E21 Uncertainty Analysis in Forensic Practice: How to Apply It Wherever Scientific Integrity Demands Its Use

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The goal of this presentation is to educate forensic practitioners who have not yet introduced uncertainty analysis into their work and to hone the skills of those who have.

This presentation will impact the forensic science community by providing a general understanding of uncertainty/error analysis, enhancing their ability to quantitatively assess the reliability of forensic evidence, and to knowledgeably demand such assessments in evidence presented by others.

"In science, the word *error* does not carry the usual connotations of the terms *mistake* or *blunder*. Error in a scientific measurement means the inevitable uncertainty that attends all measurements. As such, errors are not mistakes; you cannot eliminate them by being very careful. The best you can hope to do is to ensure that errors are as small as reasonably possible and to have a reliable estimate of how large they are."[1]

Those in the general scientific and engineering communities are astonished when they hear some forensic practitioners claim: "I don't know what error analysis is; I cannot find its definition" or "There are so *many* definitions of error analysis, it cannot have any significance" or "There is no need to use numbers in describing reliability." The fact is that the presentation of the results of a key measurement without a quantitative characterization of its uncertainty is non-scientific, that is to say, meaningless.[2] Now that the courts are increasingly recognizing this truth,[3] all forensic and legal practitioners need to develop a facility understanding of and a facility with uncertainty/error analysis—especially in the wake of the 2009 National Academy of Sciences Report on forensic science. The effort here is directed at facilitating that development, starting and ending with the defusing of a number of mistaken concerns about applying uncertainty/error analysis in the forensic context.

The existence of varying definitions for uncertainty/error is to be expected. As with most important concepts, scientific and otherwise, the definition of uncertainty/error varies with the context in which it is applied. Indeed, different definitions can be used within the same context, as will be described below. The important point is not this variety but rather that one be aware of the specific definition being used at a particular time. A statement of the uncertainty/error in one's results is incomplete without a statement of the method you used for estimating the uncertainty/error.

One often hears concern that once error/uncertainty analysis is universally required in the forensic setting, the practitioner will have to carry it out for every measurement made, no matter how mundane or preliminary. This concern is misplaced, as the results requiring a statement of uncertainty/error are those going to the determinations to be made by a trier-of-fact. Those results can be divided into two broad categories: quantitative and qualitative.

- Quantitative results include such things as the blood-alcohol concentration (BAC), the speed of a car involved in a crash, the time elapsed between time of death and the discovery of a corpse, etc.;
- Qualitative results include such things as the match/no-match determinations encountered in signature, fingerprint and DNA analysis.

Uncertainty/error analysis in the first category is the more amenable to short definitions; however, even here one must take care to ensure that the meaning of a statement is understood. For example, what does the statement "the defendant's BAC was measured to be 0.12±0.02 g/100ml" mean? When dealing with the statement of uncertainty/error, that is, the number following the ±, the wise person will withhold judgment until its definition is revealed. Is this a maximum range outside of which one would not expect the "true" value to fall? Or does it refer to a more rigorously determined range within which the "true" value is expected to fall with a given probability? The answers to these questions will lead to the most important question of all: How was the uncertainty/error determined? Forensic scientists and attorneys must know and understand these issues in order for the results of forensic measurements to be competently presented to the parties to litigation and the ultimate triers of fact.

In the DUI/OUI field, it is common to be presented with a result such as 0.12 g/100ml, with no characterization at all of the number's uncertainty/error. This is an indefensible practice from a scientific perspective, which should be the forensic perspective. The party adverse to the one presenting it is on firm ground in making a motion *in limine* to exclude any statement about this number until its reliability has been revealed through a statement of uncertainty/error.

The determination of the uncertainty/error of a BAC result is relatively simple compared to doing so for the speed of a car involved in a crash, often a key number in criminal prosecutions for vehicular homicide. In general, the ultimate number testified to involves a several independent measurements, each of which carries a its own range of uncertainty/error. Once one has all the individual values for uncertainty/error, there are a number of methods for combining those values so as to determin the uncertainty/error of the final result. The most comprehensive and appealing, but one which most attorneys shy away from identifying by name in court, is the Monte Carlo approach. We will discuss this method as well as two simpler ones, one of which is acceptable and one of which should be attacked when it is introduced. Fortunately or unfortunately, it is the latter that seems to come up most often in court.

When dealing with qualitative tests, such as signature, fingerprint or DNA analysis, the result itself is often of the nature match/no-match, with the ultimate conclusion of whether this implicates or excludes a particular suspect or defendant left to the trier of fact. When the *Daubert* court and its progeny wrote of "reliability" of a forensic result, it was referring to the likelihood that the result was what it purported to be. Thus, reliability of a qualitative statement is usually quantified by stating the probability that it is correct. Conversely, it can be stated in terms of the probability (which should be low) that the result shows a match where it should not ("false positive") or a non-match where it should show a match ("false negative"). How are such probabilities to be determined? To what do they relate? Should one distinguish between the uncertainty/error of the result, that is, the match/no-match, and the ultimate conclusion of association?

Pattern evidence, such as expert testimony that a fatal wound was made by a four-inch blade with a broken-off tip just like the blade found in the defendant's possession, is also to be considered. This evidence is proffered for its indirect role in identifying a perpetrator. The probability of a false positive in this instance necessarily requires at least two questions to be answered. What is the probability that the weapon's characterization is correct? If it is correct, what is the probability that the wound was made by the defendant's knife?

Finally, if the fact is considered that uncertainty/error analysis is never absolute and relies, to a large extent, on judgment and the use of prior measurements and information not necessarily obtained during the course of the forensic test in question. The fact is that one never has complete knowledge concerning anything, including the probability that a particular result deviates from physical reality. Contrary to arguments seeking to block legitimate attempts to characterize uncertainty/error, this state of affairs is precisely what requires such efforts. Rational inferences can be made only when our incomplete knowledge/information is adequately understood and characterized. To see this, reflect on the fact that to one assessing the survey of a particular parcel of land, it is useful to know whether Surveyor A or Surveyor B did the work, in light of the knowledge that Surveyor A has a record of doing very good work and Surveyor B a record of not-so-good work. Even though this knowledge of past events does not tell us with certainty that new work by A will be good or that new work by B will be poor, there are few people who would use that as an argument for not taking account of who did the surveying in question. Indeed, no rational person would do so.

References:

1. An introduction to Error Analysis; The Study of Uncertainties in Physical Measurements, 2d ed., J.R. Taylor, University Science Books, 1997, p.3.
2. See, for example, Chapter 4, "The Principles of Science and Interpreting Scientific Data," in Strengthening Forensic Science in the United States: A Path Forward, National Academies Press, Washington, D.C., 2009.
3. See, for example, State v. Fausto, No. C076949, Order Suppressing Defendants Breath Alcohol Measurements Under in the Absence of a Measurement for Uncertainty (King Co.Dist. Ct. WA 9/20/10), City of Kent v. McDaniel, No. K81862 Order Suppressing Defendants Breath Alcohol Measurements in the Absence of a Measurement for Uncertainty (Kent Muni. Ct. WA 5/4/11), People v. Jabrocki, No. 08-5461-FD (79th Dist. Ct. Mason Co. MI 5/6/11)

Error, Uncertainty, Measurement Reliability