

Evaluation of Expert Research Results Based on the Probabilistic Approach (on Published Foreign Papers)

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The Research Paper Purpose is to analyze the genesis of procedural and scientific principles of modern foreign standards for evaluating expert research results; clarify uncertainty sources that result in ambiguous expert conclusions; substantiate the need to use the probabilistic (Bayesian) approach while formulation of forensic experts' answers. To fulfil this goal, the following research methods have been chosen: historical and legal; systemic and structural; comparative legal; formal and legal. The procedural, epistemological and doctrinal factors complicating evaluation of the objectivity and veracity of the expert conclusion in domestic law enforcement practice are named. Evaluation standards of expert evidence at different times throughout the world have been analyzed (universal adoption of the Frye standard, substantiation and validation of the Daubert standard, prove beyond a reasonable doubt). It is emphasized that provision of probable conclusions by the forensic expert is due to a continuum of uncertainties, which source are peculiarities of the formation of crime traces and methods of collecting traces at the scene, the level of expertise development and methodologies of expert research, interpretation and evaluation of forensic examination results. To shape the expert's conviction in research findings, a statistical Bayesian method of establishing the likelihood ratio is

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proposed, which enables to evaluate significance of versions proposed by the forensic expert and is the basis for the court to take a reasoned decision. The probabilistic approach is proposed to be applied both for evaluation of a random coincidence of features when identifying forensic examination objects, as well as in relation to possible errors in laboratory tests and interpretation of results drawn by a forensic expert.

Keywords: forensic science, expert conclusion; probability, veracity, expert conclusion uncertainty; Frye standard and Daubert standard; likelihood ratio; Bayes' theorem.

Research Problem Formulation

The ability of a forensic expert to evaluate results of a conducted research, taking into account circumstances of specific proceedings and scientific provisions, and to submit them to the court in an understandable form is important for any legal process. That is why modern researchers put an increasing emphasis on objectification and unification of the procedure for evaluating forensic research results. The most challenging aspect is associated with evaluation of features coincidence during identification examination of various objects. To establish identity in forensic science, the frequency-probabilistic, or probabilistic-statistical, method of objectifying evaluation significance of identification features is proposed. However, this method has not been widely spread since such an approach in forensic expert practice encountered difficulties in accumulating required statistical data on occurrence frequency and interdependence degree of the qualitative or quantitative characteristics of relevant

objects. Accordingly, in domestic forensic expert practice, evaluation of obtained identification features is mostly subjective and depends on the expertise of the forensic expert.

In foreign and domestic specialized literature, researchers have repeatedly tried to solve issues of objective evaluation of expert conclusion veracity. Analysis of judicial and investigative practice demonstrates the existence of several factors significantly impeding evaluation of objectivity and veracity of expert conclusions:

- procedural: acceptance of the adversariality principle in conformity with Art. 22 of the Criminal Procedural Code of Ukraine ¹ resulted in performing forensic examinations at the initiative of the prosecution and defense parties and in drawing alternative, oftentimes contradictory expert conclusions; provision of oral consultations and written explanations of specialists regarding unreasonableness of expert conclusions; appearance

1 Кримінальний процесуальний кодекс України від 13.04.2012 р. № 4651-VI (зі змін. та доп.). URL: <https://zakon.rada.gov.ua/laws/show/4651-17#Text> (date accessed: 09.01.2023).

of negative reviews on expert conclusions; clear criteria that would enable to objectively evaluate and verify veracity of expert research results by professional participants in procedure are not enshrined in law;

- cognitive (epistemological): *objective*: are due to the fact that acceleration of scientific and technical progress and the growing role of highly specialized fields of expertise have increased dependence of investigators, prosecutors, judges, and defense counsels on forensic experts when adopting decisions (in the lack of specific expertise in such investigators, prosecutors, judges and defense counsels); *subjective*: when expert research results directly depend on a forensic expert's competence (the scope and level of specific expertise, the choice of the expert methodology suitable for a specific situation, interpretation of obtained data, etc.);
- doctrinal conditioned by the strict division in the domestic theory of forensic examinations (forensic science) of expert conclusions based on research results, where conclusions are divided into categorical and probable depending on the degree of certainty. Moreover, probable conclusions are often replaced by assumptions that cannot be considered as evidence, and the fact that probable conclusions are the result of statistical and probabilistic measurements is also being ignored.

Unlike domestic practice, expert conclusions (as a type of the results of any scientific research activity) are viewed as an objective but probabilistic characteristic in the world forensic expert doctrine. Foreign forensic expert practice successfully applies the probabilistic approach based on Bayes' theorem ² to objectify evaluation of identification examination results. Ukraine's approach towards the international and European community necessitates the analysis of foreign experience in the use of the probabilistic approach to interpreting results of forensic examinations, most frequently identification examinations, which has been formed over the past 20 years.

Article Purpose

To trace the genesis of the procedural and scientific principles of modern foreign standards for evaluating forensic research results; clarify sources of uncertainty that result in ambiguous expert conclusions; substantiate the need to use the probabilistic (Bayesian) approach in formulation of experts' answers.

Research methods

In view of peculiarities of the set goal, the following methods were chosen: *historical-legal* (used for retrospective analysis to regulate evaluation of expert conclusions in court proceedings of the countries of the Anglo-Saxon legal system); *systemic-structural* (contributed to the systematic consideration and identification of sources of uncertainty emerging at all stages of forensic examination); *comparative-legal* (helped to compare provisions regulating admissibility of probable conclusions in domestic and foreign practice, to

2 Bozza S., Taroni F., Biedermann A. Bayes Factors for Forensic Decision Analyses with R. Springer, 2022. 187 p.

establish the possibility of applying positive international experience in domestic judicial practice); *formal-legal* (became the basis for disclosure of certain concepts). The above-mentioned methods were applied as interrelated and complementary, contributing to the research completeness and the validity of formulated scientific conclusions and proposals.

Analysis of Essential Researches and Publications

The majority of scientists have put an emphasis on the study of theoretical questions regarding evaluation and veracity of expert research and expert conclusions (both in forensic, expert, and criminal procedural literature), including: L. Yu. Arotsker, V. D. Arseniev, R. S. Bielkin, V. F. Berzin, A. I. Vinberh, L. M. Holovchenko, V. H. Honcharenko, I. V. Hora, O. O. Eisman, O. M. Zinin, N. I. Klymenko, Yu. H. Korukhov, O. P. Kuchynska, V. K. Lysychenko, Yu. K. Orlov, I. L. Petrukhin, I. V. Pyrih, O. R. Rossynska, T. V. Sakhnova, M. Ya. Sehai, V. V. Sednev, E. B. Simakova-Yefremian, O. R. Shliakhov, V. D. Yurchyshyn, Yu. Yu. Yaroslav, the author of this paper and other researchers. The analysis of literature shows that there is no common understanding of the procedural, formal and meaningful sides of such a phenomenon as the expert conclusion. The procedural side means development of conclusions in compliance with requirements of the current legislation; under formal: consistency of the laws of

logic (primarily formal), case files and requirements of fundamental (in relation to a specific examination) science; under the meaningful: argumentation and veracity of the expert's response. Summarizing views expressed by scientists, it is necessary to note the following. The meaningful side is reflected in the conceptual framework of expert conclusions, which are formed on the basis of specific expertise; it is an output, indirect knowledge (not informational, direct, empirical) stemming from objective communication forms. The formal side is embodied in the following requirements to the expert conclusions: they should follow from the introductory and research sections of a conclusion; include evaluation of information obtained in the course of forensic examination; be clear, precise, understandable; be specific, definite, exclude different interpretations; testify about facts on which they are based; do not contain special terms; rely on general rules of science³.

In line with the subject of our research, categorical and probable conclusions are of particular interest because they are distinguished by the degree of certainty of the forensic expert's statement in forensic science. The forensic expert draws a categorical conclusion when available research results fully confirm the substantiated statement. A probable conclusion means that a statement is partially confirmed. Both categorical and probable conclusions of the forensic expert must be confirmed and argued in compliance with Arts. 101 and 102 of the Criminal Procedure Code of Ukraine⁴, Art. 102 of the Civil Procedure Code of Ukraine⁵,

3 Щербаківський М. Г. Призначення та провадження судових експертиз : навч. посіб. Харків, 2011. С. 321–342.

4 Кримінальний процесуальний кодекс України URL: <https://zakon.rada.gov.ua/laws/show/4651-17#Text> (date accessed: 09.01.2023).

5 Цивільний процесуальний кодекс України від 18.03.2004 р. № 1618-IV (зі змін. та доп.). URL: <https://zakon.rada.gov.ua/laws/show/1618-15#Text> (date accessed: 09.01.2023).

Art. 101 of the Code of Administrative Proceedings of Ukraine⁶. Unlike categorical conclusions, probable conclusions do not contain required certainty, which results in difficulties in their evaluation while court proceedings, and the issue of their admissibility and evidential value remains urgent and debatable in legal literature.

While not caving in a long-standing debate, we emphasize that scientists hold opposite positions on evidentiary value of probable conclusions. Some scientists (on the basis of mixing such conclusions with assumptions, reject their evidentiary value) believe that in accordance with Part 3 of Art. 62 of the Constitution of Ukraine⁷, Part 3 of Art. 373 of the Criminal Procedure Code of Ukraine⁸, Part 6 of Art. 81 of the Code of Civil Procedure of Ukraine⁹ proof cannot be based on assumptions. Other researchers give probable conclusions the value of evidence, consider probable expertise as a type of results substantiated by expert research, which cannot be replaced by completely unsubstantiated assumptions and guesses. Judicial practice is also inconsistent in evaluating

evidentiary value of probable conclusions. A review of court decisions indicates that expert conclusions in a probative form are accepted as a source of evidence in 86 % of verdicts in criminal proceedings and in 78% of court decisions in civil cases¹⁰.

Let's stress that probable conclusions are the result not only of subjective uncertainty of a forensic expert, but also of objective factors. In recent years, there have been papers in domestic literature in which authors prove that results of a comparative molecular genetic study of biological traces using the most modern instrumental method of DNA analysis, the research on complex objects using information technologies inevitably lead to formulation of expert answers exclusively in the form of probability based on statistical data evaluation¹¹. In our viewpoint (taking into account introduction into expert practice of modern scientific technologies, international forensic expert experience), the role of substantiated expert answers expressed in a probable form will likely grow over time. This is conditioned by the stochastic distribution of characteristics of

- 6 Кодекс адміністративного судочинства України від 06.07.2005 р. № 2747-IV (зі змін. та доп.). URL: <https://zakon.rada.gov.ua/laws/show/2747-15#Text> (date accessed: 09.01.2023).
- 7 Конституція України : Закон України від 28.06.1996 р. № 254к/96-ВР (зі змін. та доп.). URL: <https://zakon.rada.gov.ua/laws/show/254%D0%BA/96-%D0%B2%D1%80#Text> (date accessed: 09.01.2023).
- 8 Кримінальний процесуальний кодекс України URL: <https://zakon.rada.gov.ua/laws/show/4651-17#Text> (date accessed: 09.01.2023).
- 9 Цивільний процесуальний кодекс України URL: <https://zakon.rada.gov.ua/laws/show/1618-15#Text> (date accessed: 09.01.2023).
- 10 Щербаковский М. Г. Судебная практика оценки вероятных выводов эксперта. *Актуальні питання судової експертології, криміналістики та кримінального процесу* : мат-ли II Між-нар. наук.-практ. конф. (Київ, 19.11.2020). Київ, 2020. С. 647—651. URL: <https://m3rkxutm8pk3eqapl5ynjvb3gips8uao.cdn-freehost.com.ua/wp-content/uploads/2021/06/5fd09ad02772c.pdf> (date accessed: 09.01.2023).
- 11 Shcherbakovskyi M., Stepaniuk R., Kikinchuk V., Petrova I., Hanzha T. Assessment of the conclusions of molecular genetic examination in the investigation of crimes. *Amazonia investiga*. 2020. Vol. 9. No. 25. Pp. 479—486. URL: <https://amazoniainvestiga.info/index.php/amazonia/article/view/1097> (date accessed: 09.01.2023) ; Рыбальский О. В., Соловьев В. И., Чернявский С. С., Журавель В. В. Вероятность в современной криминалистике. *Криміналістичний вісник*. 2019. № 1 (31). С. 6—12. DOI: [10.37025/1992-4437/2019-31-1-6](https://doi.org/10.37025/1992-4437/2019-31-1-6) (date accessed: 09.01.2023).

objects submitted for forensic examination, instrumental errors of measurement methods, and subjective evaluation of the analysis results by forensic experts.

The overview of foreign and domestic published papers allows us to state that the problem of objectification and veracity of expert conclusions is of global importance and does not depend either on the legal system and peculiarities of the national judiciary, or on the level of economic development of countries. Thus, generalization of problems within forensic expert activity in the USA, Great Britain, Australia and Switzerland revealed common shortcomings, in particular: lack of a common terminology that could be used by forensic experts and unified approaches to the forms of conclusions; insufficient scientificity of expert methodologies suitable for obtaining veracious data; misunderstanding by judges of experts' conclusions provided in the probable form, etc.¹². That is why the analysis of theoretical developments of leading foreign researchers in the field of forensic expert activity associated with development of experts' conclusions and implementation of a probabilistic approach to evaluating results obtained in the course of expert analysis will come in handy to domestic specialists.

Main Content Presentation

Let's look at the development history of evaluating the veracity of expert data in the Anglo-American legislation. After a number of well-known court precedents, American lawyers developed certain standards (criteria, rules) for evaluating expert conclusions¹³.

Since 1923, the *Frye standard*, which is also known as the *standard of general recognition*¹⁴, had been prevalent in judicial practice when it came to adopting expert conclusions. Under this standard, the court accepted the forensic expert's testimony only if the scientific principle or discovery on the basis of which a conclusion was provided had been generally accepted by the scientific community. This rule had been used for 70 years until it was replaced by a new one adopted in 1993 in *Daubert v. Merrell Dow Pharmaceuticals case, Inc.* which provided its additional clarification¹⁵. *Daubert standard* identified 5 criteria of admissibility of pieces of evidence obtained with application of expert methods (methodologies). First, the scientific method which is based on the evidence and should adhere to Karl Popper's Falsification Principle¹⁶. This means that a method must be empirically tested for falsification or refutation and tested successfully to be considered

- 12 McCartney C., Amoako E. N. The UK Forensic Science Regulator: A Model for Forensic Science Regulation?. *Georgia State University Law Review*. 2018. Vol. 34. Is. 4. Pp. 946–948. URL: https://www.researchgate.net/publication/328019895_The_UK_Forensic_Science_Regulator_A_Model_For_Forensic_Science_Regulation_THE_UK_FORENSIC_SCIENCE_REGULATOR_A_MODEL_FOR_FORENSIC_SCIENCE_REGULATION (date accessed: 09.01.2023).
- 13 Щербаківський М. Г. Стандарти допустимості результатів експертних досліджень в судопроизводстві США і України: порівняльний аналіз. *Криміналістика і судова експертиза*. 2021. Вип. 66. С. 37–48. DOI: 10.33994/kndise.2021.66.05 (date accessed: 09.01.2023).
- 14 *Frye v. United States*, 293 F. 1013 (DC Cir. 1923). Court of Appeals of the District of Columbia. Dec 3, 1923. URL: <https://casetext.com/case/frye-v-united-states-7> (date accessed: 09.01.2023).
- 15 *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U. S. 579 (1993) / Justia U. S. Supreme Court. URL: <https://supreme.justia.com/cases/federal/us/509/579/> (date accessed: 09.01.2023).
- 16 Popper K. R. *The Logic of Scientific Discovery Basic*. This ed. publ. in the Taylor & Francis e-Library, 2005. 545 p. URL: <http://philotextes.info/spip/IMG/pdf/popper-logic-scientific-discovery.pdf> (date accessed: 09.01.2023).

scientific. *Second*, frequency (probability), the potential level of errors that can be assumed during method application, must be known. *Third*, the scientific method must be peer-reviewed and published. *Fourth*, the method must be adopted by a corresponding scientific community similar to the Frye standard. *Fifth*, there should be the monitoring mechanism for applying the algorithm of the method actions (individual stages).

As of today, this standard is established in the Anglo-Saxon legal system. The Daubert standard provides increasing demands for expert evidence acceptance. The introduction of the Daubert standard resulted in adoption of the amendment of Rule 702 *Testimony of expert witnesses* of the US Federal Evidence Code (hereinafter referred to as *Rule 702*), where examination of the scientific validity of expert researches is also emphasized¹⁷. Gradually, criteria for expert evidence admissibility according to the *Daubert standard* began to be applied in court proceedings, in particular, in the Anglo-Saxon legal system¹⁸.

The *Daubert standard* became the impetus for a substantial revision of scientific principles of forensic examinations and an increase in the role of judges in evaluating and accepting expert conclusions.

The most essential results on application of this standard: revision of the empirical principles of traditional types of forensic examinations based on epistemological approaches established in science; determination of uncertainty sources that do not allow to reliably find out event circumstances; searching for ways to identify errors in methods applied by forensic experts; assigning the “gatekeeper” function to the judge to protect the courtroom from scientifically unveracious evidence. The set of requirements stipulated by the *Daubert standard* helps to define it as a *standard of substantiation and verification*.

Another reason that prompted researchers to put emphasis on the level of methodology of forensic examinations was the increasing number of cases of conviction of innocent suspects under erroneous incriminating expert conclusions. Within the framework of the *Innocence project*, it was found that 185 (74 %) out of the first 250 acquitted prisoners were convicted on the basis of unveracious expert conclusions¹⁹; and as of March 2018, 2,152 recorded acquittals (24 %) are associated with false or misleading forensic evidence²⁰.

Many of the so-called traditional forensic identification methods

17 Rule 702 — Testimony by Expert Witnesses / Federal Rules of Evidence. Edition 2023. URL: <https://www.rulesofevidence.org/article-vii/rule-702> (date accessed: 10.01.2023).

18 Jurs A. W. Balancing Legal Process with Scientific Expertise: A Comparative Assessment of Expert Witness Methodology in Five Nations, and Suggestions for Reform of Post-Daubert U. S. Reliability Determinations. *Marquette Law Review*. 2012. Vol. 95. Is. 4. Pp. 1329—1425. URL: <https://scholarship.law.marquette.edu/cgi/viewcontent.cgi?article=5134&context=mulr> (date accessed: 10.01.2023) ; Ward T. An English Daubert? Law, Forensic Science and Epistemic Deference. *The Journal of Philosophy, Science & Law: Daubert Special Issue*. 2015. Vol. 15. Pp. 26—36. DOI: 10.5840/jpsl20151513 (date accessed: 10.01.2023) ; Okoye J., Oraegbunam I. Daubert and Frye Models: Implications for Admissibility of Expert Testimony for Nigeria. *International Review of Law and Jurisprudence*. 2019. Vol. 1. No 3. Pp. 10—15. URL: <https://nigerianjournalonline.com/index.php/IRLJ/article/view/278> (date accessed: 10.01.2023).

19 Garrett B. L. Convicting the Innocent: Where Criminal Prosecutions Go Wrong. Harvard University Press, 2012. C. 8.

20 % Exonerations by Contributing Factor / The National Registry of Exonerations. URL: <https://www.law.umich.edu/special/exoneration/Pages/ExonerationsContribFactorsByCrime.aspx> (date accessed: 10.01.2023).

(handwriting, fingerprinting, traces of weapons, etc.) forensic experts systematically compared with more substantiated and well-studied scientific fields (in particular, molecular genetic DNA analysis) and ultimately came to a conclusion about the lack of fundamental researches and predominant reliance on arbitrary expert conclusions. In the well-recognized report of the National Academy of Sciences of the United States of America of 2009 (where the state of forensic evidence, the problems of forensic examinations and directions for their solution were considered) it is emphasized that a substantial part of *scientific evidence* lacks scientific substantiation. It stressed the lack of fundamental scientific research in the field of forensic science and highlighted the importance of conducting real academic research in this field, particularly to evaluate the suitability (validity) and veracity of methods applied in the course of forensic examination of evidence ²¹.

Researchers have criticized the postulates of identification examinations carried out within traditional forensic science, the basic principle as to the individuality of objects: *"It is time for traditional forensic science to replace outdated assumptions about the uniqueness of objects with a more reliable empirical and probabilistic basis... The concept of individualization, which lays the basis for many branches of forensic science, exists only in a metaphysical or rhetorical sense. Perhaps,*

the only scientifically based approach in forensic identification is the use of estimates of the probabilities of accidental coincidence, which are not yet used in any of the traditional forensic identification sciences ²²."

In 2022, a group of researchers from Australia, Great Britain, Canada, the USA, Finland and Switzerland published the *Sydney Declaration*, where 7 fundamental principles of the theory of forensic science are set out, in particular *"forensic science is evaluation of results in the context of the circumstances of an event that took place"* and *"forensic science deals with a continuum of uncertainties"*. Uncertainties exist at every stage of the process starting from the discovery of traces at the scene and continuing during their investigation and subsequent interpretation of obtained data: until the notification of forensic examination results. Uncertainties cannot be completely eliminated, but they can be estimated and taken into account. The presence of uncertainties provides a basis for making probabilistic judgments about an event. Forensic experts cannot determine with great confidence final circumstances of traces formation, but only evaluate a relative significance of results under various probable causes or scenarios ²³. Uncertainty was recognized as one of the most significant circumstances affecting the weight of expert evidence. The analysis of uncertainties conditioning provision of probable conclusions of forensic experts demonstrates that they have several sources: the mechanism (features) of formation of

- 21 Strengthening Forensic Science in the United States: A Path Forward. The National Academies Press. Washington, DC, 2009. Pp. 22–23, 27–28, 44. DOI: [10.17226/12589](https://doi.org/10.17226/12589) (date accessed: 10.01.2023).
- 22 Koehler J. J., Saks M. J. Individualization Claims in Forensic Science: Still Unwarranted, *Brooklyn Law Review*. 2010. Vol. 75. Is. 4. Pp. 1194–1195, 1203. URL: <https://brooklynworks.brooklaw.edu/blr/vol75/iss4/9> (date accessed: 10.01.2023).
- 23 Roux C., Bucht R., Crispino F. et al. The Sydney Declaration — Revisiting the Essence of Forensic Science through its Fundamental Principles. *Forensic Science International*. 2022. Vol. 332. P. 4. DOI: [10.1016/j.forsciint.2022.111182](https://doi.org/10.1016/j.forsciint.2022.111182) (date accessed: 10.01.2023).

traces of offenses, methods of collecting traces at the crime scene, the level of knowledge development about forensic examination object, methods of expert research, interpretation and evaluation of data obtained by a forensic expert²⁴.

The doctrine of uncertainty implies the need to specify the degree of conviction for a specific event under investigation, assumptions about past events, or identification of the object under study. A statistical, in particular, the Bayesian method (Bayesian networks), which supports the transition from theoretical analysis to practical tasks, is suggested as the basis for formation of the forensic expert's internal conviction. The application of such a method of computational facilitation for implementation of probabilistic reasoning in practice has opened up prospects for providing experts' conclusions with greater objectivity and validity. It is stressed that researchers' duty is to determine sources of uncertainty, identify their influence on solution of typical expert tasks, establish likelihood ratio²⁵.

The Bayesian method within the probabilistic approach to interpretation of forensic evidence was first proposed in the 70s of the last century²⁶. Since then, numerous research papers dedicated to Bayesian reasoning in a certain form for solving problems in forensic science had

been published. In 2011, after a long-standing scientific debate on this issue, over 30 leading scientists in the field of forensic science from 11 countries supported by the leadership of the *European Network of Forensic Science Institutes* (ENFSI) set out 10 basic principles for evaluating results of expert research based on the Bayesian approach, the most significant of which include:

- the theory of probabilities, the Bayesian approach provides a common consistent logical basis for interpreting expert data;
- the ratio of the probability of observations considering the assumption of the prosecution to the probability of observations taking into account the defense assumption, known as the likelihood ratio, provides the most reasonable basis for the court in establishing the significance of forensic examinations results;
- a verbal scale, stemming from the concept of likelihood ratio, is the most expedient for conveying to the court evidentiary value of the expert conclusion²⁷.

For identification examination, the likelihood ratio (Bayes ratio) is defined as ratio of two conditional probabilities. In the numerator, there is probability

- 24 Georgiou N., Morgan R. M., French J. C. The Shifting Narrative of Uncertainty: a Case for the Coherent and Consistent Consideration of Uncertainty in Forensic Science. *Australian Journal of Forensic Sciences*. 2022. Pp. 6–9. DOI: [10.1080/00450618.2022.2104370](https://doi.org/10.1080/00450618.2022.2104370) (date accessed: 10.01.2023).
- 25 Taroni F., Biedermann A. Uncertainty in Forensic Science: Experts, Probabilities and Bayes' Theorem. *Statistica Applicata – Italian Journal of Applied Statistics*. 2015. Vol. 27. No. 2. Pp. 132–134. URL: <http://sa-ijas.stat.unipd.it/sites/sa-ijas.stat.unipd.it/files/Taroni-Biedermann.pdf> (date accessed: 10.01.2023).
- 26 Finkelstein M. O., Fairley W. B. A Bayesian Approach to Identification Evidence. *Harvard Law Review*. 1970. Vol. 83. No. 3. Pp. 489–517. URL: <https://www.marcellodibello.com/mathtrial/resources/FinkelsteinFairley1970.pdf> (date accessed: 10.01.2023) ; Tribe L. H. Trial by Mathematics: Precision and Ritual in the Legal Process. *Ibid*. 1971. Vol. 84, No. 6. Pp. 1329–1393. URL: <https://www.maths.ed.ac.uk/~v1ranick/dreyfus/tribe.pdf> (date accessed: 10.01.2023).
- 27 Berger C. E. H., Buckleton J., Champod C., Evett I. W., Jackson G. Expressing Evaluative Opinions: A Position Statement. *Science and Justice*. 2011. Vol. 51. Is. 1. Pp. 1–2. DOI: [10.1016/j.scijus.2011.01.002](https://doi.org/10.1016/j.scijus.2011.01.002) (date accessed: 10.01.2023).

of forensic examination results (for example, the coincidence of the set of features in compared objects), provided that one statement (version) is true (for example, *the object being tested left a trace*). In the denominator, there is probability of features coincidence in objects, provided that the second, opposite statement is true (*the trace was not left by the object being tested*). A likelihood ratio shows support for one of a pair of clearly articulated statements. The peculiarity of the likelihood ratio is that it is not the probability of a specific version – in the given example – *formation of a trace by a specific object that is being tested*. The likelihood ratio only indicates that one version is more likely than the opposite²⁸. That is, the value of the likelihood ratio enables to draw a conclusion about the strength of support, significance, degree of confidence that forensic examination results provide for specific source data of one version compared to an alternative one.

Most commonly, the likelihood ratio has a numerical expression. In line with this approach, expert conclusions outline the degree of conviction in a specific statement depending on the likelihood ratio value. For likelihood ratio values closer to one, a conclusion means that the results do not support one version

over the other, or the results support each version equally. For the likelihood ratio values greater than one, a conclusion is that received data to some extent supports one version (for example, that the object being tested was correctly identified as the sought one). For values of the likelihood ratio less than one, a conclusion means that obtained data to some extent supports the other version (the object being tested is not the one sought and was mistakenly identified).

The presented probabilistic approach was supported by ENFSI²⁹ and the Royal Statistical Society in the UK³⁰. This testifies to a widespread belief in the foreign expert community under which probability (uncertainty) should be the subject of evaluation, quantitative or qualitative measurement. At the same time, it is emphasized that the probabilistic approach does not deny the quality of scientific evidence or expert conclusions, as long as uncertainty is established, addressed and brought to the attention of uninformed persons (court, jury, etc.) who adopt decisions clearly and transparently³¹. We believe that evaluation and further informing of forensic examination customers about the degree of superiority of one expert version over another is vital for handling objective, legal and fair criminal proceedings or civil cases.

28 Thompson W. C., Kaasa S. O., Peterson T. Do Jurors Give Appropriate Weight to Forensic Identification Evidence? *Journal Empirical Legal Studies*. 2013. Vol. 10. Is. 2. P. 370. DOI: [10.1111/jels.12013](https://doi.org/10.1111/jels.12013) (date accessed: 10.01.2023).

29 ENFSI Guideline for Evaluative Reporting in Forensic Science. Strengthening the Evaluation of Forensic Results across Europe (STEOFRAE). URL: https://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf (date accessed: 10.01.2023).

30 Roberts P, Aitken C. The Logic of Forensic Proof: Inferential Reasoning in Criminal Evidence and Forensic Science. Guidance for Judges, Lawyers, Forensic Scientists and Expert Witnesses. London. Royal Statistical Society, 2014. Pp. 102–143. URL: https://www.researchgate.net/publication/318596438_The_Logic_of_Forensic_Proof_-_Inferential_Reasoning_in_Criminal_Evidence_and_Forensic_Science (date accessed: 10.01.2023).

31 Almazrouei M. A, Dror I. E., Morgan R. M. The Forensic Disclosure Model: What Should be Disclosed To, and By, Forensic Experts? *International Journal of Law, Crime and Justice*. 2019. Vol. 59. P. 16. DOI: [10.1016/j.ijlcrj.2019.05.003](https://doi.org/10.1016/j.ijlcrj.2019.05.003) (date accessed: 10.01.2023).

The Bayesian approach to evaluation of identification studies results is exhaustively outlined in the published *ENFSI Guideline for Evaluative Reporting in Forensic Science. Strengthening the Evaluation of Forensic Results across Europe*, which is a standard and methodological document on evaluation of evidentiary significance of expert conclusions provided as a result of conducting identification research in various types of forensic examinations³². This document testified to the recognition by the international expert society of the need to develop and implement uniform methodical criteria for forensic interpretation and reporting in ENFSI laboratories. The document provides instructions for the expert's preparation of evaluation results within the framework of the so-called evaluation report (in the domestic interpretation: the forensic report). The *Guideline...* also contains a compilation of practical guidelines for evaluating the significance of the forensic expert's conclusions and presenting results of this evaluation in a conclusion; glossary of basic terms; examples of applying the probabilistic approach to expert research on DNA, glass, video recordings, gunshot residues, and shoe prints. As of today, the *Guideline...* is mandatory for forensic expert organizations of the European Union.

The *Guideline...* is based on several concepts: *true and false statements, probability of research results, the likelihood ratio, explanatory information*. Given the adversarial nature of justice, true and false statements (versions) are made, for example, in relation to the identification question put to the forensic expert: *The object being tested has left a trace* and *Another object has left a trace*. Such an expert

conclusion in the form of evaluation differs in that it considers results obtained in view of alternative hypothetical descriptions of an event. Probabilities of research results testify to the event uncertainty in numerical terms (objective probability) or to the expert's personal confidence (subjective probability). A forensic expert determines probability on the basis of availability of scientific, experimental and personal data about objects under study.

Explanatory information refers to information extracted from case materials, which is given to the forensic expert to aid in addressing the issues, proposing alternative versions, and selecting an appropriate research approach. The concept of explanatory information means that in order to clarify issues raised by the initiator of the expert task, the forensic expert must analyze all meaningful information in a case, provided to the forensic expert or requested additionally. What is more, we are talking about not all information in a case, but only about the meaningful information (in accordance with the subject of the examination), since it can affect the future evaluation of evidentiary value of forensic examination results. Within the chosen approach, both theoretically and practically, such information acquires the value of one of the fundamental components necessary for conducting an accurate expert assessment. Additionally, it is recommended to note in the expert conclusion that in case of change of explanatory information, re-evaluation of significance of the identified features should be implemented. The aforementioned provision correlates with the provisions of clauses 1 and 2 of Part 3 of Art. 69 of the Criminal Procedural Code of Ukraine³³,

32 ENFSI Guideline URL: https://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf (date accessed: 10.01.2023).

33 Кримінальний процесуальний кодекс України URL: <https://zakon.rada.gov.ua/laws/show/4651-17#Text> (date accessed: 09.01.2023).

which give the forensic expert the right to access case files of criminal proceedings associated with the research subject as well as request provision of additional materials and samples and carry out other actions related to forensic examination.

Stemming from research results, proposed versions, explanatory, scientific and other types of information, probabilities are determined and the likelihood ratio is calculated. Formulating conclusions for those cases where the likelihood ratio is qualitative is to use a verbal qualifier to convey the strength of support for expert conclusions. The following values of the likelihood ratio (hereinafter referred to as LR) and its verbal equivalent are suggested:

$1 < LR \leq 10$ — *slight support / limited support*;

$10 < LR \leq 100$ — *moderate support*;

$100 < LR \leq 1000$ — *moderately strong support*;

$1000 < LR \leq 10\,000$ — *strong support*;

$10\,000 < LR \leq 1\,000\,000$ — *very strong support*;

$LR > 1\,000\,000$ — *extremely strong support*³⁴.

The verbal scale limits the forensic expert's capabilities to a certain range of indicators and provides an approximate ranking that at best implies that "strong" is stronger than "moderate", but not as strong as "very strong". It should be accepted that discrete limitations are not caused by the verbal scale itself, but rather by the complexity of expert data results and the lack of data for their interpretation³⁵. Thus, *The Guideline...*, based on the Bayesian

approach, outlines the main principles of forensic interpretation and objectification of identification research results, regardless of the scope of their application.

A close approach to evaluation of forensic examination results in the form of probabilistic statements, where categorical conclusion about identification is not provided, is presented in the Guidelines of the U.S. Department of Justice: *Unified Language for Testimony and Findings*³⁶. The guidelines are designed to be used by laboratory experts of the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), Drug Enforcement Administration (DEA), and Federal Bureau of Investigation (FBI). The set of documents includes wordings intended to standardize testimony and conclusions of forensic experts. Guidelines are developed for identification research on handwriting, handprints, tires and shoes, firearms, glass, metals, fibres, drugs, DNA, etc. Depending on research objects, the number of proposed conclusions varies, but all documents contain three wordings common to any type of forensic examination: *inclusion*, which is a conclusion that forensic examination results provide convincing support for an assumption about the origin of traces from the object being tested (identification); *exclusion*, which is a conclusion that forensic examination results provide convincing support for an assumption about the origin of traces from different objects (lack of identification); *inconclusive*: results of forensic examination do not allow the forensic expert to include or exclude the object being tested as a source

34 ENFSI Guideline ... URL: https://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf (date accessed: 10.01.2023).

35 Standards for the Formulation of Evaluative Forensic Science Expert Opinion / Association of Forensic Science Providers. *Science and Justice*. 2009. Vol. 49. Is. 3. P. 162. DOI: 10.1016/j.scijus.2009.07.004 (date accessed: 10.01.2023).

36 Uniform Language for Testimony and Reports / Office of Legal Policy. U. S. Department of Justice. 26 Sept 2022. URL: <https://www.justice.gov/olp/uniform-language-testimony-and-reports> (date accessed: 10.01.2023).

of traces. Guidelines which are based on a probabilistic approach implying that forensic experts should not apply the *individuality* term to identification objects are common to all objects, as this may give the false impression of examining all existing similar objects in nature. It is stressed that a conclusion on identity is only a probable opinion of the forensic expert.

Upon completion of the consideration of the Bayesian approach to evaluation of forensic examination results, it is worth noting that probabilities are most frequently determined not in the course of expert research, but while preliminary experimental-scientific analysis and testing of several models regarding emergence of traces of crimes of various nature. During experiments, the mechanism of formation of traces and their characteristics are determined, which enables to calculate the probability ratio in advance.

We believe that, given a common purpose and conditions of proof, application of the probabilistic approach indicates the introduction of a new standard of proof into forensic expert practice: *the standard of prove beyond a reasonable doubt*.

As demonstrated above, uncertainties conditioning provision of probable answers by a forensic expert emerge not only due to insufficient knowledge of the mechanism of occurrence and properties of traces of committed offense, but also due to mistakes made by forensic experts

in the course of researching and evaluating obtained data. Therefore, the probabilistic approach should be applied not only to evaluation of a random coincidence of features in the case of identification of forensic examination objects, but also to possible errors that a forensic expert could have made during laboratory tests and interpretation of obtained results. In contrast to incomplete knowledge or lack of determinism concerning forensic examination objects, errors are perceived as inaccuracies that can be known or discovered during verification³⁷. Note that domestic researchers classified expert errors as procedural, methodological and operational³⁸. In our viewpoint, the author unreasonably attributed objective current level of knowledge (which is the bases for forensic science) to subjective methodological errors, which are unintentional wrong reasoning. Moreover, instrumental errors are overlooked in the paper.

The possibility of error (mistake) in the course of laboratory analyzes is an integral aspect of every scientific test and, therefore, it cannot be ignored while forensic examination³⁹. Errors are made even in the best expert laboratories and even when all test reports are followed⁴⁰. If the possibility of features coincidence is too small (for example, such as in molecular genetic comparisons where the chance of coincidence can be as low as one in a million or even a billion) or, conversely, the possibility of an error in laboratory tests is very likely, it is advisable to

37 Georgiou N., Morgan R. M., French J. C. Op. cit. DOI: [10.1080/00450618.2022.2104370](https://doi.org/10.1080/00450618.2022.2104370) (date accessed: 10.01.2023).

38 Абрамова В. М. Експертні помилки: сутність, генезис, шляхи подолання : автореф. дис. ... канд. юрид. наук. Київ, 2005. С. 11.

39 Cole S. A. More than Zero: Accounting for Error in Latent Print Identification. *The Journal of Criminal Law and Criminology*. 2005. Vol. 95. Is. 3. Pp. 1034, 1073. URL: <https://scholarlycommons.law.northwestern.edu/jclc/vol95/iss3/10> (date accessed: 10.01.2023).

40 Thompson W. C. Tarnish on the «Gold Standard»: Understanding Recent Problems in Forensic DNA Testing. *The Champion*. 2006. Vol. 30. Pp. 10–14. URL: <https://www.researchgate.net/publication/287959814> (date accessed: 10.01.2023).

request information about errors from the prosecution as admissibility condition of expert evidence in court. Such information is significant not only for drawing expert conclusions but also for assessing evidence value⁴¹. Since there are no adequate statistics on the frequency of errors made in different laboratories, the prosecution was asked to determine this indicator for a specific laboratory that carried out forensic examination at the prosecution's request⁴².

In addition to the probability of features coincidence in compared objects and instrumental errors, foreign authors emphasize subjective errors made by forensic experts in evaluation, interpretation of obtained results on coincidence of features in compared objects (especially when the comparison is made at a qualitative level). Thus, examination of dactyloscopists found that out of 156 forensic experts, only 64 properly identified 5 prints they were supposed to identify and correctly excluded 2 prints they were not supposed to identify. A total of 48 wrong answers were discovered in relation to coincidences. The combined

results of these tests have proved that when examining fingerprints, forensic experts are wrong on average 0.8 % of the time⁴³. As a result of incorrect interpretation of relevant features, leading experts in dactyloscopy are calling to abandon *absolute conclusions* and insisting on recognizing the probabilistic nature of dactyloscopy evidence⁴⁴. In the mentioned report, it is recommended (in addition to dactyloscopic examination conclusions) to inform the court about the probability of false-positive results obtained on the basis of duly planned verification studies⁴⁵.

Within the context of the probabilistic approach, let's return to the *Frye standard* and the *Daubert standard*. Despite the fact that the Daubert standard is of paramount importance today, both standards coexist side by side in American case law. However, oftentimes, instead of carefully considering scientific validity and methodology of expert evidence (in the spirit of the *Daubert standard*, with a stricter approach to evaluation of forensic examination results), judges, not wanting to delve into scientific foundations of performed examination,

41 Sangero B. Safety from Flawed Forensic Sciences Evidence. *Georgia State University Law Review*. 2018. Vol. 34. Is. 4. P. 1141. URL: <https://readingroom.law.gsu.edu/cgi/viewcontent.cgi?article=2943&context=gsulr> (date accessed: 10.01.2023).

42 Sangero B., Halpert M. Why a Conviction Should Not Be Based on a Single Piece of Evidence: A Proposal for Reform. *Jurimetrics*. 2007. Vol. 48. No. 1. P. 80. URL: <https://www.researchgate.net/publication/228296786> (date accessed: 10.01.2023).

43 Haber L., Haber R. N. Error Rates for Human Latent Fingerprint Examiners. *Automatic Fingerprint Recognition Systems*; ed. N. Ratha, R. Bolle. Springer r-Verlag New York Inc., 2004. P. 340. URL: https://link.springer.com/chapter/10.1007/0-387-21685-5_17 (date accessed: 10.01.2023).

44 Champod C., Evett I. W. A Probabilistic Approach to Fingerprint Evidence. *Journal of Forensic Identification*. 2001. Vol. 51. Is. 2. P. 110. URL: https://www.researchgate.net/publication/285822580_A_probabilistic_approach_to_fingerprint_evidence (date accessed: 10.01.2023).

45 Report to the President. Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods. Executive Office of the President. President's Council of Advisors on Science and Technology. Sept 2016. P. 91. URL: https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf (date accessed: 10.01.2023).

turn to a more simplified Frye standard and recognize testimony of forensic experts as scientific evidence, relying only on the *recognition of the methodology by the scientific community* ⁴⁶.

The need for not only objective but also accessible and understandable evaluation criteria (first of all, the results of identification studies) is due to the fact that judges and jurors are not well-versed about forensic examination. Despite the necessity to verify scientific validity of an expert's testimony or conclusion specified in the *Daubert standard* and Rule 702, this requirement is objectively impossible to fulfil. Judges are trained lawyers who have to adopt decisions on a wide range of issues from all areas of life, including scientific ones. At the same time, whenever a forensic expert participates in trial, he/she becomes the authority (in the epistemological sense) whom the judge and jury are unable to question about the research conducted or dispute her/his conclusions, and on whom the judge and jury have to rely in their judgments. However, if this happens, the decision will actually be adopted by a forensic expert, not the court. This situation is only exacerbated by the fact that forensic experts often have polarized opinions (e.g., defense and prosecution experts). It can easily turn a trial into a "*battle of experts*" in which judges and/or juries are presumed to be unable to make a decision ⁴⁷. The objective inability

of judges and jurors to fully evaluate answers provided by forensic experts is similar to the domestic one, confirming the existence of common global issues in the use of forensic examination in the judicial system of different states. It is worth mentioning that a distinguished criminalist R. S. Bielkin harshly criticized the theory "*forensic expert is a scientific judge*", which is an echo of the theory of formal evidence; instead, he suggested to clearly define real and publicly available criteria that the investigator and the court should be guided by when evaluating expert conclusions ⁴⁸.

The current legal regulations require judges to not only consider the probabilistic approach to scientific evidence, which involves disclosing the level of uncertainty to the court, but also to familiarize themselves with the relevant scientific field. They must check the veracity and validity of the scientific method (methodology or technology) used to obtain the data, and evaluate the expert conclusions before adopting a legal decision. In this context, *veracity* is understood as a methodology that allows different experts to obtain the same result at different points in time. *Validity* means that the method corresponds to the purpose for which it was applied. The methodology may be veracious, but not valid. On the contrary, veracity is a prerequisite for validity. If different experts can reach different results or if results can change later then the methodology or

46 Faigman D. L. Admissibility regimes «The Opinion Rule» and Other Oddities and Exceptions to Scientific Evidence, the Scientific Revolution, and Common Sense. *Southwestern University Law Review*. 2008. Vol. 36. P. 701. URL: https://repository.uchastings.edu/cgi/viewcontent.cgi?article=2033&context=faculty_scholarship (date accessed: 10.01.2023).

47 Godden D. M., Walton D. Argument from Expert Opinion as Legal Evidence: Critical Questions and Admissibility Criteria of Expert Testimony in the American Legal System. *Ratio Juris*. 2006. Vol. 19. Is. 3. P. 265. URL: <https://scholar.uwindsor.ca/cgi/viewcontent.cgi?article=1003&context=crrarpub> (date accessed: 10.01.2023).

48 Белкин Р. С. Курс криминалистики : учеб. пособ. для вузов. Москва, 2001. С. 623.

method cannot be recognized as valid ⁴⁹. Therefore, the standard of *substantiation and verification* obliges judges to verify methods (methodologies) applied by the forensic expert, turning them, as mentioned above, into a kind of “gatekeepers” protecting the courtroom from scientifically unveracious evidence. This requirement reflects an important guiding principle, which consists in the fact that the court should not recognize evidence provided by a forensic expert only on the basis of her/his authoritative opinion stemming from the principle of *ipse dixit* (from Latin, “he said himself”), that is, uncritically trusting forensic expert’s answers without any further substantiation ⁵⁰.

Conclusions

Procedural, epistemological and doctrinal factors existing in domestic theory and law enforcement practice significantly complicate evaluation of objectivity and veracity of expert conclusions. The most urgent and debatable in legal literature and practice is the problem of assessing admissibility and evidentiary value of probable conclusions conditioned not only by the subjective uncertainty of a forensic expert but also by the results of statistical processing of data obtained with the help of instrumental methods and using information technologies.

The analysis of foreign papers demonstrates that forensic examination is connected with a continuum of uncertainties, which determine the provision of probable conclusions. The source of uncertainty is the mechanism

(peculiarities) of crime traces formation, methods of collecting traces at the scene, the level of expertise development, expert research methodologies, interpretation and evaluation of data obtained by the forensic expert. To shape the expert’s conviction in research findings, a statistical Bayesian method of establishing the likelihood ratio is proposed, which enables to evaluate significance of versions proposed by the forensic expert and is the basis for the court to take a reasoned decision. Examples of practical application of the mentioned probabilistic approach to developing the expert conclusions are provided in the guidance documents of ENFSI and the US Department of Justice. The probabilistic approach is suggested to be applied both to evaluation of a random coincidence of features in case of identifying forensic examination objects as well as to possible errors in laboratory tests and interpretation of results obtained by the forensic expert.

We believe that theoretical analysis and adaptation of certain provisions of probabilistic approach into expert research findings for domestic use will significantly contribute to innovative development of Ukrainian forensic science in particular and forensic expert activity in general. The above is primarily concerned with the spread of the Bayesian method and application of likelihood ratio concept both in the methodology and in practice of domestic forensic expert activity. The value of the likelihood ratio allows us to conclude on the strength of support and significance of forensic examination results for specific source data of one version compared to the alternative one.

49 Sangero B. Safety from False Convictions. Jerusalem, 2016. P. 104. URL: <http://sangero.co.il/wp-content/uploads/2017/11/SAFETY-Sangero-final-280716.pdf> (date accessed: 10.01.2023).

50 Guthel T. G., Bursztajn H. Avoiding Ipse Dixit Mislabeling: Post-Daubert Approaches to Expert Clinical Opinions. *The Journal of the American Academy of Psychiatry and the Law*. 2003. Vol. 31. No. 2. P. 206. URL: <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=59696238b68d23de80a2348ee98b3350d7f28051> (date accessed: 10.01.2023).

Оцінка результатів експертного дослідження на підставі ймовірного підходу (за матеріалами закордонних публікацій)

Михайло Щербаковський,
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Мета роботи — проаналізувати генезис процесуальних і наукових засад сучасних закордонних стандартів оцінки результатів судово-експертних досліджень; уточнити джерела невизначеності, що спричиняють неоднозначні експертні висновки; обґрунтувати необхідність застосування ймовірного (баєсівського) підходу до формулювання відповідей експертів. Для досягнення поставленої мети обрано такі методи дослідження: історико-правовий; системно-структурний; порівняльно-правовий; формально-юридичний. Названо процесуальні, ґносеологічні та доктринальні чинники, які ускладнюють оцінку об'єктивності й достовірності висновку експерта у вітчизняній правозастосовній практиці. Проаналізовано стандарти оцінки експертних доказів у світі в різний час (загального визнання *Frye standard*, обґрунтування та перевірки *Daubert standard*, правдоподібності поза розумним сумнівом). Акцентовано, що надання ймовірних висновків експерта обумовлено континуумом невизначеностей, джерелом яких є особливості утворення слідів правопорушень і способи збирання слідів на місці події, рівень розвитку експертних знань і методики експертного дослідження, інтерпретування і оцінка результатів експертизи. Для формування переконання експерта в результатах дослідження запропоновано статистичний баєсівський метод установлення відношення правдоподібності, що дає змогу оцінити значущість версій, висунутих експертом, та є підставою для ухвалення судом обґрунтованого рішення. Ймовірнісний підхід запропоновано застосовувати як до оцінки випадкового збігу ознак у разі

ідентифікації об'єктів експертизи, до можливих помилок лабораторних випробувань, так і до інтерпретування експертом здобутих результатів.

Ключові слова: *судова експертиза, висновок експерта; ймовірність, достовірність, невизначеність висновку експерта; стандарти доказування Frye та Daubert; відношення правдоподібності; теорема Баєса.*

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Declaration of Competing Interest

Authors declare no conflict of interest.

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- ENFSI Guideline for Evaluative Reporting in Forensic Science. Strengthening the Evaluation of Forensic Results across Europe (STEOFRAE). URL: https://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf.
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