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- The role of the subjectivist position in the probabilization of forensic science

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Review Article

The Role of the Subjectivist Position in the Probabilization of Forensic Science

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Abstract

This paper is concerned with the contribution of forensic science to the legal process by helping reduce uncertainty. Although it is now widely accepted that uncertainty should be handled by probability because it is a safeguard against incoherent proceedings, there remain diverging and conflicting views on how probability ought to be interpreted. This is exemplified by the proposals in scientific literature that call for procedures of probability computation that are referred to as "objective," suggesting that scientists ought to use them in their reporting to recipients of expert information. I find such proposals objectionable. They need to be viewed cautiously, essentially because ensuing probabilistic statements can be perceived as making forensic science prescriptive. A motivating example from the context of forensic DNA analysis will be chosen to illustrate this. As a main point, it shall be argued that such constraining suggestions can be avoided by interpreting probability as a measure of personal belief, that is, subjective probability. Invoking references to foundational literature from mathematical statistics and philosophy of science, the discussion will explore the consequences of this interdisciplinary viewpoint for the practice of forensic expert reporting. It will be emphasized that—as an operational interpretation of probability—the subjectivist perspective enables forensic science to add value to the legal process, in particular by avoiding inferential impasses to which other interpretations of probability may lead. Moreover, understanding probability from a subjective perspective can encourage participants in the legal process to take on more responsibility in matters regarding the coherent handling of uncertainty. This would assure more balanced interactions at the interface between science and the law. This, in turn, provides support for ongoing developments that can be called the "probabilization" of forensic science.

Key words: Forensic science, legal process, subjective probability, uncertainty reduction

"The modern conception of scientific method as an objective and value-free learning procedure is the source of the distrust and disrespect shown to science by many people today. In defiance of this conception, I believe the (…) community should openly participate in the development of a revitalised image, accentuating the crucial role of beliefs and values in the conduct of scientific activity. The conception of science as a belief-centered and value-oriented process is supported technically by the operational subjective theory of probability (….)."[32]

Introduction

Standpoint and objectives

In the context of law[3,43] and in what is more generally called "fact analysis"[46] it has been argued that discourses on evaluative matters should include a clear indication of one's standpoint, because standpoints are personal and, hence, can vary among different discussants. One's standpoint is said to affect the weighing of arguments constructed on the basis of new information and the propositions (hypotheses) that one entertains. Declaring one's standpoint is important to favor mutual understanding and to help recognize the sources of potential disagreement. This paper will adhere to this precept by following Anderson and Twining[3] who consider that a standpoint may be declared by answering questions of the following kind: Who am I? At what stage and in what process am I? What am I trying to do? Although Anderson and Twining raise these questions in the context of individual case analysis,

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it also makes sense to consider them in a broader discussion of evaluating the strength of scientific results in the legal process.

This paper is written from the viewpoint of a forensic scientist, with a main interest in the generic principles that underlie inference in situations characterized by uncertainty, a topic that typically arises when scientists are asked to assist a court in dealing with results of forensic examinations. This typically comes at an advanced stage in the legal process where the guilt or innocence of an individual is at issue, and information provided by forensic scientists needs to be placed meaningfully into a context, alongside other elements in the case. The discussion pursued throughout this paper intends to look at this stage from a probabilistic viewpoint. The argument will not, however, be directed toward justifying the choice of probability as a reference framework for reasoning under uncertainty. There is already strong and persuasive argument on this elsewhere in existing literature.[39] Moreover, the probability is now being increasingly accepted, not only in theory,[2,44] but also among practitioners.[1,4] Instead, attention will be drawn to some of the argumentative and practical consequences of choosing probability—in one of its interpretations—as the general framework of reasoning. The main emphasis is placed on the implications for forensic scientists in their activity at the interface between science and the law, although the considerations may also be of interest in broader legal contexts.

The main objective of this paper is to justify the thesis that a beneficial application of probability as a measure of uncertainty should rely on a subjectivist position, that is, probability ought to be interpreted as a measure of an individual's belief about something (e.g., an event of interest) that is unknown to that individual. Although, on first sight, this topic relates to the academic discussion because of its reference to the nature of probability, it is also of direct practical relevance. This will be illustrated through an example drawn from the context of forensic DNA analysis, a proposal regarding the elaboration of probabilities by scientists and the subsequent prescription of such probabilities to legal decision makers.[12] Although such a suggestion may appear to conflict with procedural requirements of contemporary legal systems, it will be argued in this discussion that such conflict can be avoided if probability is properly considered from a subjective point of view.

From a mathematical and statistical point of view, the question of how to interpret probability pertains to the specific application. For forensic science, however, the discussion touches on fundamental issues and is the object of recurrent debates.[1] Notwithstanding the current state still leaves room for thought-provoking discussion on aspects that ask for reconciling answers. The discussion proposed in this paper seeks to provide an original contribution to this topic by re-examining a selection of arguments and standpoints from several foundational disciplines, in particular mathematical statistics and philosophy of science, that otherwise tend to be sidestepped in discussions that remain largely confined to forensic science and the law. In essence, this paper will promote an interdisciplinary perspective in approaching selected conceptual and practical questions that pertain to reasoning under uncertainty in forensic science and the law.

Structure of the paper

Section 2 (Motivation) starts by providing examples of questions about probability and its nature as encountered in applied contexts, including forensic science and the law, with the intention of illustrating the importance of the main topic pursued in this paper, which is the choice of an interpretation of the abstract concept of probability. Section 3 (Interpreting Probability) presents both traditional approaches and the subjectivist approach for interpreting probability, with an emphasis on how the latter can avoid complications associated with the former. Section 4 (Discussion) further explores the consequences of adopting a subjective perspective for what may be termed the ongoing "probabilization" of forensic science. The conclusion (Section 5) assesses the sense in which the adoption of this understanding of probability in forensic science and the law is supported elsewhere in literature,[38] and how this may benefit society.

Motivation

What is a probability? What does it mean to express a probability? Should scientists assign probabilities? If so, what type of probability? Questions of this kind continue to trouble many scientists, and not only in legal contexts. The questions arise similarly in many other areas where reasoning under uncertainty plays a central role. Aven[5] provides a telling illustration of this through an anecdote about his professional experience in risk analysis:

"I had an active role in the analysis and on the day I referred to, I presented the results of the assessment to the top management of the company. Then one of the managers asked me:

"What is the meaning of the probability figures you have presented?"

It was a good question. The company planned to spend large sums on the basis of this assessment and to adequately use its results he needed to understand what the numbers really expressed.

The problem was that I could not give the manager a good answer. Yes, I fret and grieve today over the answer. And I said to myself that this I could not live with. I am an expert on probability but have no clear and convincing answers to this basic question."[5]

This example clearly illustrates that apparently simple questions about probability can turn out to be challenging and that there is a need to deal with this issue in practical settings if scientists do not want to fail in their duty to assist recipients of expert information.

It requires little effort to imagine that the situation described in the above quote similarly arises at the interface between

[1]A recent example is R v T[42] (EWCA Crim 2439). A detailed discussion of this case can be found in the special issue of Law, Probability and Risk (Vol. 11, Issue 4, 2012).

forensic science and the law. It is sufficient to replace "manager" by "lawyer" or "judge," "expert" by "forensic scientist," and "spend large sums on the basis of this assessment" by "taking a decision with potentially profound consequences for the defendant." Thus, where the probability is already an integral part of evaluation and reporting by forensic science experts, courts may legitimately ask scientists to explain the meaning of the probability figures they have presented. Moreover, they may also ask how the court ought to use the proposed probability figures.

Turning to core forensic science, discussions about how to deal with probability can readily be found. For the purpose of illustration, consider the commentary "Use of prior odds for missing persons identifications,"[12] where the authors hold that "[t]he forensic DNA community needs to develop guidelines for objectively computing prior odds."[12][2] In this quote, the prior odds refer to the event that particular (unidentified) human remains are those of a particular missing person. The quote raises a series of tightly intertwined issues regarding the understanding of the concept of probability. I have addressed some of them in previous comments.[10,50] The subsequent sections of this paper will expound on further aspects, in particular on whether scientists should elaborate probabilities, whether they ought to recommend probabilities to other participants in the legal process, and whether "computed" probabilities can be regarded as objective. Mainly, it will be pointed out that the reasoned apprehension and use of probabilities is rooted in deeper considerations about the interpretation of probability with respect to particular needs of the legal context of the application.

Interpreting Probability

Probability in its uninterpreted form

Mathematical probability, as it is most commonly known, is formulated via the analysis of a function that satisfies three uninterpreted axioms. These are known as "the Kolmogorov axioms." A theorem deriving from these axioms, known as Bayes' theorem, is central to the understanding of statistical inference. In one of its forms, this theorem says that the prior odds of a proposition (hypothesis) H, written O (H), modify to so-called posterior odds through consideration of new information (i.e., data).[39] Posterior odds are commonly written O (H|D), where the "|" denotes "conditional" and D are some data, such as results of scientific examinations. In forensic contexts, it is common to write E (short for "evidence") instead of D. In addition to E, the scientific finding considered by the court, there will also be background knowledge I, and strictly one should write O (H|E and I) to denote this explicitly. This way of looking at E and I already amounts to an interpretation with respect to a particular context of application: The law.

From a mathematical point of view, Bayes' theorem is universally accepted as correct. It is equally uncontroversial that the entities upon which Bayes' theorem builds, that are probabilities, are numbers that obey the rules of probability calculus. These rules or laws define only a very limited number of restrictions so that they can be seen as a very liberal concept.[34] That is, probability theory defines the scope of numerical values that probabilities can take and how probabilities are to be combined, but the theory does not tell one what value a probability in any given case should take. Scientists seem rather uncomfortable with this liberty as is illustrated by the fact that they seek to conceive of "devices" amenable to "produce" probabilities. In forensic science, one such instance was mentioned in Section 2 (Motivation), drawn from the context of missing person identification. Similarly, recommendations can also be found in other forensic disciplines, such as comparative examinations of marks, where it has been suggested that prior probabilities − in particular, equal prior probabilities - ought to be derived with the help of notions such as the principle of maximum entropy and the principle of indifference.[25] Both these principles are borrowed from other science disciplines. The applicability of such ideas to inference problems in forensic science is questionable on a conceptual account,[8,9] but perhaps more intriguing is that, through their technical names, these principles may suggest themselves to the general practitioner as necessary constraints in the same way as the laws of probability. However, this is clearly not the case. Although thinking individuals are of course free to choose additional constraints on their probabilities, coherence, as stipulated by probability theory, do not require them to do so.

One way to look at the "laws of probability," as they stand, is to consider them as a collection of uninterpreted terms and rules. That is, the meaning to be assigned to the terms that make up the formulation of the laws of probability can be considered independently from the formulation of the laws itself. This means that it is necessary to interpret the abstract probability calculus in order to make it meaningful within the context of a particular branch of application. This is a subtle task, however, because it extends the discussion to further aspects, such as the specification of criteria to judge the adequacy of an interpretation of probability. It is worth emphasizing that this view is based on a formalist view of mathematics as opposed to the constructivist view.[31] The so-called intuitionist-constructive attitude to mathematics is that it is a formal language for saying specific things. Every formula in the language means something, beginning with the most basic items. In particular, in de Finetti's construction "the laws" derive from meaningful assertions regarding prices. Stated otherwise, in this view one does not consider probability, for example, to be a function on a space of sets, as in Kolmogorov's axioms, but rather a price assessed for specific economic transactions if the sentence assessed is true, and 0 if not.

We now move on to a discussion of interpretations of probability commonly encountered in forensic science and the law. A particular emphasis will be placed on examining the

[2]Note that "odds," a technical term in probability theory, designates an equivalent form for expressing a probability. That is, odds on an event E is the ratio of the probability of the event E to that of its complement $-E$. The term "prior" refers to the particular moment when the odds are considered, that is prior to the consideration of new information. Alternatively, the term "initial" is sometimes used instead of "prior." See also Section 3.1 (Probability in its uninterpreted form).

extent to which the definitions of probability can be termed "operational."

Limitations of selected interpretations of probability

In judicial contexts, two perspectives on probabilities appear recurrently. Their designation varies somewhat throughout literature, but generally they can be classified according to the subjectivist belief-type approach and approaches that do not subscribe to a belief-type perspective. Among the latter are the so-called "frequency concept" and Laplace's[33] "classical definition." It is often said that it is hardly helpful to oppose the two perspectives, notably in short communications such as the present discussion, where limitations of space inevitably lead to a partial presentation of the competing views. Notwithstanding, it is sometimes felt that the subjectivist belief-type interpretation of probability cannot be advocated without offering some justification as to why other common interpretations are left aside. Thus, they are briefly addressed below. By retaining practical applicability as a main criterion for comparison, it is hoped that the reader will accept a short digression on nonsubjectivist approaches, and the subsequent adherence to the view that probability ought to be understood as personal belief.

As one of the most commonly known definitions of probability, the frequentist interpretation involves, as its name says, the notion of frequency of occurrence of an event in a sequence of so-called "repeated trials" (under stable conditions). This concept gravitates around the idea of "chance," a notion associated with the relative frequency with which some outcome occurs on repeated trials. This way of thinking about the variability associated with target outcomes is appealing because it lends itself to idealizations, such as the consideration of infinitely long-runs, or, infinite sequences. As such, this is a conceptual nicety, but it appears to be hard to maintain for a reasonable person facing a real-world problem. In the context of law, Lindley has challenged the frequency concept as follows:

"There is nothing wrong with the frequency interpretation, or chance. It has not been used in this treatment because it is often useless. What is the chance that the defendant is guilty? Are we to imagine a sequence of trials in which the judgements, 'guilty' or 'not guilty', are made and the frequency of the former found? It will not work because it confuses the judgement of guilt, but, more importantly, because it is impossible to conceive of a suitable sequence. Do we repeat the same trial with a different jury; or with the same jury but different lawyers; or do we take all Scottish trials; or only Scottish trials for the same offence? The whole idea of chance is preposterous in this context."[35]

In similar terms, Kaplan wrote:

"Given a typical contested trial, for instance, it is meaningless to speak of the probability of the defendant's guilt in terms of the number of times he would be guilty in an infinite number of exactly similar cases because, first, there are not even two exactly similar cases, and, second, even if there were many identical cases the court must reach a verdict, not a ratio, in the case at bar."[30]

Due to the unclear meaning of "repeated trials" that, strictly speaking, do not exist, the frequentist definition of probability is vague. In the forensic context, absurd considerations as illustrated in the quotation above appear to be inevitable because of the very features of the topic under study. Typically, events of legal interest have properties—notably lacking replicability and varying (i.e., unstable) circumstances—that are opposed to basic tenets of the frequency view, such as long-run replicability and stable conditions. This is an applicability problem, a reason for which the frequency concept is often avoided. Note, however, that this objection relates to the identification of frequency as a probability. There is no problem with the concept of frequency (of occurrence) as such. Both a count of the number of items in a certain class (i.e., the absolute frequency) and the proportion of the number of items in a certain class (i.e., the relative frequency, obtained by dividing the absolute frequency by the total number of items) can be useful concepts. Moreover, it is often useful to assess probabilities for the possible value of such frequencies.

Another interpretation of probability, different from the belief-type perspective, is the so-called "classical definition" of probability as given by the works of Pierre-Simon Laplace. This interpretation maintains that the probability of an event is given by the ratio of the situations in which that event holds, that is the event is verified, to the number of all possible cases which, according to information one has, appear all equally possible. This definition also looks at a collection of cases and focuses on a proportion, but it is circular in the sense that it relies on the assumption of "equally probable cases," for which no independent definition is given.

The subjectivist standpoint

From the notion of event to subjective probability

A characterizing feature of the interpretations of probability outlined in the previous section is their understanding of the notion of an event in terms of what may be called "collective." Another view of the notion of event, which does not run into operational limitations as outlined above, emphasizes an "atomistic" view.[23] It considers an event as any detailed statement that can be ultimately either verified or disproved. In the light of this view, probability can be given a natural and nonconflicting interpretation: "(…) probability characterizes the knowing subject's attitude with regard to a given statement."[21] Probability thus describes the assessment of an individual making a subjective statement about something that is unknown to this individual. In the words of de Finetti, "[t]he notion of probability (….) consists (….) of the (subjective) confidence level that a specific individual (I, You, or anybody else and anyone in his own way) has in the fact that a particular statement is true (…)."[20][3] According to this view, probability is not a characteristic of an event of interest. In particular, it is not

[3]Note, however, that the term "confidence" in this quote has nothing to do with the expression "confidence interval" used in frequentist statistics.

a property of the physical world and that could be investigated independently of a thinking individual. It represents a judgment made by someone based on his/her assessment of the available evidence.

Defining probability operationally

Understanding probability as a relationship between a person and the world that this person is contemplating,[34] satisfies an operational definition. An operational definition is one that allows one "(…) to give an effective meaning to a notion and not merely an appearance of such in a metaphysical-verbalistic sense (…)."[18] It is "(…) a definition based on a criterion which allows us to measure it. (…) the criterion, the operative part of the definition which enables us to measure it, consists in this case of testing, through the decisions of an individual (which are observable), his opinions (previsions, probabilities), which are not directly observable."[18]

Stated otherwise, an operational relates probability "(…) to actual experiences, which are at least conceptually feasible."[18][4]

That being said, the question thus is how to measure an individual's opinion, which is not directly observable. There are different devices available for eliciting a person's probability. A very general approach says that to measure a person's probability for a single event one can proceed in much the same way as measuring other things, that is by comparison with a standard. An elementary standard that can be expected to be the most widely understood, because of its simplicity is an urn or bag containing a certain number n of balls, of which m are white, and the remaining are black. Using this device, a person's probability for an event, about which this person is uncertain, is equal to m/n if that person judges the event's uncertainty to be the same as the uncertainty of drawing a white ball from the urn. Thus, the operational part of the measurement of an individual's probability consists of adjusting the proportion of white balls until an observable point of indifference is achieved.[5] This involves some important features. First, there is exactly one proportion that characterizes such a point of indifference as two different proportions express two different probabilities for extracting a white ball. Hence, the probability is given by a single number. Second, the measurement process concentrates on the single event (Section 'From the notion of event to subjective probability') of interest: There is exactly one ball to be drawn from the urn and there is only a single unique event for which our probability is being assessed. There are no repeated draws of balls as might be imagined by reference to frequentist ideas. Thus, in summary, the notion of probability can operationally be considered in terms of an equivalence judgment in comparison with various proportions.

[4]The insistence on an operational definition is not original to the field of probability. de Finetti,[15,16,18] for example, refers repeatedly to physics.[11] Further references can also be found in Lad.[31]

[5]As an aside, note that it is in the logic of this scheme to equate the sure event with an urn in which all balls are white and the impossible event with an urn with no white balls.

A side-note on objectivity

An aspect that deserves a brief comment at this juncture is that persons inclined to question or doubt the subjective view of probability often advocate the notion of "objectivity" as the counterpart ideal. This notion is so widely and commonly used that its vague and usually undefined meaning often goes unnoticed. For example, the well-known National Academy of Science report[40] contains statements such as: "The goal is to make scientific investigations as objective as possible so the results do not depend on the investigator" (p. 107); "the premium that science places on precision, objectivity, critical thinking (…)" (p. 108); "this is not to say that tool mark [sic] analysis needs to be as objective as DNA analysis in order to provide value" (p. 130); "an attempt at an objective system for identifying "matches" (…)" (p. 133) or "(…) questioning of the value and scientific objectivity of such evidence" (p. 146). Such expressions intend to describe a feature of science and its practice that purportedly exists independently of human activity. This character is similarly transposed to probability as an aspect ascribed to the outside world, rather than as a connection between thinking individual and the outside world as emphasized in the subjectivist approach.

One is obviously free not to regard probability as a personal belief, but still one's analyses are inevitably based on hypotheses that are judged reasonable. In forensic science, a typical example for this is found in models used to characterize the rarity of analytical features (e.g., DNA profiles). Evett and Weir, for instance, consider that "(…) objectivity is itself an illusion because it exists only within a framework of assumptions."[26] They exemplify this position by arguing that "(…) we do not accept that DNA statistics are objective in the sense of being independent of human judgment. In spite of the often elegant mathematical arguments we have presented, we stress that the final statistical values depend wholly on the initial assumptions. The validity of these assumptions in any given case are [sic] a matter for expert opinion, so that we claim "objective science" can exist only within the framework of subjective judgment"[26] (This is a particular instance of a more general standpoint that Lindley has described as follows: "[M]y own view is that the probabilities that are essential for the appreciation of uncertain affairs, must be subjective (…). Objectivity is merely subjectivity when nearly everyone agrees."[37] Similarly, Bernardo and Smith consider that "(…) objectivity has no meaning in this context apart from that pragmatically endowed by thinking of it as a shorthand for subjective consensus."[7] Objectivity is sometimes upheld as an ideal because subjectivity is seen with prejudice and negative connotations such as partiality, bias, or arbitrariness. This is not the intended meaning; however, because subjectivity as an attribute of probability merely means that it is a personal judgment of an individual. To help avoid misunderstandings, standard literature on this interpretation of probability, including discussions with forensic scientists,[6,47] sometimes uses the term "personal" (i.e., personal probability) as an equivalent to "subjective." It emphasizes that interpreting probability as belief thus is not tantamount to uninformed or deliberate opinion.

Discussion: Implications of Adopting Subjective Probability

The general outline of key aspects of the subjectivist interpretation of probability, as presented in Section 3.3 (The subectivist standpoint), sheds a clarifying light on questions and issues about the nature and understanding of probability raised in Section 2 (Motivation). Moreover, it also offers an opportunity to explore further implications regarding reasoning under uncertainty as encountered by forensic scientists and other participants in the legal process. We now turn to these.

Does it make sense to enquire about "the probability"?

"What is the probability that these unidentified human remains are those of this missing person?" This is one example of a question that might be asked in the context of forensic identification of human remains. At first sight, it would seem that this question is appropriately formulated, but from a genuinely subjectivist viewpoint one needs to conclude that the question does not make any sense. Missing person identification is surely an activity worthy of practicing, but the formulation "the probability" is defective. According to the belief-type interpretation of probability presented throughout Section 3.3 (The subectivist standpoint), probability only makes sense to an individual person. That may be you, the reader of these lines, the author of this text, or any other person. Reasoning individuals thus should enquire about *their* probability, not *the* probability. For de Finetti, it is this relative character of probability that deconstructs "(…) the myth of a true probability, existing in the "realm of darkness and mystery" of ultrasensible reality (…)."[22] Let us recall that he described his own position as follows:

"Probability exists for me only as a function of the degree of ignorance in which I find myself at the time; it would be absurd, even if it were not meaningless, to consider probability as a mysterious and unreachable metaphysical entity, existing in abstraction, on which the occurrence of an event somehow or other depends."[22]

Arguing otherwise, still according to de Finetti, is prone to lead to absurd considerations:

"To consider probability (…) as a metaphysical entity that exists in abstract is like thinking that it is possible (without being Alice in Wonderland) that the cat's smile can remain and continue to be visible even after the cat has disappeared. I have vehemently rejected all conceptions of probability in such an absolute sense (in the preface to the English edition of my treatise) by suggesting as a motto: "Probability does not exist" by which I mean that probability does not "exist" on its own, independently of the evaluations we make of it mentally or instinctively. As a result, it has no meaning to wonder "what probability is," we should instead mediate (…) in which sense we evaluate it (…)."[19]

The question "what is the probability (…)" is not only defective because of the "the," but also because of the "is".

Are probabilities a case of computing?

In the absence of an explicit reference to a particular person, the notion of probability is suggestive of a property of the outside world that exists independently of the reasoning individual, and that could be worked out through the application of an abstract computational procedure. This seems to be the idea underlying the proposals for computing probabilities, as conveyed by the "guidelines for objectively computing prior odds," mentioned previously in Section 2 (Motivation). On a conceptual account, this is a debatable view because it suggests that artificial devices or computational procedures[6] could serve as a substitute for the expert's reasoning. This is not meant to question the wider use of models[7] for representing phenomena and processes of the real world at some level of abstraction. The point is that a distinction needs to be made between the specification of a model, the use, and the analysis of a model. Merely running a model can well reduce to an abstract operation run by a machine, but the definition of a model for the particular needs in a case at hand requires informed judgment by the scientist.[36] As noted by Lindley:

"In the application of Bayesian methods, you first need to assign some basic probabilities (…) to give the problem structure; then the computer can derive other probabilities. One must think about the basic values and it is not usually satisfactory to use (…) noninformative priors. You must think about the real quantities involved, like temperature or blood pressure, and not about symbols that represent them. This distinction between the thinking you and the unthinking, calculating personal computer is essential."[29]

The opinion that one could obtain a probability as a direct output of the application of an abstract procedure also raises more fundamental problems. With respect to the principle of indifference, for example, literature in philosophy of science has objected against a rule that claims to "produce" probabilities out of "nothing," by calling such a pretension epistemological magic:[45]

"Of course, there are always ways of transforming ignorance into knowledge – by further investigation and the accumulation of more information. It is the same with all "magic"; to get the rabbit out of the hat you first have to put him in. The principle of indifference tries to perform 'real magic.'"[45]

At times, artificial devices for "deriving" probabilities are proposed as a way to deal with the commonly raised difficulty according to which "one does not know the probability," so it is worthwhile to include this aspect in the discussion. The problem of (absence of) "knowledge of the probability" may appear real to anybody thinking about the task of assigning a probability in a given case, in particular where this may be difficult to do. This, however, is neither an issue of

[6]A very general example is the idea of taking the initial probability of guilt to be $1/N$ if there are N people who could have committed the crime.

[7]Typical examples for models in forensic science are found in population genetics, where models are specified to work out population proportions (i.e., proportions of populations that have particular genetic traits).

"knowledge of probability," nor a "problem" of probability itself. It is merely a problem of a particular interpretation of probability (i.e., other than the subjectivist interpretation). It is, in the words of de Finetti, a "pseudo-problem,"[17] that vanishes if probability is understood as personal belief:

"Among the answers that do not make sense, and cannot be admitted, are the following: "I do not know," "I am ignorant of what the probability is," "in my opinion the probability does not exist." Probability (or prevision) is not something which in itself can be known or not known: It exists in that it serves to express, in a precise fashion, for each individual, his choice in his given state of ignorance."[18]

The difficulties experienced in probability assessment relate only to the practice of the concept (of probability measurement), but not to the concept itself.[38]

Should scientists recommend probabilities?

Given that probability is a personal affair, it cannot be contested that scientists have their own opinions on a given issue. On some issues, their opinions may concur fairly and precisely while on others they may diverge. What can be questioned, however, is whether such opinion is contextually relevant and whether it should be imposed or recommended to other participants in the legal process. To use again the example of missing person identification, the question is whether a scientist should elaborate on prior probabilities for a proposition (i.e., regarding the origin of unidentified human remains) that is in the area of competence of another person (e.g., an official who is in charge of a decision). This kind of question arises analogously in virtually any branch where forensic science results are used to infer about propositions of interest in legal cases (e.g., the question whether a particular person wrote a signature, left a fingermark, etc.).

More generally, the recommendation and prescription of probabilities raises both procedural and conceptual questions. The procedural concerns are most typically illustrated with respect to prior probabilities:

"The expert, however, has no role in assessing the prior odds: These are for the fact-finder, based on the nonexpert evidence she has heard. Nor has the expert any business in testifying in terms of the posterior odds; these, too, are for the fact-finder, and because they can only be arrived at by assessing the prior odds, the expert cannot legitimately make statements about them. To put it less abstractly, the expert should not testify in terms such as "in my opinion the glass came from the broken window," or "the blood probably came from the defendant," because one can only reach conclusions of this sort by making assumptions about the strength of other evidence against the defendant."[41]

This constitutes strong procedural advice against the recommendation of prior odds by forensic scientists. Interestingly, they concur entirely with the insight that stems from the conceptual account advocated throughout this paper: The very understanding of prior odds as a distinct personal belief of each reasoning individual opposes the idea that one ought to prescribe to others what their prior beliefs ought to be. The best that one can do in such situations is to establish the range of inferences that might be made from available evidence on the basis of a range of prior opinions.

A situation in which the elaboration of prior probabilities by scientists could be considered as procedurally and conceptually acceptable is when it is the scientist who is also in charge of acting upon his belief, as may be the case in some jurisdictions with coroners who investigate the cause and time of death for legal purpose.[50] Yet another situation in which scientists may legitimately formulate probabilities is when they intervene at the investigative phase and express, for example, an opinion about a matter that can reasonably be confined to technical and scientific considerations only (e.g., the cause of a technical failure, cause of a fire etc.).[28]

Further implications

The role of scientists in the legal process

That probability assignment is met with skepticism is not peculiar to forensic science and the law. The concern is well-known throughout science and has preoccupied the thinkers that have worked at the forefront of probability theory. Savage, for instance, has been most prudent by emphasizing the following:

"Quite contrary to a misconception that has been encountered, we do not advocate that the personal opinions of the statistician be foisted on the scientific community, the business executive, or other "clients" of the statistician. Rather, the role of the statistician is to help his clients mature and co-ordinate their own opinions."[17][8]

Lindley also uses the term "client" in reference to persons such as lawyers who need to reason with imperfect information:

"The philosophical position adopted here is that statistics is essentially the study of uncertainty and that the statistician's role is to assist workers in other fields, the clients, who encounter uncertainty in their work."[36]

"[I]n doing this, the subject, whose probabilities are being sought, the "you" in the language adopted here, is not the statistician, but the client, often a scientist who has asked for statistical advice. The statistician's task is to articulate the scientist's uncertainties in the language of probability, and then to compute with the numbers found."[36]

This standpoint is well in agreement with traditional argument according to which probability concepts (in particular Bayes' theorem) have long been presented and promoted as a way to clarify the respective roles of the court and the forensic scientists commissioned as experts witnesses.[49] It is the court's or jury's initial opinions, typically based on other evidence present in the file, that ought to be combined and, hence, refined with scientific findings provided by the forensic scientist. In essence, this translates Savage's idea of "maturing opinions" quoted above. The understanding of probability as

[8]Chapter 8, "how to choose the initial probabilities," p. 144; "English summary" by L. J. Savage for the joint paper with de Finetti[24] published in Italian.

an expression of a personalized view is most supportive of this way of proceeding. As noted by Evett and Weir, "[u]ltimately, it must always be the jurors, or other triers of fact, whose belief in the proposition of an identical source that matters."[26]

The probabilization of forensic science

In his paper entitled "the scientification of forensic practice," Garbolino[27] argues that the introduction of probabilistic considerations in forensic science provides an instance of what the historian of science Cohen[13] has called the "probabilizing revolution," a fundamental influence on a field through probability. In forensic science, the impact of probability is groundbreaking in that it provides, since its early usage by Darboux, Appell, and Poincaré in the Dreyfus case,[49] a reference scheme for measuring uncertainty that allows scientists and other participants in the legal process to investigate, expose, and communicate the strengths and limitations of scientific findings at unprecedented levels of insight. Moreover, the continuing accumulation of quantitative data that asks for coherent treatment, and novel frameworks for probabilistic model construction and analysis (e.g., Bayesian networks[48]), make the probabilization of forensic science an ongoing process. It is a process that adds value to the use of forensic science for legal purposes.

Notwithstanding the position of probability in legal proceedings is fragile. Beyond its uncontested mathematical foundations, the probability is perceived in divergent ways and disagreement exists about the extent to which it can be applied for evaluating forensic findings. Recurrent controversies over topics such as initial probabilities as referred to throughout this article exemplify this. It is worth noting, however, that such instances of disagreement are essentially ones that are rooted in the question of how to interpret probability; they are not an issue about probability as such. The proper choice of an interpretation of probability thus is central for a meaningful use in forensic practice and this, hence, represents a critical factor for the ongoing probabilization of forensic science. The subjectivist perspective offers one such interpretation. It is both a meaningful and operationally feasible interpretation that, according to the positions justified in the previous sections, can help avoid inferential impasses to which other common interpretations may lead.

Conclusions

The probabilization of forensic science is an important topic that, on a more general account, can be seen as part of a broader intellectual development according to which "(…) the availability of powerful and logical tools accessible to all is essentially a question of democracy, as it involves the ability of citizens to understand and control the decision-making processes upon which their welfare and their own lives depend."[9][14]

[9]Translation by the author (*Italics* as in the original): "Così, la disponibilità di strumenti logici potenti e *accessibili a tutti* è essenzialmente una questione di democrazia, in quanto investe la possibilità dei cittadini di comprendere e controllare i processi decisionali dai quali dipende il loro benessere e la loro stessa vita."14, p. 11

Understanding probability in a subjective perspective is valuable for this endeavor in that it emphasizes an individual's viewpoint. Probability is not a concept that is exclusively reserved to scientists, but a personal matter that everyone ought to care about seriously because it is the key concept to "(…) equip you with enough skill, so that you can appreciate an uncertain situation sufficiently well to see whether another person, lawyer, politician, scientist, or journalist, is talking sense, posing the right questions, and obtaining sound answers."[38] These features crystallize most prominently in the context of the legal process where the reasoning processes of the various participants ought to be individualized (i.e., personal), transparent and based on logical considerations. By embracing real situations faced by any reasoning individual, the subjectivist viewpoint emphasizes an operational perspective that is accessible to all participants in the legal process, yet encourages them to take on an active part and responsibility in the scrutinizing of reasoning processes. This offers a viable alternative to so-called objectivist concepts and probability interpretations that come at the cost of applicability problems.

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References

1. Aitken CG, Roberts P, Jackson G. Fundamentals of Probability and Statistical Evidence in Criminal Proceedings (Practitioner Guide No. 1), Guidance for Judges, Lawyers, Forensic Scientists and Expert Witnesses, Royal Statistical Society's Working Group on Statistics and the Law; 2010.
2. Aitken CG, Taroni F. Statistics and the Evaluation of Evidence for Forensic Scientists. 2nd ed. Chichester: John Wiley and Sons; 2004.
3. Anderson T, Twining W. Analysis of Evidence: How to do Things with Facts Based on Wigmore's Science of Judicial Proof. Evanston: Northwestern University Press; 1998.
4. Association of Forensic Science Providers. Standards for the formulation of evaluative forensic science expert opinion. Sci Justice 2009;49:161-4.
5. Aven T, Reniers G. How to define and interpret a probability in a risk and safety setting. Saf Sci 2013;51:223-31.
6. Berger CE, Buckleton J, Champod C, Evett IW, Jackson G. Evidence evaluation: A response to the court of appeal judgment in R v T. Sci Justice 2011;51:43-9.
7. Bernardo JM, Smith AF. Bayesian Theory. 2nd ed. Chichester: John Wiley and Sons; 2000.
8. Biedermann A, Taroni F, Aitken CG. Letter to the Editor: ENFSI Expert Working Group, Marks Conclusion Scale Committee. Conclusion scale for shoeprint and toolmarks examinations. J Forensic Identification 2006;56:685-9.

9. Biedermann A, Taroni F, Garbolino P. Equal prior probabilities: Can one do any better? Forensic Sci Int 2007;172:85-93.
10. Biedermann A, Taroni F, Margot P. Reply to Budowle, Ge, Chakraborty and Gill-King: Use of prior odds for missing persons identifications. Investig Genet 2012;3:2.
11. Bridgman P. The Logic of Modern Physics. New York: Macmillan; 1927.
12. Budowle B, Ge J, Chakraborty R, Gill-King H. Use of prior odds for missing persons identifications. Investig Genet 2011;2:15.
13. Cohen B. Scientific revolutions, revolutions in science, and a probabilistic revolution 1800-1930. In: Krger L, Daston LJ, Heidelberger M, editors. The Probabilistic Revolution. Ideas in History. Vol. 1. Cambridge (Mass): The MIT Press; 2013. p. 23-44.
14. D'Agostino M, Giorello G, Veca S, editors. Ragionare dobbiamo, e spesso. In: Logica e politica, per Marco Mondadori. Milano: Il Saggiatore; 2001. p. 11-4.
15. de Finetti B. La prévision: Ses lois logiques, ses sources subjectives. Ann Inst Henri Poincaré 1937;7:1-68. (English translation), In: Kyburg HE, Smokler HE, editors. Studies in Subjective Probability. 2nd ed. New York: Dover; 1980. p. 93-158.
16. de Finetti B. The theory of probability in its relationships with the analysis (Translation of an essay published in "Relazioni della XXVIII Riunione della Società Italiana per il Progresso delle Scienze" (Reports of the XXVI Meeting of the Italian Society for the Advancement of Science), Pisa, 11-15, October 1939, Vol. 3, Sec. A, Roma, 1940, pp. 27-35), In: Monari P, Cocchi D, editors. Bruno de Finetti, Probabilità e Induzione (Probability and Induction). Bologna: Bibliotheca di Statistica; 1993. p. 365-74.
17. de Finetti B. Probability, Induction and Statistics, The Art of Guessing. New York: John Wiley and Sons; 1972.
18. de Finetti B. Theory of Probability, A Critical Introductory Treatment. Vol. 1. London: John Wiley and Sons; 1974.
19. de Finetti B. Probability: Beware of falsifications! (Reprinted from: Scientia 1976;111:283-303). In: Kyburg HE, Smokler HE, editors. Studies in Subjective Probability. New York: Robert E. Krieger Publishing Company; 1980. p. 195-224.
20. de Finetti B. The role of probability in the different attitudes of scientific thinking (1977). In: Monari P, Cocchi D, editors. Bruno de Finetti, Probabilità e induzione (Probability and Induction). Bologna: Biblioteca di Statistica; 1993. p. 491-511.
21. de Finetti B. Probabilità. In: Enciclopedia. Vol. 10. Torino: Einaudi; 1980. p. 1146-87.
22. de Finetti B. Probabilism. Erkenntnis 1989;31:169-223.
23. de Finetti B. The notion of event (Translation of the essay published in "Atti del Congresso di Metodologia" (Proceedings of Congress of Methodology), Centro di Studi Metodologici, Torino, (17-20 dicembre 1952), Edizioni Ramella, Torino, 1952. p. 170-4), In: de Finetti B, editor. Probabilità e induzione (Probability and Induction). Bologna: Biblioteca di Statistica, Cooperativa Libraria Universitaria Editrice Bologna; 1993. p. 415-9.
24. de Finetti B, Savage LJ. Sul modo di scegliere le probabilità iniziali. Bibl Metron 1962;1:81-154.
25. ENFSI Expert Working Group Marks Conclusion Scale Committee. Conclusion scale for shoeprint and toolmarks examinations. J Forensic Identification 2006;56:255-80.
26. Evett IW, Weir BS. Interpreting DNA Evidence. Sunderland: Sinauer Associates Inc.; 1998.
27. Garbolino P. The scientification of forensic practice. In: Andersen H, *et al*., editors. New Challenges to Philosophy of Science. The Philosophy of Science in a European Perspective. Vol. 4. Dordrecht: Springer Science+Business Media; 2013. p. 287-97.
28. Jackson G, Aitken CG, Roberts P. Case Assessment and Interpretation of Expert Evidence (Practitioner Guide No. 4), Guidance for Judges, Lawyers, Forensic Scientists and Expert Witnesses, Royal Statistical Society's Working Group on Statistics and the Law; 2013.
29. Joyce H. Bayesian thoughts. Communication with Dennis Lindley. Significance 2004;1:73-5.
30. Kaplan J. Decision theory and the factfinding process. Stanford Law Rev 1968;20:1065-92.
31. Lad F. Operational Subjective Statistical Methods: A Mathematical, Philosophical, and Historical Introduction. New York: John Wiley and Sons; 1996.
32. Lad F. Objective Bayesian statistics Do you buy it? Should we sell it? (Comment on articles by Berger and by Goldstein). Bayesian Anal 2006;1:441.
33. Laplace PS. Essai Philosophique sur les Probabilités (1814) (Reprinted in: Cambridge Library Collection). Paris (Cambridge): Bachelier (Cambridge University Press); 2006.
34. Lindley D. Making Decisions. 2nd ed. Chichester: John Wiley and Sons; 1985.
35. Lindley DV. Probability. In: Aitken CG, Stoney DA, editors. The Use of Statistics in Forensic Science. New York: Ellis Horwood; 1991. p. 27-50.
36. Lindley DV. The philosophy of statistics. Statistician 2000;49:293-337.
37. Lindley DV. That wretched prior. Significance 2004;1:85-7.
38. Lindley DV. Understanding Uncertainty. Hoboken: John Wiley and Sons; 2006.
39. Lindley DV. Understanding Uncertainty. Revised Edition. Hoboken: John Wiley and Sons; 2014.
40. National Research Council. Strengthening Forensic Science in the United States: A Path Forward. Washington, DC: National Academy Press; 2009.
41. Redmayne M. Expert Evidence and Criminal Justice. Oxford: Oxford University Press; 2001.
42. R. v T. [2010] EWCA Crim 2439. http://www.bailii.org/ew/cases/EWCA/Crim/2010/2439.html. [Last accessed on 2010 Oct 26].
43. Roberts P, Aitken CG. The Logic of Forensic Proof: Inferential Reasoning in Criminal Evidence and Forensic Science (Practitioner Guide No. 3), Guidance for Judges, Lawyers, Forensic Scientists and Expert Witnesses, Royal Statistical Society's Working Group on Statistics and the Law; 2013.
44. Robertson B, Vignaux GA. Interpreting Evidence. Evaluating Forensic Science in the Courtroom. Chichester: John Wiley and Sons; 1995.
45. Salmon WC. The Foundations of Scientific Inference. Pittsburgh, PA: University of Pittsburgh Press; 1966.
46. Schum DA. Evidential Foundations of Probabilistic Reasoning. New York: John Wiley and Sons, Inc.; 1994.
47. Taroni F, Aitken CG, Garbolino P. De Finetti's subjectivism, the assessment of probabilities and the evaluation of evidence: A commentary for forensic scientists. Sci Justice 2001;41:145-50.
48. Taroni F, Biedermann A, Bozza S, Garbolino G, Aitken CG. Bayesian Networks for Probabilistic Inference and Decision Analysis in Forensic Science, Statistics in Practice. 2nd ed. Chichester: John Wiley and Sons; 2014.
49. Taroni F, Champod C, Margot P. Forerunners of Bayesianism in early forensic science. Jurimetrics J 1998;38:183-200.
50. Thompson WC, Vuille J, Biedermann A, Taroni F. The role of prior probability in forensic assessments. Front Genet 2013;4:220.