F19 How Should Uncertainty Be Expressed and Communicated?

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Learning Overview: After attending this presentation, attendees will better understand the role played by forensic metrology in providing a universal method for expressing and communicating uncertainty. The method, originally thought for expressing uncertainty in measurement, can be applied to express and communicate uncertainty related to scientific theories and data.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by providing attendees with a better awareness that uncertainty can be expressed and communicated in a universal way, independently of the mathematical tool used to evaluate it. The methods of metrology can be usefully applied to express and communicate uncertainty also when non-physical quantities are considered, such as expert testimonies.

An important outcome of the 2009 National Academy of Sciences (NAS) and 2016 President's Council of Advisors on Science and Technology (PCAST) Reports is a greater awareness that any scientific method is inherently uncertain, and the provided results are consequently affected by uncertainty that must be expressed and communicated to avoid presenting incomplete or even misleading evidence to the trier of fact.[1,2]

These documents have opened the discussion not only on how to assess the scientific validity of forensic science methods in terms of uncertainty, but also on how to communicate it.[3,4] In particular, the discussion focused on who is communicating, what is being communicated, in what form is uncertainty communicated, to whom it is communicated, and to what effect.[4]

While some of these points involve psychological issues that must be considered, especially when communicating uncertainty to individuals and communities without a proper technical background to avoid undesired negative perceptions, other points, namely what and in what form is communicated, involve technical issues.

In this respect, the fundamental concepts of metrology, as defined by the International Vocabulary of Metrology (VIM) and the Guide to the Expression of Uncertainty in Measurement (GUM), provide a helpful background to communicate uncertainty in a scientifically sound way, encompassed by the international Standards.[5,6]

It is worth quoting clause 0.3 in the Introduction section of the GUM: "*just as the nearly universal use of the International System of Units (SI) has brought coherence to all scientific and technological measurements, a worldwide consensus on the evaluation and expression of uncertainty in measurement would permit the significance of a vast spectrum of measurement results in science, engineering, commerce, industry, and regulation to be readily understood and properly interpreted.*"[6]

Moreover, the proposed method is *universal*, that is: "*the method should be applicable to all kinds of measurements and to all types of input data used in measurements*" (clause 0.4).[6]

This presentation seeks to show that the uncertainty definition proposed by the GUM is indeed universal and can be usefully employed in evaluating, expressing, and communicating uncertainty also when non-physical quantities have to be measured (the so-called *soft measurements*).[6]

It will be shown that the method for quantitatively evaluating uncertainty is presently based on the mathematical theory of probability. It will be shown as well that this mathematical approach has some limitations, due to the required mathematical assumptions on the way limited information is modeled, and that more recent mathematical theories are available, such as the theory of evidence, to model limited information in a more general way than probability, thus leading to the ability to also express, evaluate, and communicate uncertainty on non-physical quantities, such as human reasoning, in a strict and scientifically sound way.

Reference(s):

1. National Research Council (NRC), Committee on Identifying the Needs of the Forensic Science Community. (2009). *Strengthening Forensic Science in the United States: A Path Forward*. Washington, DC: The National Academies Press.
2. President's Council of Advisors on Science and Technology (PCAST). *Report to the President: Forensic Science in Criminal Courts: Ensuring Scientific Validity Of Feature-Comparison Methods.* (2016). Washington, DC: Executive Office of the President of the United States.
3. Ferrero, Alessandro and Scotti, Veronica. An Interpretation of the 2016 PCAST Document in Terms of Forensic Metrology. *Proceedings of the American Academy of Forensic Sciences*, 70th Annual Scientific Meeting, Seattle, WA. 2018. 581.
4. van der Bles Anne Marthe, van der Linden Sander, Freeman Alexandra L.J., Mitchell James, Galvao Ana B., Z aval Lisa, Spiegelhalter David J. Communicating uncertainty about facts, numbers and science. *R. Soc. Open Sci.* 6: 181870 (2019).
5. *International vocabulary of metrology: basic and general concepts and associated terms (VIM)* (Geneva: ISO, 2007).
6. *ISO IEC Guide 98-3: Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)* (Geneva: ISO, 2008).

Methods, Data, Uncertainty

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