181, the P.W. Allen award for the best paper published in *Science and Justice* in 2008.

In 2005, for the paper Champod, C., I.W. Evett and G. Jackson, Establishing the Most Appropriate Database for Addressing Source Level Propositions, *Science and Justice*, 2004, 44 (3): 153-164, the P.W. Allen award for the best paper published in *Science and Justice* in 2004.

In 1997, for the doctoral dissertation “Reconnaissance automatique et analyse statistique des minuties sur les empreintes digitales” the annual prize from the *Banque Cantonale Vaudoise*. In 1998, for the above dissertation, the first prize “*Fondation Claude Verdan*”.

PROFESSIONAL EXPERIENCE BEFORE JUNE 2003

From October 1999 to May 2003	**Senior forensic scientist** grade A2 for the Forensic Science Service, acting as team member in the interpretation Research Group (R&D), under the direction of Dr. Ian Evett. From January 2001: senior forensic scientist grade A2 for the Forensic Science Service, acting as **project area manager** of the Interpretation Research Group (part of R&D). The position includes managing a research group of 9 scientists and directing research on interpretation issues in various fields among them DNA, trace evidence and mark evidence. The position involves also training commitments internally and externally and acting as an expert witness for Courts in the UK and abroad.
From March 1996 to September 1999	**Assistant Professor** at the Institut de Police Scientifique et de Criminologie (IPSC). Fields of teaching and research include: forensic statistics (56 hours course); fingerprint detection techniques and identification (40 hours course + laboratory exercises); shoemark collection and identification (30 hours: courses and proficiency tests). The position also includes duties in expert appraisal for the following fields: identification, fingerprint detection, glass, paint and fibre analysis, document analysis (toner, ink, signature and typewriter). In a few cases, the evidence was presented in court.
From October 1995 to February 1996	Part-time (30%) **replacement for Professor P.-A. Margot** (in sabbatical) for fingerprint lectures and research at the IPSC.
From October 1994 to February 1996	Held the position of **principal assistant** 50% (thereafter assistant professor) for Professor P.-A. Margot at the IPSC.
From November 1991 to March 1996	Foundation and development of a bureau of **forensic consultants** *Champod & Taroni* CH-2028 Vaumarcus (NE). This service was intended for lawyers and jurists in various fields of forensic science.

	About twenty penal cases were treated in Switzerland and Italy, some with courtroom attendance.
From November 1990 to September 1994	**Research assistant** to Professor P.-A. Margot at the IPSC, including expert appraisal in the following fields: fingerprint detection, glass, paint and fibre analysis, questioned documents analysis (toner, ink, signature and typewriter).

MEMBERSHIP, COOPERATION AND EDITORIAL/SCIENTIFIC RESPONSIBILITIES

Membership

Affiliate member of the *Forensic Science Society* (UK) since 1991.

Life Active member of the *International Association of Identification* (USA), active member since 1991.

Member of the scientific working group on friction ridge skin impressions (SWGFAST - Scientific Working Group on Friction Analysis, Study and Technology) from 2004 to 2014.

Affiliate member of Friction Ridge subcommittee (part of the Physics and Pattern Evidence Scientific Area Committee) of the Organization for Scientific Area Committees (OSAC) since 2014. These committees have been established by the US National Institute of Standard and Technology (NIST) to coordinate development of standards and guidelines for the forensic science community.

Cooperation

Member of the management committee (MC) for Switzerland of two COST (European Cooperation in Science and Technology) actions:

- IC1106: IC1106 Information and Communication Technologies Integrating Biometrics and Forensics for the Digital Age (March 2012 to March 2016).
- CA16101: COST Association MULTI-modal Imaging of FOREnsic SciEnce Evidence - tools for Forensic Science (March 2017 to March 2021).

Editorial activities and scientific review

Member of the Editorial Board of the journal *Law, Probability and Risk (a journal of Reasoning under Uncertainty*) edited by *Oxford University Press* (UK) since 2000.

Member of the Editorial Board of the journal *Science and Justice* official journal of the Forensic Science Society (UK) since from 2001 to 2004 and from 2007 to 2014.

Member of the Editorial Board of *Journal of Forensic Identification* since 2007.

Member of the Editorial Board of *Problemy Kryminalistyki (Forensic Science Issues)* since 2012.

Member of the Editorial Board (as honorary editor-in-chief) of *journal of Forensic Science and Medicine* – A journal published by the Institute of Evidence Law and Forensic Science of the China University of Political Science and Law (China) since 2014.

Member of the Editorial Board (as academic advisor) of *Forensic Science and Technology* – A journal published by the Ministry of Public Security (China) since 2015.

Member of the Editorial Board of Forensic Sciences Research (FSR) – A Taylor and Francis journal published by The Institute of Forensic Science, PRC, Ministry of the Justice, Shanghai, China from 2016 to 2020.

Member of the Committee of the Key laboratory of Forensic Marks Ministry of Public Security (China) between February 2014 until February 2017.

Regular scientific reviewer for *Journal of Forensic Sciences*, *Forensic Science International, Forensic Science International: Genetics* and for international conferences on biometrics (including BTAS, ICB and BIOSIG).

Occasional scientific reviewer for *Psychology, Crime and Law*, *Psychonomic Bulletin Review*, *Science*, *PLOS ONE*, and *PNAS*.

Scientific reviewer for projects submitted to the *US National Institute of Justice* (NIJ): Graduate Research Fellowship Program (2011); Technical Reports (2010); Fundamental Research Solicitation (2009); *The Fingerprint Sourcebook* (2007-2009). In 2012, appointed by the Director of the NIJ as a member of the standing Scientific Review Panel (SRP) on Pattern and Impression Evidence – Applied Research and Development and Basis Scientific Research.

Acted as scientific reviewer for the US National Academies of Sciences of the National Research Council report, *Strengthening Forensic Science in the United States: A Path Forward*. Washington, D.C.: The National Academies Press, 2009.

Acted as section editor (with Dr. T, Hicks) for the interpretation section of *Encyclopedia of Forensic Sciences*. Editors in chief: A. Moenssens and A. Jamieson, London: John Wiley & Sons (2009-2010, 2012).

Acted as section editor for the forensic section of *Encyclopedia of Biometrics*. Editors in chief: S. Z. Li and A. Jain, New York: Springer-Verlag (2009).

Acted as co-editor (with Prof. Massimo Tistarelli) of the book *Handbook of Biometrics for Forensic Science* (New York: Springer-Verlag 2017).

Organization of International Conferences

Co-responsible for the organization of the 18th annual meeting of the ENFSI fingerprint working group (Lausanne, 4-7 September 2018).

Co-director of the NATO Advanced Research Workshop on Identity in the Context of Security (Lausanne, 10-12 July 2018). NATO Grant Number 5356 obtained in collaboration with the UK Home Office.

Co-responsible for the organization of the 3rd International Symposium on Sino Swiss Evidence Science (Hangzhou, 25-27 June 2018).

Co-responsible for the organization of the 2nd International Symposium on Sino Swiss Evidence Science (Lausanne, 6-9 September 2016), with the support of Chinese funding sources and the Swiss National Science Foundation (SNSF Grant no. IZ32Z0_168366).

Responsible for the organization of the 9th annual meeting of the ENFSI marks working group – SPTM2011 (Lausanne, 7-9 September 2011).

Member of the Steering Committee of the *International Fingerprint Research Group*, responsible for the organization of the 7th meeting (Lausanne, 29 June - 3 July 2009).

Member of the scientific committee for the organization of the series of the *International Conference on Forensic Inference and Statistics*, co-responsible for the organization of the 7th meeting (Lausanne, 20-23 August 2008).

Member of the local organizing committee for the first European Meeting of Forensic Science supported by ENFSI (*European Network of Forensic Science Institutes*), Lausanne (16-19 September 1997). Responsibilities: organization, registration, abstracts, scientific program and trade exhibition.

PhD thesis supervision

The following students have finished their PhD under the supervision of the undersigned:

[1] Béatrice Schiffer, *The Relationship between Forensic Science and Judicial Error: A Study Covering Error Sources, Bias, and Remedies*, 2009.

[2] Nicole Egli, *Interpretation of Partial Fingermarks Using an Automated Fingerprint Identification System,* 2009.

[3] Fabiano Riva, *Etude sur la valeur indicielle des traces présentes sur les douilles,* 2011.

[4] Glenn Langenburg, *A Critical Analysis and Study of the ACE-V Process*, 2012.

[5] Sébastien Moret *Application de nanoparticules luminescentes pour la détection de traces papillaires,* 2013.

[6] Isabelle Montani, *Exploring Transparent Approaches to the Authentication of Signatures on Artwork*, 2015.

[7] Ray Palmer, *The Evaluation of Fibre Evidence in the Investigation of Serious Crime*, 2016.

[8] Ka-Man Pun, *Interprétation des profils génétiques obtenus à partir des traces de contact*, 2016.

[9] Austin Hicklin, *Improving the Rigor of the Latent Print Examination Process*, 2016.

[10] Joshua Abraham, *Statistical Models for the Support of Forensic Fingerprint Identifications*, co-supervisor, thesis delivered by the University of Technology Sydney, 2017.

[11] Nicolas Thiburce, *De la valeur de l'expertise en empreinte digitale comme moyen de preuve scientifique en matière pénale*, thèse en co-tutelle avec Jean-Paul Jean de l'Université de Poitiers), 2017.

[12] Julien Pasquier, *Exploitation des traces de semelles dans la lutte contre la délinquance sérielle - Conception et apport d'une banque de données dans le cadre du renseignement forensique,* 2018.

[13] Lydie Samie-Foucart, *Evaluation des résultats ADN considérant des propositions au niveau de l'activité*, 2019.

[14] Heidi Eldridge, Understanding, *Expanding, and Predicting the Suitability Decision in Friction Ridge Analysis*, 2020.

[15] Alexandre Beaudoin, *Faire le pont entre les sciences forensiques et la gestion : indice synthétique d'analyse préacquisition "Forensic Assessment of Technologies Effectiveness" (ForATE) pour les laboratoires de développement des traces*, 2021.

[16] Maëlig Jacquet, *Interprétation des scores de reconnaissance faciale automatique pour l'investigation et le tribunal*, 2021.

OTHER PROFESSIONAL ACTIVITIES

From 2019	Member of the UK Forensics sub-group of the Criminal Justice Board at the invitation of the Rt Hon Robert Buckland Lord Chancellor and Secretary of State for Justice.
From 2016	Member of the UK Home Office Forensic Science Regulator's Fingerprint Quality Standards Specialist Group, chaired by Gary Holcroft (SPA, Scotland).
	"Critical friend" of the Fingerprint Bureau Future Workflow Project, chaired by CC David Shaw, Home Office Biometrics programme (UK).
	Member of the Advisory board of the Master's Forensic Science of the University of Amsterdam.

From 2012	Member of the Academic Committee of the Key Laboratory for Mark Evidence of Ministry of Public Security. Institute of Forensic Science, Ministry of Public Security, Beijing, China.
From November, 2012 – April, 2014	Member of the Working Group on Presenting Forensic Science Evidence Using Quantitative and Qualitative Terms (QQWG) sponsored by the National Institute of Standards and Technology (NIST). Project managed by Prof. D. Kaye, Prof. C. Neumann and Anjali Ranadive (The Pennsylvania State University – PSU).
From 2012	Through a ministerial *mesure nominative* (OCC1204476A), nominated, as international member, on the scientific Council of the *Institut national de police scientifique* (INPS, France).
2008-2012	Member of the Expert Working Group on Human Factors in Latent Print Analysis funded by the National Institute of Standards & Technology Office of Law Enforcement Standards (NIST) and the National Institute of Justice (NIJ).
2008-2009	Member of the Standardization Review II Committee for the IAI (International Association for Identification) under the chairmanship of Ron Smith (2008-2009).
From September 2007	Member of EAFS R&D Committee of the European Network of Forensic Science Institutes (ENFSI).
From October 2004	Through *arrêté préfectoral* (n° 2004-18078), nominated on the scientific Council of the *laboratoire central de la préfecture de police de Paris*.
From 2004	Member of the directorate of the *Groupe de travail intercantonal Police Judiciaire – Police Scientifique* (currently chaired by Com. Nicola Albertini, cantonal police Vaud).
From September 2003	Scientific advisor (correspondant scientifique) for the *Institut de recherche criminelle* of the French Gendarmerie (IRCGN) on the training and casework issues in relation to the interpretation of forensic evidence.
From October 2003	Technical assessor for national accreditation bodies in the application of ISO 17025 in forensic laboratories (fields of fingerprints, toolmarks and footwear marks). Technical audits carried out (roughly every two years) in Finland, Sweden, Norway, Ireland and the Netherlands.
From August 2001 to May 2004	Member of the UK fingerprint working group *Third level detail* under ACPO (chaired by M. Leadbetter).
From July 1997	Member of the *Swiss fingerprint working group* (currently chaired by Axel Glaeser, FedPol). Responsibilities involved organizing and delivering professional training for Swiss fingerprint examiners, more specifically scientific course director of the Swiss level 3 expert course.
From March 1996	Member of the Bureau and the Council of the IPSC/ESC. Member of the Council of the Law Faculty. Member of the local FNRS committee from 1996 to 2012.

Since September 1991 Participated in the preparation and presentation of annual workshops for police officers in various fields of forensic science (microscopy techniques, fingerprint detection techniques preservation and collection of trace evidence). Co-director of the 1996 workshop on *fingerprint detection techniques and identification*. Co-director of the 1998, 2011 and 2015 workshops on *shoemark detection and identification*.

RESEARCH FUNDS AND PUBLICATIONS

Research Funds

In the past 15 years, more than CHF 3.5 million have been obtained for research activities either as principal investigator (PI), co-PI or co-investigator.

Project Title	*Duration*	*Funding body*	*Principal investigator*	*Co-investigator(s)*	*Amount*
Statistical Analysis of Forensic Friction Ridge Matching Criteria	June 2003 May 2005	US Department of Defence (DoD) – Unité TSWG. In collaboration with the Forensic Science Service (UK)	C. Champod		Total : USD 345'602 Contract from FSS for ESC :USD 154'000
Multimodal Biometrics for Identity Documents – Les techniques biométriques appliquées aux documents d'identité (MBioID)	Sept. 2004 Sept. 2006	Fondation Banque Cantonale Vaudoise	C. Champod	A. Drygajlo (EPFL)	CHF 160'000
Cours on-line de photographie scientifique et forensique	Sept. 2004 Sept. 2006	Swiss Virtual Campus and « matching funds » UNIL	C. Champod	S. Süsstrunk (EPFL) R. Gschwind (UNIBA) L. Rosenthaler (UNIBA) P. Etique (EIAJ)	Total : CHF 500'000 CVS : CHF 225'000 EPFL : CHF 25'000 UNIBAS : CHF 58'900 ESC: CHF 191'100
Cours on-line de photographie scientifique et forensique – phase de maintenance de Nicephor[e]	Sept. 2006 Aug. 2007	Swiss Virtual Campus and « matching funds » UNIL	C. Champod	S. Süsstrunk (EPFL) R. Gschwind (UNIBA) P. Etique (HES-ARC)	Total : CHF 128'830 ESC : 108'830
Probabilistic Graphical Models in Forensic Science	Mar. 2004 Mar. 2006	FNRS 100011 - 103795/1	F. Taroni	C. Champod	CHF 79'547
Développement de techniques de révélation d'empreintes digitales basées sur la reconnaissance moléculaire	Oct. 2004 Oct. 2006	FNRS 200021–105580/1	P. Margot	C. Champod	CHF 176'026
Wrongful Conviction	Oct. 2004 Oct. 2006	FNRS 101312-104167/1	M. Killias	C. Champod W. Bär (UniZH)	CHF 250'500
A Topological Model for the Evidential Value Assessment of Partial Fingerprints Design and deployment – TSWG task IS-FE-2478, NIJ contract 2005-IJ-R-051	Nov. 2006 Nov. 2008	US Department of Defence (DoD) – TSWG and National Institute of Justice (NIJ).	C. Champod	–	USD 562'166

Fingerprints : Distortion and data acquisition	Sept. 2004 Sept. 2006	Forensic Science Service (UK)	C. Champod	–	CHF 350'000
ABID 1 et ABID 2 – Applying Biometry to Identity Documents	Sept. 2006 Sept. 2009	FNRS 105211-108294 105211-118049 PhD thesis of M. Espinoza	C. Champod	A Drygajlo (EPFL) B. Cottier (UNISI) G. Domenighetti (UNISI)	Total : CHF 240'000 ESC : CHF 113'000
The forensic use of antibodies for the detection of latent fingermarks	Sept. 2006 Sept. 2009	FNRS 200021-113809 200020_125126/1 PhD thesis of Valérie Drapel	P. Margot	C. Champod A, Bécue	CHF 68'280 CHF 29'135
Digital Ink library	Feb. 2007 Jan. 2009	US Homeland Security ARPA for the US Secret Service	C. Champod	Collaboration with *Camag USA and* C. Neumann	Total : USD 559'135 ESC : USD 276'622
PiAnoS : Picture Annotation System	May 2007 May 2008	UNIL – FID	C. Champod	RISET R. Voisard J. Furrer	CHF 29'445
PiAnoS : Integration with FSS calculator		Forensic Science Service (UK)	C. Champod	T. Genessay	GBP 27'418

Testing for Potential Contextual Bias during the Verification Stage of the ACE-V Methodology When Conducting Latent Print Examinations A Statistical Analysis of the Application of the ACE-V Methodology During Friction Ridge Skin Examinations	2006 and 2009	Midwest Forensics Resource Center	Glenn Langenburg	C. Champod	Funds (about USD 30'000) for the thesis of Glenn Langenburg
Objectivation of Firearm Investigations	Jan. 2010 Jan. 2012	National Forensic Institute (The Netherlands)	C. Champod	F. Riva	EURO 50'000
Collaboration pour la création d'un recueil des procédures standardisées en sciences forensiques	Jan. 2010 Jan. 2012	Concordat des commandants de police RBT	C. Champod	Chefs SIJ RBT	CHF 118'000
Improving the Understanding and the Reliability of the Concept of "Sufficiency" in Friction Ridge Examination, NIJ contract 2010-DN-BX-K267	Mar. 2011 Mar. 2013	US National Institute of Justice (NIJ)	C. Neumann (Pennsylvania State University) C. Champod	T. Genessay G. Langenburg	Total : USD 459'412 Contract from PennState University for ESC : USD 189'100
Strengthening the Evaluation of Forensic Results across Europe (STEOFRAE)	Jan. 2012 Dec. 2014	ENFSI monopoly funds through the European Commission	C. Champod P. Margot	F. Taroni T. Hicks A. Biedermann R. Voisard	EURO 197'948
Innovative technology for Fingerprint Live Scanners (INGRESS) http://www.ingress-project.eu/	Nov. 2013 Apr. 2017	FP7 program of the EU: Grant. Capability project, agreement N°: 312792	C. Champod (for UNIL work packages)	Members of the INGRESS consortium	Total EU contribution: EURO 3'233'782 For UNIL: EURO 232'339

Occurrence and Utility of Latent Print Correspondences Insufficient for Identification, NIJ contract 2016-R2-CX-0060	Jan. 2017 Dec. 2019	US National Institute of Justice (NIJ)	D. Stoney (Stoney forensic, Inc.) C. Champod	Marco De Donno	Total: USD 883'694 Sub-contract from Stoney forensic Inc. for ESC: USD 156'340
Testing the Accuracy and Reliability of Palmar Friction Ridge Comparisons: A Black Box Study, NIJ contract 2017-DN-BX-0170	Jan. 2018 Dec. 2020	US National Institute of Justice (NIJ)	H. Eldridge (RTI international) C. Champod	Marco De Donno	Total: USD 370'454 Sub-contract from RTI for ESC: USD 132'329
Coping with Close Non-Matches in Latent Print Comparison (re-) Training, NIJ contract 2018-DU-BX-0227	Jan. 2019 Mar. 2022	US National Institute of Justice (NIJ)	H. Eldridge (RTI international) C. Champod	Marco De Donno	Sub-contract from RTI for ESC: USD 162'998
Improved Latent Fingerprint Quality Metrics (ILFQMetrics) Support	Feb.2020 Feb 2022	Combating Terrorism Technical Support Office (CTTSO), now the Irregular Warfare Technical Support Directorate (IWTSD).	H. Eldridge (RTI international) C. Champod	Alex Anthonioz Collaboration with IDEMIA	Total: USD 868'853 Sub-contract from RTI for ESC: USD 178'235
Evaluation of the Occurrence and Associative Value of Non-Identifiable Fingermarks on Unfired Ammunition in Handguns for Evidence Supporting Proof of Criminal Possession, Use and Intent15PNIJ-21-GG-04192-RESS	April 2022 April 2024 (to be confirmed)	US National Institute of Justice (NIJ)	D. Stoney (Stoney forensic, Inc.) C. Champod		Total: USD 330'044 Sub-contract from Stoney forensic Inc. for ESC: USD 40'952

Peer-reviewed articles (original publications, submitted papers in italics)

[1] Swofford, H. J. & C. Champod, Probabilistic Reporting and Algorithms in Forensic Science: Stakeholder Perspectives within the American Criminal Justice System, Forensic Science International: Synergy, 2022, 100220, https://doi.org/10.1016/j.fsisyn.2022.100220.

[2] Samie, L., Champod, C., Delémont, S., Basset, P., Hicks, T., & V. Castella. Use of Bayesian Networks for the investigation of the nature of biological material in casework. Forensic Science International, 2022, 111174, https://doi.org/10.1016/j.forsciint.2022.111174.

[3] Attinger, D., De Brabanter, K. & C. Champod, On the use of the Likelihood Ratio in Bloodstain Pattern Analysis, Journal of Forensic Sciences 2021, https://doi.org/10.1111/1556-4029.14899.

[4] Saguy, M., Almog, J., Cohen, D. & C. Champod, Proactive Forensic Science; Biometrics; Presentation Attack Detection; Fingerprint Spoofing; Hydrogels; Polyethylene Glycol, Journal of Forensic Sciences 2021, https://doi/10.1111/1556-4029.14908.

[5] Taylor, D., Volgin, L., Kokshoorn, B. & C. Champod, The importance of considering common sources of unknown DNA when evaluating findings given activity level propositions, Forensic Science International: Genetics 2021, 53, 102518, https://doi.org/10.1016/j.fsigen.2021.102518.

[6] Swofford, H. J. & C. Champod, Implementation of Algorithms in Pattern & Impression Evidence: A Responsible and Practical Roadmap, Forensic Science International: Synergy 2021, 3, 100142, https://doi.org/10.1016/j.fsisyn.2021.100142.

[7] Eldridge, H., De Donno, M. & C. Champod, Predicting suitability of finger marks using machine learning techniques and examiner annotations, Forensic Science International 2021, 320, 110712, https://doi.org/10.1016/j.forsciint.2021.110712.

[8] Swofford, H., Champod, C., Koertner, A., Eldridge, H., & M. J. Salyards, A Method for Measuring the Quality of Friction Skin Impression Evidence: Method Development and Validation, Forensic Science International, 2021, 110703, https://doi.org/10.1016/j.forsciint.2021.110703.

[9] Eldridge, H, De Donno, M. & C. Champod, Testing the Accuracy and Reliability of Palmar Friction Ridge Comparisons – A Black Box Study, Forensic Science International, 2021, 318, 110457, https://doi.org/10.1016/j.forsciint.2020.110457.

[10] Eldridge, H., De Donno, M., Furrer, J. & C. Champod, Mind-set – How bias leads to errors in friction ridge comparisons, Forensic Science International, 2021, 218, 110545, https://doi.org/10.1016/j.forsciint.2020.110545.

[11] Eldridge, H., De Donno, M., Furrer, J. & C. Champod, Examining and expanding the friction ridge value decision, Forensic Science International, 2020, 314, 110408, https://doi.org/10.1016/j.forsciint.2020.110408.

[12] Riva, F., E.J.A.T. Mattijssen, R. Hermson, P. Pieper, W. Kerkhoff, & C. Champod, Comparison and interpretation of impressed marks left by a firearm on cartridge cases – Towards an operational implementation of a likelihood ratio based technique, Forensic Science International Forensic Science International, 2020, 313, 110363, https://doi.org/10.1016/j.forsciint.2020.110363.

[13] Samie L., Champod, C., Taylor, D. & F. Taroni, The use of Bayesian Networks and simulation methods to identify the variables impacting the value of evidence assessed under activity level propositions in stabbing cases, Forensic Science International: Genetics, 2020, 48, 102334, https://doi.org/10.1016/j.fsigen.2020.102334.

[14] Becue, A., Eldridge, H. & C. Champod, Interpol review of fingermarks and other body impressions 2016–2019, Forensic Science International: Synergy, 2020, https://doi.org/10.1016/j.fsisyn.2020.01.013

[15] Stoney, D. A., De Donno, M., Champod, C., Wertheim, P. A. & P. Stoney, Occurrence and Associative Value of Non-Identifiable Fingermarks, Forensic Science International, 2020, 309, 110219, https://doi.org/10.1016/j.forsciint.2020.110219

[16] Jacquet, M. & C. Champod, Automated face recognition in forensic science: Review and perspectives, Forensic Science International, 2020, 307:110124, https://doi.org/10.1016/j.forsciint.2019.110124.

[17] Samie L., Taroni, F. & C. Champod, Estimating the quantity of transferred DNA in primary and secondary transfers, Science and Justice, 2020, 69(2): 128-135.

[18] Hicks T., Biedermann, A., Taroni, F. & C. Champod, Problematic Reporting in DNA Cases: The Need for Accredited Formats and Certified Reporting Competence, Forensic Science International: Genetics Supplement Series, 2019, https://doi.org/10.1016/j.fsigss.2019.09.079

[19] Taylor D., Champod, C. & L. Samie, Using Bayesian Networks to track DNA movement through complex transfer scenarios, Forensic Science International: Genetics, 2019, 42, 69-80.

[20] Cadola, L., Marquis, R. & C, Champod, Le processus d'écriture et la maladie d'Alzheimer: un état de l'art, Canadian Society of Forensic Science Journal, 2019, 52(2): 53–77.

[21] Samie L., Champod C., Glutz V., Garcia M., Castella, V. & F. Taroni, The efficiency of DNA extraction kit and the efficiency of recovery techniques to release DNA using flow cytometry, Science and Justice, 2019, 59. 405-410.

[22] Montani I., Marquis, R., Egli Anthonioz, N. & C. Champod, Resolving differing expert opinions, Science and Justice, 2019, 59: 1-8.

[23] Gittelson, S., C.E.H. Berger, G. Jackson, I.W. Evett, C. Champod, B. Robertson, J.M. Curran, D. Taylor, B.S. Weir, M.D. Coble & J.S. Buckleton, A response to "Likelihood ratio as weight of evidence: A closer look" by Lund and Iyer. Forensic Science International, 2018, 288, e15-e19.

[24] Chen X.H., C. Champod, X. Yang, S-P. Shi, Y.-W. Luoa, N. Wang, Y.C. Wang & Q-M. Lu, Assessment of Signature Handwriting Evidence via Score-based Likelihood Ratio Based on Comparative Measurement of Relevant Dynamic Features, Forensic Science International, 2018, 282: 101-110.

[25] Taylor D., A. Biedermann, T. Hicks and C. Champod, A template for constructing Bayesian networks in forensic biology cases when considering activity level propositions, Forensic Science International: Genetics, 2018, 33: 136-146.

[26] Champod C., Forensic laboratories: is it all about survival? Policing: A Journal of Policy and Practice, 2017, 13(1) 47-54.

[27] Evett I.W., C.E.H. Berger, J. Buckleton, C. Champod & G. Jackson, Finding the Way Forward for Forensic Science in the US – A commentary on the PCAST report, Forensic Science International, 2017, 278: 16-23.

[28] Taylor D., A. Biedermann, L. Samie, K.-M. Pun, T. Hicks and C. Champod, Helping to distinguish primary from secondary transfer events for trace DNA, Forensic Science International: Genetics, 2017, 28: 155-177.

[29] Riva F., Hermsen R., Mattijssen E., Pieper P. and C. Champod, Objective Evaluation of Subclass Characteristics on Breech Face Marks, Journal of Forensic Sciences, 2017, 62(2): 417-422.

[30] Moreillon L., J. Vuille, A. Biedermann & C. Champod, Les nouvelles lignes directrices du *European Network of Forensic Sciences Institutes* en matière d'évaluation et de communication des résultats d'analyses et d'expertises scientifiques, Forumpoenale, 2017, 2: 105-110.

[31] Kerkhoff W., Stoel R.D, Mattijssen E.J.A.T., Hermsen R., Hertzman P., Hazard Ð., Gallidabino M., Hicks T., Champod C., Cartridge Case and Bullet Comparison: examples of evaluative reporting, AFTE Journal, 2017, 49(2): 111-121.

[32] Biedermann A, Champod C. & S. Willis, Development of European Standards for Evaluative Reporting in Forensic Science: The Gap Between Intentions and Perceptions. The International Journal of Evidence & Proof, 2017, 21(1-2):14-29.

[33] Biedermann A., C. Champod, G. Jackson, P. Gill, D. Taylor, J. Butler, N. Morling, T. Hicks, J. Vuille and F. Taroni, Evaluation of forensic DNA traces when propositions of interest relate to activities: analysis and discussion of recurrent concerns, Frontiers Genetics, 2016, 7 (215), doi: 10.3389/fgene.2016.00215.

[34] Taylor D., Hicks T. and C. Champod, Using Sensitivity Analyses in Bayesian Networks to Highlight the Impact of Data Paucity and Direct Future Analyses, Science & Justice, 2016, 56 (5), pp. 402-410.

[35] Marquis R., Biedermann A., Cadola L., Champod C., Gueissaz L., Massonnet G., Taroni F. and T. Hicks, Discussion on Verbal Scales: Pragmatic Proposals to Improve Communication of Probative Value, Science & Justice, 2016, 56 (5), pp. 364-370.

[36] Champod C., Biedermann A., Vuille J., Willis S. and J. De Kinder, ENFSI Guideline for Evaluative Reporting in Forensic Science: A Primer for Legal Practitioners, Criminal Law and Justice Weekly, 2016, 180(10) pp. 189-193, http://www.criminallawandjustice.co.uk/features/ENFSI-Guideline-Evaluative-Reporting-Forensic-Science.

[37] Moret S., Bécue A. and C. Champod, Functionalised Silicon Oxide Nanoparticles for Fingermark Detection, Forensic Science International, 2016, 259, pp. 10-18.

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INTERNATIONAL CONFERENCES ATTENDED AS INVITED/PLENARY/KEYNOTE SPEAKER

2021 USA – online conference, July 9, 2021, C. Champod, Discussion on Error Rates and Black Box Studies (BBS), National Forensic College at the invitation of Julia Leighton and Jennifer Friedman (July 9, 2021).

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2017 Washington DC (USA), January 10, 2017, C. Champod, *Reliable experts in pattern evidence*, National Commission on Forensic Science, Meeting12, Washington DC (January 10-11, 2017). See video of the National Institute of Standards and Technology: National Commission on Forensic Science - Meeting 12, Part 4, https://cdnapisec.kaltura.com/index.php/extwidget/preview/partner_id/684682/uiconf_id/31013851/entry_id/0_j79qncx0/embed/dynamic

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2016 Washington DC (USA), February 14, 2016, C. Champod, The Development of a European Guideline for Evaluative Reporting in Forensic Science, The Annual Meeting of the American Association for the Advancement of Science (AAAS), special session organized by Prof. Alicia Carriquiry (February 11-15, 2016).

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2015 London (UK), February 2, 2014, C. Champod, *Developments in Fingerprint Identification (post 2009 NAS Report)*, Royal Society meeting The Paradigm Shift for UK Forensic Science, organized by Prof. Sue Black and Prof. Niahm Nic Daed (February 2-3, 2014), [paper published in *Philosophical Transactions B* 2015].

Kincardine-on-Forth (Scotland), November 12, 2015, C. Champod, *Forensic Science – the International Dimension*, Lord Advocate’s Cold Case Conference, Scottish Police College, Tulliallan Castle (November 12-13, 2015)

2014 Leiden (The Netherlands), August 20, 2014, C. Champod, *Evaluating DNA Findings at Activity Level: the Contribution of Bayesian Networks and Simulations of Cases*, 9th International Conference on Forensic Inference and Statistics (ICFIS 2014), Leiden University (August 19-22, 2014).

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Shanghai (China), November 9, C. Champod, "*Interpreting and combining various pieces of forensic evidence in complex cases*", Shanghai Forum on Crime Scene Physical Evidence Technology (November 8-9, 2011).

2010 Paris (France), March 25, 2010, C. Champod, *Interpretation of Conflicting Evidence: New Tools for the SIO*, CEPOL (European Police College) Course 5/2010 – Forensic sciences against terrorism (March 22-26, 2010).

Newcastle (UK), June 8, 2010, C. Champod, *The perspective of a European forensic scientist*, Forensic Science in the 2010s: How to Survive a Difficult Decade, Inaugural Conference of the Centre for Forensic Science, Northumbria University (June 8, 2010).

Clearwater (Florida), C. Champod, *Probabilities, decision making and individualization* (workshop), *The Use of Probabilistic Networks in the Area of Fingerprints*, NIJ Impression and Pattern Evidence Symposium, (August 2-5, 2010).

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2009 Denver (USA), February 19, 2009, C. Champod, *From Statistics to Individualization ?*, invited speaker for a panel session on individualization, 61st Annual Scientific Meeting of the American Academy of Forensic Sciences (February 16-21, 2009).

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Istanbul (Turkey), October 23, 2009, C. Champod, *Basic Techniques for Detecting and Avoiding Forgeries*, Séminaire Commission des Affaires Européennes, Union International du Notariat.

2008 Lyons (France), October 15, 2008, C. Champod, *Les enjeux et les spécificités de l'intégration de la preuve scientifique dans le domaine penal*, Seminar "Scientific proof in criminal justice", organised by the French presidency of UE (October 15-16, 2008).

Wyboston (UK), November 1 and November 2, 2008, C. Champod, *Evaluating Fingerprint Evidence*; C. Champod & I. Evett, *Case Study – From Statistics to Individualisation*, AGM and Autumn Conference of the Forensic Science Society, *Research, Evaluation & Interpretation* (October 31 – November 2, 2008).

2007 Montréal (Québec, Canada), July 20, 2007, C. Champod, *Towards a Statistical Approach in Fingerprint Examination*, Annual Educational Conference of the Canadian Identification Society (July 15-20, 2007).

2006 Helsinki (Finland), June 14, 2006, C. Champod, *Is it Time for Fingerprint Evidence to Adopt the DNA Paradigm?,* Fourth European Academy of Forensic Science Meeting EAFS2006 (June 13-16, 2006).

2005 London (UK), April 14, 2005, participation to a round table on "is fingerprint evidence a Science", Human Identification E-Symposium (http://www.humid.e-symposium.com/).

Madrid (Spain), November 25, 2005, C. Champod, *Valoracion de la fuerza de la evidencia*, La Investigacion criminalistica – presente y futuro, Instituto Universitario de Investigacion sobre Seguridad Interior (November 24-25, 2005).

Heidelberg (Germany), October 29, 2005, participation to a panel discussion on science and technology of identification, 6th EMBO-EMBL joint conference on science and society (October 28-29, 2006).

2004 Washington DC (USA), October 24, 2004, C. Neumann, R. Puch-Solis, A. Bromage-Griffiths, C. Champod, N. Egli, A. Anthonioz, *Statistical Analysis of Forensic Friction Ridge Matching Criteria*. US Secret Service, Washington DC.

Crystal City (USA), October 26, 2004, C. Champod, *Review of the Statistical Models for Assessing Fingerprint Evidence*, NIJ Fingerprint Research Advisory Panel, Arlington, VA, USA (October 26-27, 2004).

2003 Wiesbaden (Germany), March 27, 2003, C. Champod, *Standard and Statistics in Fingerprint Identification*, 100 Jahre Daktyloscopie in Deutschland – Symposium für dactyloskopische Sachverständige (March 26-27, 2003).

Bologne (Italy), September 23, 2003, C. Champod, The Use of Bayesian Networks in Forensic Science Casework, CLADAG 2003, meeting of the Classification and Data Analysis Group of the Italian Statistical Society (September 22-24, 2003).

2002 Stockholm (Sweden) /Helsinki, (Finland), February 5, 2002, C. Champod, *Fingerprint identification, numerical standard and statistics*, First Conference of the Scandinavian fingerprint experts (February, 5-7, 2002).

Cardiff (UK), March 8, 2002, C. Champod, *The contribution of statistics to fingerprint identification,* Fingerprint Society Annual Meeting (March 8-10, 2001).

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2001 Edinburgh (UK), March 9, 2001, C. Champod, *Bayesian Networks for Interpreting Trace Evidence*, Fibre, Glass and Paint Conference (March 9-10, 2001).

London (UK), April 10, 2001, C. Champod, *The Evidential Use of DNA*, Joint meeting under the umbrella of the Expert Witness Institute and the Forensic Science Society and the CRFP.

Paris (France), September 20, 2001, C. Champod, *Some Issues in Fingerprint Evidence Interpretation*, 1st meeting of the ENFSI fingerprint working group (September 19-21, 2001).

2000 Dublin (Ireland), May 4, 2000, C. Champod and I. W. Evett, *A Probabilistic Approach to Fingerprint Evidence*, Forensic Science: From Crime Science to Court Room (May 3-5, 2000).

1999 Zürich (Switzerland), June 10, 1999, C. Champod, A Bayesian approach for interpreting two case scenarios, 7th European Fibres Group Meeting (June 9-11, 1999).

London (UK), October 26, 1999, C. Champod, *The Inference of Identity of Source*, First International Conference on Forensic Human Identification in the Millennium. (October 24-26, 1999) [proceedings].

1998 Avignon (France), April 22, 1998, Ch. Champod and D. Meuwly, *The Inference of Identity in Forensic Speaker Recognition*, Colloque RLA2C "la reconnaissance du locuteur et ses applications commerciales et criminalistiques" (20-23 April) [proceedings].

Avignon (France), April 22, 1998, *The Deontological Aspects of Speaker Recognition for Forensic Applications (panel session)*, Colloque RLA2C "la reconnaissance du locuteur et ses applications commerciales et criminalistiques" (20-23 April).

Kincardine-on-Forth (Scotland), July 22, 1998, Ch. Champod, F. Taroni and P.-A. Margot, *The Dreyfus Case – An Early Debate on Conclusions*, Joint meeting of the European Conferences for Police and Government Handwriting Experts and Documents Experts (22-24 July).

1995 Bramshill (Hampshire, UK), November 14, 1995, C. Champod, *The Future of Dactyloscopy – A Researcher's Point of View*, National Fingerprint Conference.

MEETINGS & PRESENTATIONS

2020 Anaheim (USA), February 21, 2020, H. Eldridge, M. De Donno and C. Champod, *Testing the Accuracy and Reliability of Palmar Friction Ridge Comparisons: a Black Box,* 72nd Annual Meeting of the American Academy of Forensic Sciences, February 17-22, 2020.

2019 Sheffield (UK), June 25, 2019, three papers (one as presenter) given at the 12th biennial meeting of the International Fingerprint Research Group IFRG (June 24-28, 2019):

H. Eldridge, M. De Donno and C. Champod, *Testing the Accuracy and Reliability of Palmar Friction Ridge Comparisons: a Black Box Study.*

H. Eldridge, M. De Donno and C. Champod, *A Consensus-based Approach to Reducing Variability in Suitability Determinations using a Hybrid Examiner-Automation Model.*

G. Langenburg, C. Champod and M. De Donno, *An End-User Validation of the UNIL PiAnoS-Based Likelihood Ratio Model.*

Baltimore (USA), two papers given at the 71st Annual Meeting of the American Academy of Forensic Sciences, February 18-23, 2019:

M. De Donno, C. Champod, D. Stoney & P. Stoney, *Assessing the Expected Weight of Evidence for a Latent Print (Fingermark) That Is Insufficient for Identification and Without Reference to a Putative Source*,

D. Stoney, M. De Donno, C. Champod, P. Stoney, *The Associative Value of Latent Print Correspondences That Are Insufficient for Identification.*

2018 Arlington (USA), D. Stoney, P. Stoney, C. Champod, M. De Donno, Occurrence and Utility of Latent Print Correspondences that are Insufficient for Identification, Impression, Pattern and Trace Evidence Symposium, 22–25 January 2018.

Seattle (USA), February 23, 2018, L. Samie, C. Champod & F. Taroni, *Evaluation of DNA Results Considering Propositions at the Activity Level*, paper presented at the 70th Annual Meeting of the American Academy of Forensic Sciences (February 19-24, 2018).

Hangzhou (China), June 25, 2018, C. Champod, *The expert, the court and the quest for certainty*, 3rd International Symposium on Sino-Swiss Evidence Science (June 25-27, 2018).

Lyon (France) at 8th European Academy of Forensic Science Conference (August 27-31, 2018), the following two contributions:

- Oral presentation August 29, 2018: M. De Donno, C. Champod, D. Stoney, P. Stoney, *Occurrence and Utility of Latent Print Correspondences that are Insufficient for Identification.*
- ePoster presentation: T. Hicks, A. Biedermann, C. Champod, D. Monti, C. El Bez & F. Taroni, MOOC: Challenging forensic science; how science should speak to court.

Copenhagen (Denmark), October 4th, G. Gobat, D. Werner, M. De Donno, D. Rhumorbarbe, C. Champod, *Use of the Automatic Ballistic Identification System Evofinder® to evaluate forensic cases*, 25th Annual Meeting of the ENFSI Firearms and GSR working group – Copenhagen, October 3th -5th 2018.

Geneva (Switzerland), October 8, 2018, C. Champod, Sources ou Activités, Conférence "*L'ADN: la reine des preuves ?*" organisée par la Commission de droit pénal de l'Ordre des avocats de Genève.

2017 Paris (France), September 13, 2017, M. De Donno, C. Champod, D. Stoney and P. Stoney, *Assessing the expected associative value of fingermarks deemed of "no value" using a score-based likelihood ratio*, ENFSI fingerprint working group annual meeting (September 13–15, 2017). Also presented in Beijing (China) at the 11th IFRG meeting.

Beijing (China), October 18, 2017, two papers (one as presenter) given at the 11th biennial meeting of the International Fingerprint Research Group IFRG (October 16-20, 2017):

J. Haller, C. Grisoni, M. De Donno, and C. Champod, *Minutiae differences between palmar and finger deltas from right and left hands.*

H. Eldridge, and C. Champod, *Assessing and reducing variability in friction ridge suitability determinations.*

2016 Las Vegas (USA), Ka-Man Pun & C. Champod, Using Bayesian Networks for the Interpretation of Low-Template DNA Profiles considering Activity Level propositions, 68th Annual Scientific Meeting of the American Academy of Forensic Sciences (February 22-27, 2016).

Limassol (Cyprus), March 3, 2016, R. Haraksim, A. Anthonioz, C. Champod, M. Olsen, J. Ellingsgaard, C. Busch, Altered Fingerprint Detection – Algorithmic Performance Evaluation, 4th International Workshop on Biometric and Forensics (IWBF 2016) (March 3-4, 2016) [Proceedings].

Ispra (Italy), May 31, 2016, C. Champod and F. Bochet, *Specific Q-metrics for fingermarks*, Workshop on Fingerprint Quality in the context of SIS-II, Joint Research Centre (May 30-31, 2016).

Lyons (France), October 20, 2016, C. Champod and A. Bécue, *Fingermarks and other Impressions – A Review (July 2013–July 2016),* 18th International Forensic Science Manager Symposium (October 11-13, 2016). [Proceedings].

2015 Patiala (India), three papers (one as presenter) given at the 10th biennial meeting of the International Fingerprint Research Group IFRG (October 19-23, 2015):

M. De Donno, N. Egli Anthonioz, A. Anthonioz, C. Champod, M. Andersson, M. Helgesson, G. Kidfelt, and B. Rasmusson, *Towards an operational deployment of a LR-based model to assist fingerprint examination.*

J. Abraham, C. Champod, C. Lennard, and C. Roux, *Modelling the Variability of Minutiae using Statistical Analysis to Calculate Likelihood Ratios for Multiple Suspect Case Scenarios*.

S. Liu and C. Champod, *Study on accuracy of judgments by Chinese fingerprint examiners*.

2013 Washington DC (USA), C. Neumann, C. Champod, M.Yoo, G. Langenburg and T. Genessay, *Understanding the concept of 'sufficiency' in friction ridge examination*, 65st Annual Scientific Meeting of the American Academy of Forensic Sciences (February 18-23, 2013). Paper also presented in Providence (Rhode Island, USA), at the 98st Annual Educational Conference of the International Association for Identification (August 4-8, 2013) and at the 2014 NIJ grantees meeting held at the American Academy of Forensic Sciences in Seattle (WA, USA) on February 18, 2014.

Jerusalem (Israel), two papers given at the 9th biennial meeting of the International Fingerprint Research Group IFRG (June 10-14, 2013):

C. Champod, C. Neumann, M. Yoo, G. Langenburg and T. Genessay *An inquiry into the concept of "sufficiency" in fingerprint ridge examination*.

F. Bochet and C. Champod, *The use of an AFIS lights-out system to optimize the workflow of friction ridge skin marks and provide early intelligence.*

Lyons (France), October 10, 2013, N. Egli, S. Moret, A. Bécue and C. Champod, *Fingermarks and other Impressions – A Review (August 2010 – June 2013)*, 17th International Forensic Science Manager Symposium (October 8-10, 2013) [Proceedings].

2011 Chicago (USA), February 25, 2011, J. Vuille & C. Champod, *Relevant, Reliable, and Valid Forensic Science in Continental Europe Criminal Justice Systems*, 63rd Annual Scientific Meeting of the American Academy of Forensic Sciences (February 21-26, 2011).

Telford (UK), April 9th, 2011, N. Egli, C. Champod, G. Kidfelt & M. Helgesson, *An Evaluative Model Based on AFIS Scores and Casework Comparisons – Issues, Solutions and Performance*, 2011 Annual Education Conference of the Fingerprint Society, University of Wolverhampton (April 8-11, 2011).

Linköping (Sweden), two papers given at the 7th biennial meeting of the International Fingerprint Research Group IFRG (June 13-17, 2011):

A. Rand Topper Jr. & C. Champod, *A Statistical Analysis of Minutiae on Prints Obtained from the Papillary Surfaces of Intermediate Phalanges*.

C. Geissbühler, N. Egli, T. Genessay & C. Champod, *Development of a Set of Objective Criteria and a Method for Finding Close Non-Matches after a Search on an AFIS System*.

2010 Spokane (WA, USA), G. Langenburg, C. Champod, T. Genessay, J. Jones, *Informing the Judgments of Fingerprint Analysts Using Quality Metric and Statistical Assessment Tools*, 95nd Annual Educational Conference of the International Association for Identification (July 11-17, 2010).

Delft (The Netherlands), C. Champod, *Identification workshop with PiAnoS* (workshop), *The Use of Probabilistic Networks in the Area of Fingerprints* (paper), 10th ENFSI European Fingerprint Working Group Annual Meeting (September 22-24, 2010).

Lyons (France), October 6, 2010, A. Bécue, N. Egli, C. Champod & P.-A. Margot, *Fingermarks and other Impressions Left by the Human Body – A Review (August 2007–July 2010)*, 16th Interpol Forensic Science Symposium, (October 5-8, 2010) [Proceedings].

2009 Virginia beach (USA), C. Champod and A. Anthonioz, *Statistical Assessment of Latent Print Evidence (level 1, 2 and 3)*, Chesapeake Bay Division of the IAI Educational Conference (March 29, 2009 – April 03, 2009).

2008 Madrid (Spain), F. Riva, D. Dörig, D. Sulca, G. Marti and C. Champod, *Development of a Prototype to Generate 2D Standards from Shoe Soles using 3D Scanning Technology*, Annual meeting of the ENFSI SPTM working group, May, 2008.

Lyons (France), June 6, 2008, N. M. Egli, C. Champod and P. Margot, *Evidence Evaluation in Fingerprint Comparison using AFIS*, Interpol 5th International Symposium on Fingerprints – From Crime Scene to International Searching, June 4-6, 2008.

Lausanne (Switzerland), I. Arsic, C. Dauly, A. Anthonioz, C. Champod and D. Ashbaugh, *Computing Likelihood Ratios for Partial Fingerprints Using a Hierarchical System of Matches*, The 7th International Conference on Forensic Inference and Statistics, August 20-23, 2008.

Split (Croatia), N. Thiburce, A. Bécue and C. Champod, *Design of Control Sample for Cyanoacrylate Polymerisation, Its Application to the Cyanoacrylate / Bluestar® Sequence*, European Fingerprint Working Group –8th Annual Meeting, 16 -19 September, 2008 –Split –Croatia.

2007 Canberra (Australia) (two as presenter) given at the 6th biennial meeting of the International Fingerprint Research Group (IFRG) (April 26-30, 2007):

April 27, 2007, E. Stauffer, A. Bécue, C. Champod and P. Margot, *Luminescent nanoparticles based on semiconductors – Synthesis and application to fingermarks detection*.

April 28, 2007, A. Bécue, E. Stauffer, C. Champod and P. Margot, *Use of gold nanoparticles for latent fingermarks detection*.

April 29, 2007, N. Egli, C. Champod and P. Margot, *Evidence Evaluation in Fingerprint Comparison using AFIS: Reducing the number of marks to be acquired*.

April 29, 2007, C. Champod, A. Anthonioz, R. Rozsnyo, I. Arsic, C. Comment and D. Ashbaugh, *A topological approach to assess the evidential contribution of partial fingerprints*.

Madrid (Spain), G. Massonnet, P. Buzzini, R. Voisard, J. Curchod, S. Hafsi, C. Champod, J. Furrer, *On-line course on microscopy: Swiss Virtual Campus CVS*, ENFSI European Fibre Group meeting, Madrid (June 6-8, 2007).

San Diego (USA) at the 92nd Annual Educational Conference of the International Association for Identification (July 23-27, 2007):

July 24, 2007, C. Champod, A. Anthonioz, R. Rozsnyo, I. Arsic, F. Bochet and D. Ashbaugh, *A Topological Approach to Assess the Evidential Contribution of Partial Fingerprints*.

July 24, 2007, C. Champod, *The Use of Statistics in Fingerprint Evaluation – Likelihood ratios made easy.*

Lyons (France), October 26, 2007, A. Bécue, C. Champod & P.-A. Margot, *Fingermarks, Bitemarks and other Impressions (Barefoot, Ears, Lips) – A Review (September 2004 – July 2007)*, 15th International Forensic Science Symposium (October 22-26, 2007) [Proceedings, review].

2006 Helsinki (Finland), Fourth European Academy of Forensic Science Meeting EAFS06, June 13-16, 2006:

N. Egli, C. Champod, and P. Margot, *Evidence Evaluation in Fingerprint Comparison and Automated Identification Systems – Modelling Within Finger Variability* [Paper].

R. Voisard, C. Champod, J. Furrer, J. Curchod, A. Vautier, G. Massonnet, P. Buzzini, *Nicephor[e]: A Web Based Solution for Teaching Forensic and Scientific Photography* [Paper].

A. Anthonioz, N. Egli, C. Champod, R. Puch-Solis,C. Neumann, A. Bromage-Griffiths, *What are level 3 characteristics and their role in fingerprint identification? A survey among practitioners* [Poster].

D. Dessimoz, J. Richiardi, C. Champod and A. Drygajlo, *Multimodal Biometrics for Identity Documents (MBioID)* [Poster, Paper].

B. Schiffer and C. Champod, *Experimental Research on the Possible (Negative) Impact of Observational Biases in the Analysis Stage of Fingermark Individualisation* [Poster, Paper].

A. Bécue, C. Champod and P. Margot, *Use of Gold Nanoparticles as Molecular Intermediates for the Detection of Fingermarks* [Poster].

S. Mizrahi, P. Esseiva, R. Voisard and C. Champod, *Forensic Images Management Using Metadata* [Poster].

C. Albrecht, R. Coquoz, S. Birrer, C. Champod and P. Margot, *LCN Analysis in Forensic Genetics: Study of the Success Rate on Different Surfaces* [Poster].

Boston (USA), July 3, 2006, C. Neumann, P. Chamberlain and C. Champod, *Facing the Coming Paradigm Shift in Fingerprint Identification*, The International Association for Identification's 91st International Educational Conference, Boston MA (July 2-7, 2006).

2005 Arizona (USA), March 2005, C. Neumann, R. Puch-Solis, A. Bromage-Griffiths, C. Champod, N. Egli, A. Anthonioz, *Statistical Evidential Assessment of Partial Fingerprints*, the Sixth International conference on Forensic Statistics, Arizona State University, USA (March 11-19, 2005).

The Hague (The Netherlands), April 14, 2005, two papers (one as presenter) given at the 5th biennial meeting of the International Fingerprint Research Group (IFRG), The Hague, The Netherlands (April 11-15, 2005).

C. Neumann, R. Puch-Solis, A. Bromage-Griffiths, C. Champod, N. Egli, A. Anthonioz, *Statistical Evidential Assessment of Partial Fingerprints*.

C. Champod and N. Egli, *Computing likelihood ratios for partial fingermarks using AFIS technology: A proof of Concept*.

Leipzig (Germany), June 26. 2005, J.E. Spangenberg, G. Pierrini, C. Champod and F. Taroni, *Stable Isotopes as Expert Witness in Traffic Accidents: Assessing the Likelihood between Forensic Samples of Motor Oils*, Meeting of the European Society of Isotope Research – ESIR 8 (June 25-30, 2005).

Hong-Kong (China), August 24, 2005, F. Taroni, S. Bozza, M. Bernard and C. Champod, *The value of DNA tests: a decision perspective*, 17th Meeting of the International Association of Forensic Sciences (IAFS05) (August 21-28, 2005).

Luzern (Switzerland), September 26, 2005, N. Egli and C. Champod, *Fingerprints evidence and automated fingerprint identification systems (AFIS)*, Conference Biometrics – Technology and Societal Impacts held under the auspice of the Swiss Standardization Association (September 26-27, 2005).

2004 Amsterdam (The Netherlands) 4th Annual Conference of the European Society of Criminology/ (ESC), 25-28 August 2004:

B. Schiffer and C. Champod, *Judicial Error and Forensic Science: Pondering the Contribution of (DNA) Evidence* [Proceedings].

M. Killias, C. Champod and B. Schiffer, *The Quality of Forensic Evidence and Wrongful Convictions: The American and European Experience compared.*

Tallinn (Ostonia), N. Egli, A. Anthonioz, C. Champod, A. Bromage-Griffiths, D. Meuwly, C. Neumann & R. Puch, *Minutia Type Assessment – The reliability of the examiner,* IV annual meeting of the ENFSI fingerprint working group (September 22-24, 2004).

Lyons (France), October 19, 2004, C. Champod, N. Egli & P.-A. Margot, *Fingermarls, Shoesole and Footprint Impressions, Tire Impressions, Ear Impressions, Toolmarks, Lipmarks, Bitemarks – A Review (Sept 2001 – Aug 2004)*, 14th International Forensic Science Symposium (October 19-22, 2004) [Proceedings, review].

2001 Berlin (Germany), G. Jackson, C. Champod, & I. W. Evett, *Principles of Interpretation: Application of the Likelihood Ratio in Marks Cases*, Fourth European Meeting for Shoeprint/Toolmark Examiners (May 15-18, 2001) [proceedings].

2000 Krakow (Poland), Second European Academy of Forensic Science Meeting, September 12-16, 2000:

C. Champod, I. W. Evett, G. Jackson, S. McCrossan, R. Bates, R. Puch and J. Q. Smith, *An Expert System for Fibres Interpretation.*

I. W. Evett, G. Jackson, S. McCrossan and C. Champod, *The Principles of Evidence Interpretation.*

I. W. Evett, C. Champod, G. Jackson and J. Birkett, *Reporting Conventions.*

A. Anthonioz and C. Champod, *Frequencies of Minutiæ on the Soles of Japanese Monozygotic Twins.*

1999 Stockholm (Sweden), A. Girod, R. Voisard and C. Champod, *A Statistical Study of Air Bubbles on Athletic Shoesoles*, Third European Meeting for Shoeprint/toolmark Examiners (June 1-4, 1999).

Brussels (Belgium), D. Léonard, G. Stauffer, N. Xanthopoulos, C. Champod and H. J. Mathieu, *Characterisation by ToF-SIMS and Auger of Fingermarks Revealed by Vacuum Metal Deposition*. SIMS XII, September 5-10, 1999, [poster session and proceedings].

1998 Dundee (UK), G. Massonnet, M. Schiesser and C. Champod, *Population of Textile Fibres on White T-Shirts*, Sixth meeting of the European Fibres Group (11-12 June 1988) [proceedings].

Lyons, Interpol Headquarters (France), C. Champod and P. Margot, Fingermarks, Shoesole Impressions, Ear Impressions and Toolmarks – A Review (Sept. 95 – Aug. 98), 12th International Forensic Science Symposium (20-23 October 1988) [proceedings, review].

1997 Lausanne (Switzerland), First European Meeting of Forensic Science (16-19 September 1997):

F. Wehrli, C. Champod et B. Schnetz, *An Inquiry into the Nature of Physical Developer for Revealing Fingerprints*.

E. Ertan et C. Champod, *Setting a Standard for the Evaluation of the Cyanoacrylate Fingerprint Development Procedure* [poster session].

A. Anthonioz et C. Champod, *Amino-acids Reactivity to DFO and Two New Indanediones* [poster session].

C. Champod et F. Taroni, *Evaluation of Cross-Transfer and the Consideration of Missing Evidence.*

C. Champod, A. Girod et M. Sjerps, *The Meaning of Conclusions in the Context of Identification.*

1996 Edinburgh (UK), C. Champod, F. Taroni & P.-A. Margot, *Were Earlier Criminalists Pioneers of Bayesianism in Forensic Science?*, Third International Conference on Forensic Statistics (30 June - 2 July 1996).

Tokyo (Japan), C. Champod & P.-A. Margot, *Analysis of Minutiae Occurrences on Fingerprints – The Search for Non-combined Minutiae*, Meeting of the International Association of Forensic Sciences (IAFS) (25-29 August 1996) [proceedings].

London (UK), W. Mazzella & C. Champod, *A Computer Assisted Examination of Typewritten Documents*, 6th European Conference for Police and Government Document Experts (3 October 1996) [poster session].

1995 Lausanne (Switzerland), December 7, 1995, C. Champod, *Réflexion sur l'identification par les empreintes digitales* (Thoughts on Identification by Fingerprints), Seminar for the Institute of Forensic Medicine, University of Lausanne.

Lyons, Interpol Headquarters (France), 11th Interpol Forensic Science Symposium (20-24 November 1995):

P.-A. Margot & C. Champod, *Traces et empreintes* (Marks and Impressions), [proceedings, review].

P.-A. Margot & C. Champod, *Formation en sciences forensiques – en quête de Qualité* (Forensic Science Education - In Search of Quality) [panel session].

C. Champod & P.-A. Margot, *Analysis of Minutiae Occurrences in Fingerprints* [poster].

O. Delémont, C. Champod & P.-A. Margot, *Test Strips for Fingerprint Reagents for Porous Surfaces* [poster session].

Paris (France), October 2, 1995, C. Champod, *The Identification Value of the Fingerprint*, The Morpho Users' Group Annual Conference, SAGEM.

Ne'urim (Israel), June 29, 1995, C. Champod & P. Margot, *Computer-Assisted Analysis of Minutiae Occurrences in Fingerprints*, International Symposium on Fingerprint Detection and Identification [proceedings].

Lausanne (Switzerland), November 7, 1995, C. Champod, *L'historique de l'identification* (The History of Identification), special course for the Vaud Society of Natural Sciences on new forensic identification techniques.

1994 Lausanne (Switzerland), April 21, 1994, C. Champod, *Locard et la règle des douze points* (Locard and the 12-Point Rule), public seminar presented at the IPSC.

Padova (Italy), June 8, 1994, F. Taroni & C. Champod, *L'indagine dattiloscopica e risvolti processuali*, Convegno studio sull'attività scientifica-forense nell'indagine di polizia giudiziaria.

1993 Düsseldorf (Germany), August 23, 1993, Meeting of the International Association of Forensic Sciences (IAFS):

C. Champod, C. Lennard & V. Tristan Rochaix, *The Detection and Identification of Denatured Alcohol in Fire Debris Samples*, [proceedings].

C. Champod, *Locard's Concepts of Identification Through the Tempestuous History of Dactyloscopy*.

1991 Lyons (France), Interpol Headquarters (France), 2- 4 May, 1991, P.-A. Margot & C. Champod, *Fingerprint Identification: Is There a Need of an European Standard?* Meeting of the Forensic Science Society.

LECTURES AND WORKSHOPS GIVEN IN EDUCATIONAL FORUMS (apart from the lectures or continuous education programs given at the University of Lausanne and for the Forensic Science Service)

Regular invited contributor (from 1996 to 2011) to the annual course on forensic science organised by the Ecole Nationale de la Magistrature held in Paris and the Diplôme Universitaire « Coordinateur des opérations de criminalistique » (DU COCrim). The lectures were dealing with evidence interpretation, the role of the expert witness and identification evidence. Regular (about once a year since 2003) invited scientific advisor and trainer to the Institut de Recherche Criminelle de la Gendarmerie Nationale (IRCGN), running day-workshops on interpretation issues with all units of the IRCGN.

2019 Montreux (Switzerland), J. Vuille & C. Champod, Expertise ADN, *Empreintes et Signatures, une panacée qui aurait ses limites ?*, Cours de perfectionnement de la Société Suisse de droit pénal (section latine). 7 novembre 2019 (demi journée).

2018 Beijing (China), C. Champod, 2-day workshop on *Advanced fingerprint interpretation techniques*, Forensic Science Institute, Ministry of Public Security (June 21-22, 2018).

Lyon (France) and Lausanne (Switzerland), 1-day workshop on *Fingerprints and probabilities* (with G. Langenburg, M. De Donno, A. Biedermann) respectively during the 8th European Academy of Forensic Science Conference (August 27-31, 2018) and the 18th annual meeting of the ENFSI fingerprint working group (Lausanne, 4-7 September 2018).

Nottingham (UK), C. Champod and M. De Donno, 3-day workshop on *Fingerprints and Probabilities*, East Midlands Special Operations Unit- Forensic Services (EMSOU-FS) (November 28-30, 2018).

2017 Rome & Parma (Italy), C. Champod and F. Taroni, *Introduzione all'inferenza probabilistica e valutazione della 'prova' del DNA'*, Roma, 2-day workshop for the reporting officers of the Italian Carabinieri forensic science unit (January 16-17 & February 6-7, 2017).

2016 Beijing (China), C. Champod and A. Girod, *Advanced Footwear Marks Examination*, 5-day workshop for the forensic scientists of the Beijing Forensic Science Institution (January 18-22, 2016).

Shenyang (China), C. Champod and R. Marquis, *Interpretation of questioned documents*, 3-day workshop for the forensic scientists of the National Police University (October 24-26, 2016).

2015 Linköping (Sweden), C. Champod and T. Hicks, *Workshop on reporting DNA findings given activity level propositions*, 2-day workshop for the DNA reporting scientists of the NFC-National Forensic Centre of Sweden (November 16-17, 2015).

2014 Dublin (Ireland), C. Champod & T. Hicks, *Workshop: Reporting DNA findings given activity level propositions*, 2-day workshop for the DNA reporting officers of the Forensic Science Laboratory, Dublin (January 30-31, 2014).

Adelaide (Australia), C. Champod & T. Hicks, Exploring ways to report DNA Findings given activity level propositions1-day workshop delivered in the context of the 22nd ANZFSS International Symposium Conference on Forensic Sciences, (August 30, 2014).

2013 and 2014 Beijing (China), C. Champod, 36 hours course: *Towards a logical framework for the evaluation of forensic findings*, Summer School of the China University of Political Science and Law (CUPL), MSc level. Including lectures given at CUPL and the Forensic Science Institute of Beijing.

2011 Linköping (Sweden), C. Champod and F. Taroni, *Workshop on evidence evaluation with Bayesian networks*, 2-day workshop for the Forensic Advisors of the SKL-National Forensic Laboratory of Sweden (March 24-25, 2011).

2010 Linköping (Sweden), C. Champod and F. Taroni, *Workshop on Evidence Interpretation - Advanced topics*, 2-day workshop for the Forensic Advisors of the SKL-National Forensic Laboratory of Sweden (January 26-27, 2010).

The Hague (The Netherlands, C. Champod and F Taroni, *Workshop on Case Assessment and Interpretation*, 3-day workshop for Forensic Advisors of the National Forensic Institute (September 15-17, 2010).

2009 Brussels (Belgium), C. Champod and F. Taroni, *Interpreting Scientific Evidence*, a 4-day workshop for reporting officers of the National Laboratory of Criminalistics and Criminology (January 26-30, 2009).

Virginia Beach (USA), C. Champod and A. Anthonioz, *Introduction to Software for Assessing Likelihood Ratios for Latent Print Identifications*, 2 times ½ day workshop delivered at the Chesapeake Bay Division of the IAI Educational Conference (March 29, 2009 – April 03, 2009).

Nokesville (Prince William County Police Training Academy, VA, USA), C. Champod, *Fingerprint and Statistics*, a 5-day workshop delivered to FBI latent print examiners (July 13-17, 2009).

2008 Montréal (Québec, Canada), C. Champod and F. Taroni, *Interpreting Complex DNA evidence,* 4-day workshop for the DNA reporting officers of the Laboratoire de Sciences Judiciaires et de Médecine Légale (June 16-20, 2008).

2007 Linköping (Sweden), C. Champod, *Case Assessment and Interpretation*, 3-day workshop for the reporting officers of the SKL-National Forensic Laboratory of Sweden (April 15-18, 2007).

San Diego (USA) G. Langenburg, P. Chamberlain, C. Champod and C. Neumann, *Workshop on fingerprint statistics*. 2 times ½ day workshop delivered at the 92nd Annual Educational Conference of the International Association for Identification (July 25-26, 2007).

2006 Sydney (Australia), C. Champod and A. Girod, *Footwear Marks Examination*, 5-day workshop for Australian reporting officers (February 14-17, 2006).

Helsinki (Finland), Fourth European Academy of Forensic Science Meeting EAFS06, June 13-16, 2006: P. Chamberlain, C. Neumann, D. Meuwly, C. Champod, N. Egli, *Addressing the Changing Paradigm in Fingerprint Comparison* [Workshop].

Montréal (Québec, Canada), C. Champod and F. Taroni, *Interpreting DNA evidence,* 4-day workshop for the reporting officers of the Laboratoire de Sciences Judiciaires et de Médecine Légale (October 16-20, 2006).

2004 Brussels (Belgium), C. Champod and F. Taroni, *Interpreting Scientific Evidence*, a 4-day workshop for reporting officers of the National Laboratory of Criminalistics and Criminology (February 16-19, 2004).

2003 Regular invited speaker to the Judicial Studies Board (Crown Court Continuation Seminar: an educational forum for judges and lawyers) to deliver lectures on DNA evidence and evidence interpretation (6 seminars delivered from 2001 to 2003).

2001 Brussels (Belgium), C. Champod, *L'interprétation de l'indice technique (Interpreting forensic evidence*), journées de formation organisée par le Ministère de l'Intérieur pour les magistrats instructeurs.

2000 Krakow (Poland), September 14, 2000, C. Champod, G. Jackson, K. Wiggins and M. Grieve, *Case Assessment and Bayesian Interpretation of Fibre Evidence*, Workshop organised within the European Fibre Group during the Second European Meeting of Forensic Science (13-16 September 2000).

Cranfield (UK), October 10, 2000, C. Champod, *The Bayesian Approach for Interpreting Scientific Evidence*, afternoon lecture given at Cranfield University (Royal Military College of Science, Department of Environmental and Ordonance Systems) in relation to the MSc Course in Forensic Engineering and Science.

1999 Sion (Switzerland), October 28, 1999, C. Champod, *De l'adéquation des formulations des conclusions dans les expertises forensiques (About the adequacy of experts'conclusions in forensic expertise)*. Cours de perfectionnement de la Société Suisse de Droit pénal.

1998 Neuchâtel (Suisse), October 12, 1998, Ch. Champod, *L'identification par les empreintes digitales* (Fingerprint Identification), Cours de perfectionnement pour fonctionnaires de police – Institut suisse de police [proceedings].

Lyons (France), December 11, 1998, Ch. Champod, *Les standards en dactyloscopie* (Standards in Dactyloscopy), Invited speaker at the "sous-direction de la police technique et scientifique de la police nationale".

1994 Bellinzone (Switzerland), May 4 & June 14, 1994, C. Champod, *Les Concepts de Locard sur l'identification dactyloscopique* (Locard's Concepts on Fingerprint Identification), presented to magistrates and police officers in the canton of Ticino.

Delémont (Switzerland), February 8, 1994, C. Champod & F. Taroni, *Les probabilités dans l'investigation et le procès* (Probabilities During the Investigation and the Trial), conference for magistrates in the canton of Jura.

EXHIBIT 4

AAAS, PCAST and Validation: Questions and Answers

Prepared by William C. Thompson, Chair
AAAS Latent Fingerprint Examination Working Group

The 2017 AAAS Report on Latent Fingerprint Examination and the 2016 PCAST report on forensic science both discussed validation of feature comparison methods in forensic science.

With respect to a recent suggestion that the AAAS report contradicts the PCAST report, the Chair of the AAAS working group on latent fingerprint examination provided this response.

*****Does the AAAS report suggest or imply that forensic techniques ought to be used without direct empirical tests of their accuracy?***

No, the report says exactly the opposite. It declares that empirical tests to measure the accuracy of the technique under conditions appropriate to its use in practice (sometimes called 'black-box studies') are absolutely necessary for establishing the validity of latent fingerprint examination. For example, the report states:

> **…when examining the scientific foundation of latent print examination, it is necessary to consider more than the degree of inter-finger and intra-finger variability, one must also consider research on how well examiners can, in practice, distinguish the impressions of different fingers (p. 14)**

*****Does the AAAS report contradict the PCAST report with regard to the need for direct empirical testing of forensic science techniques?***

No. The AAAS report and the PCAST report are in complete agreement on the necessity of direct empirical testing to assess the accuracy of a forensic science method under conditions appropriate to its use in practice.

The AAAS report states this agreement clearly:

> **The PCAST report concludes, *and we agree*, that foundational validity can *only* be established by empirical research [emphasis added] (AAAS report, p. 14)**

The AAAS report goes on to quote with endorsement and approval several passages from the PCAST report on the necessity of empirical testing for establishing foundational validity, including the following:

> **Scientific validity and reliability require that a method has been subjected to empirical testing, under conditions appropriate to its intended use, that provides**

valid estimates of how often the method reaches an incorrect conclusion…. Without appropriate estimates of accuracy, an examiner's statement that two samples are similar—or even indistinguishable—is scientifically meaningless: it has no probative value, and considerable potential for prejudicial impact. Nothing—not training, personal experience nor professional practices—can substitute for adequate empirical demonstration of accuracy. (AAAS report p. 14, quoting PCAST report p 46)

For subjective methods, foundational validity can be established *only* through black-box studies that measure how often many examiners reach accurate conclusions across many feature-comparison problems involving samples representative of the intended use. In the absence of such studies, a subjective feature-comparison method cannot be considered scientifically valid (AAAS report, p. 43, quoting PCAST report, p. 66)

*****Did the PCAST report and the AAAS report differ in their analysis of what kinds of studies are needed in order to establish the validity of latent fingerprint examination?***

The PCAST report distinguished what it called "foundational validity" (whether the method can in principle be reliable) from what it called "validity as applied" (whether the method has been applied in a manner that will produce accurate results in the case at hand). It concluded that sufficient research has been done to establish the "foundational validity" of latent fingerprint examination but called for a continuing program of "proficiency testing," and for careful and transparent assessment of the work in particular cases, to help assure that the technique is valid as applied.

The AAAS report agreed explicitly: "[O]ur conclusions largely align with those of the PCAST report…" (p. 44). However, the AAAS report offered a more detailed assessment and discussion of the kinds of research needed to assure that latent print examination is valid *as applied*, declaring "[p]articularly with regard to the performance of human examiners we find that more and better research is needed." (p. 14). It called for assessing examiner performance in a blinded manner by introducing known-source test samples into the flow of casework in forensic laboratories, so that examiners do not know when they are being tested. The PCAST report also mentioned the desirability of conducting what it called "proficiency testing" in a test-blind manner, and urged that such research be "vigorously pursued, with the expectation that it should be in wide use, at least in large laboratories, within the next five years." (PCAST report, p. 59). The AAAS report went beyond the PCAST report by providing recommendations on how blinded research might be performed. It also discussed how the blinded research on examiner performance could be used to answer important questions about factors that affect examiner accuracy and to provide the feedback needed to improve laboratory performance.

*****The AAAS report mentions the concept of "convergent validity." Was the report's mention of this concept intended to suggest or imply that forensic science techniques can be considered valid in the absence of direct empirical tests of their accuracy or on the basis of studies that PCAST considered flawed and inadequate?***

No. The AAAS report was designed to provide a comprehensive review of the scientific literature on fingerprint evidence. Consistent with that goal, it discussed the convergence of findings across multiple studies of the accuracy of latent print examiners, including a number of studies that PCAST noted as having design flaws or other limitations that prevented them from being appropriate empirical tests for establishing foundational validity. The AAAS report also noted these flaws and limitations; it did not suggest that these studies were appropriate tests of the accuracy of latent print examination under conditions appropriate to use in practice. It found, however, that many of these studies were nevertheless worthy of consideration for other purposes, particularly for identifying factors that might affect the validity of latent fingerprint examination as applied (such as the quality of the latent print; training of examiners, etc.).

EXHIBIT 5

SUPERIOR COURT OF THE DISTRICT OF COLUMBIA

Criminal Division

UNITED STATES OF AMERICA	:	
	:	**Case No. 2018 CF1 009709**
v.	:	
	:	
KAEVON SUTTON	:	**Hon. Robert Okun**

ORDER

Defendant's Motion to Exclude Expert Testimony in Firearms Identification ("Defendant's Motion to Exclude") is pending before the Court. For the reasons set forth below, Defendant's Motion to Exclude will be granted in part.

RELEVANT PROCEDURAL HISTORY

On February 2, 2021, Defendant filed his Motion to Exclude, requesting the following limitations on the Government's presentation of ballistics comparison evidence in this case: 1) the examiner be precluded from testifying to the source attribution opinion that, based on pattern-matching, casings and bullets were identified as having been fired from the same weapon; and 2) the examiner's discussion of markings on the ammunition be limited to class characteristics. In support of this request, Defendant asserted that there was a lack of scientific support for the Government's claim that a firearms examiner can reliably make a source determination – i.e., that the examiner can match markings on expelled casings and bullets to a single firearm. Defendant cited the findings of three reports – 1) the 2008 Ballistics Imaging Report by the National Research Council ("2008 NRC Report"); 2) the 2009 Forensic Science Report by the National Research Council ("2009 NRC Report"); and 3) the 2016 Forensic Science Report by the President's Council of Advisors on Science and Technology ("2016 PCAST Report") – in support of his argument, as well as Judge Edelman's opinion in *United States v. Tibbs,* 2016 CF1 19431, cited at 2019 D.C. Super. LEXIS 9 (Sept. 5, 2019).

On March 12, 2021, the Government filed its Opposition to Defendant's Motion to Exclude. In its Opposition, the Government asserted that studies issued subsequent to the 2016 PCAST Report undercut the conclusion reached by Judge Edelman in *Tibbs*, and cited Judge Contreras's opinion in *United States v. Harris*, 502 F.Supp.3d 28 (D.D.C. 2020), in support of its argument that a firearms examiner could reliably testify that ammunition was fired from the same firearm if there were sufficient levels of agreement among the individual characteristics of the firearm. The Government noted several limitations in any expert testimony it would offer – namely, the expert would not use unqualified terms such as "match," would not state his expert opinion with any level of scientific certainty, and would not render his opinion "to the exclusion of all other firearms" or use the phrase "to a reasonable degree of scientific certainty."

On March 31, 2022, Defendant filed his Amended Reply to the Government's Opposition. In his Amended Reply, Defendant argued that the Government ignored the growing number of judicial opinions, including those from this jurisdiction, that placed greater limits on firearm testimony than those proposed by the Government. Defendant also asserted that the scientific landscape had not changed in the Government's favor since the 2016 PCAST report was issued and that the weight of the evidence supported Defendant's proposed limitations. In addition, Defendant claimed that the Government's firearms expert (Jay Stuart) did not reliably apply firearms identification methodology in this case.

Finally, on May 3, 2022, the Government filed its Sur-Reply to Defendant's Motion to Exclude. In its Sur-Reply, the Government noted that another firearms expert (Rick Wyant) had examined the relevant ammunition and had reached almost an almost identical conclusion as Mr. Stuart, and that another examiner (Aaron Brundenell) verified Mr. Wyant's conclusions. In addition, the Government argued that Defendant's proposed limitations exceeded those imposed by the Court of Appeals or by Judge Edelman in *Tibbs*.

RELEVANT LEGAL STANDARDS

The case law concerning the admission of testimony from a firearm or toolmark expert has evolved over the past several years, but the Court of Appeals' two most recent cases are very informative. In *Gardner v. United States*, 140 A.3d 1172 (D.C. 2016), the Court of Appeals held that a firearm and toolmark expert "may not give an unqualified opinion, or testify with absolute or 100% certainty, that based on ballistics pattern comparison matching a fatal shot was fired from one firearm, to the exclusion of all other firearms." *Id.* at 1177. The Court further noted that its holding was limited "in that it allows toolmark experts to offer an opinion that a bullet or shell casing was fired by a particular firearm, but it does not permit them to do so with absolute certainty," and noted that it had doubts as to whether toolmark experts should be allowed to state their opinions "with a reasonable degree of certainty." *Id.* at 1184, n.19.

In *Williams v. United States*, 210 A.3d 734 (D.C. 2019), the Court of Appeals reiterated that it is error to allow a firearm and toolmark examiner to "provide unqualified opinion testimony that purports to identify a specific bullet as having been fired by a specific gun via toolmark pattern matching." *Id.* at 743. The Court of Appeals did not resolve the Government's argument that *Gardner* only prohibited certainty statements and otherwise continued to authorize opinion testimony identifying a specific bullet as having been fired by a specific gun, because the examiner in that case had given a certainty statement. *Id.* at 741-42. However, the Court noted that the Government's argument was "difficult to square" with the Court's holding in *Gardner* that the trial court had erred by admitting the examiner's unqualified opinion that a specific gun was the murder weapon. *Id.* at 739. The Court also noted that its opinion did "not limit firearms and toolmark examiners from making other observations about the ballistics evidence recovered in a particular case," because those observations were not at issue in the case. *Id.* at 743, n.19.

In addition, two relatively recent trial court decisions are informative. In *Tibbs*, Judge Edelman, after conducting an extensive evidentiary hearing, precluded the government from eliciting testimony identifying the recovered firearm "as the source of the recovered cartridge casing," and instead ruled that the government's expert must limit his testimony to a conclusion that "based on his examination of the evidence and the consistency of the class characteristics and microscopic toolmarks, the firearm cannot be excluded as the source of the casing." 2019 D.C. Super LEXIS 9 at *3.

By contrast, in *Harris*, Judge Contreras disagreed with Judge Edelman's analysis, after conducting an evidentiary hearing, and held that the Government's firearms and toolmark expert could testify that casings were fired from the same firearm when all class characteristics were in agreement and "the quality and quantity of corresponding individual characteristics is such that the examiner would not expect to find that same combination of individual characteristics repeated in another source and has found insufficient disagreement of individual characteristics to conclude that they originated from different sources." 502 F.Supp.3d at 45. Judge Contreras also noted with approval that the Government had agreed that its expert would not use terms such as "match" or state his opinion with any level of statistical or scientific certainty or to the "exclusion of all other firearms." *Id.* at 44.

APPLICATION OF THE RELEVANT LEGAL STANDARDS

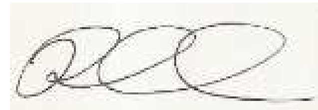
Although the issue is not free from doubt, the Court finds that the legal standards set forth above preclude the Government's firearm expert from conclusively stating that the various pieces of ammunition that are at issue in this case were fired from the same firearm. While the Court acknowledges that the Government's expert will not testify as to any level of scientific certainty or use unqualified terms such as "match," the Court nonetheless believes that opinion testimony that ammunition was fired from a particular firearm, without any qualifications or limitations on that opinion, is inconsistent with *Williams,* where the Court noted that the Government's argument on appeal was "difficult to square" with the Court's holding in *Gardner* that the trial court had erred by admitting the examiner's unqualified opinion that a specific gun was the murder weapon. 210 A.3d at 739. Thus, the Court will preclude the Government's expert from stating without any qualifications or limitations that the ammunition at issue was fired from the same firearm, and instead will limit the examiner's opinion to a conclusion that the ammunition at issue is consistent with being fired from the same firearm.

However, the Court does not agree with the other limitation proposed by Defendant – namely, that the examiner's testimony about the markings on the ammunition be limited to class characteristics. Such a limitation goes beyond the limitations set forth in *Williams* and *Gardner*, and even goes beyond the limitations imposed by Judge Edelman in *Tibbs*, because the Government's firearms expert in *Tibbs* was allowed to testify about his observations concerning individual ammunition characteristics such as the similarity in striations.

Therefore, it is this 9th day of May, 2022, hereby

ORDERED that Defendant's Motion to Exclude Expert Testimony in Firearms Identification is **GRANTED IN PART AND DENIED IN PART**; and it is

ORDERED that the Government may present expert testimony on firearms identification in a manner that is consistent with the limitations described above.



Judge Robert Okun

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