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More on the question 'When does absence of evidence constitute evidence of absence?' How Bayesian confirmation theory can logically support the answer

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ABSTRACT

In forensic science it is not rare that common sayings are used to support particular inferences. A typical example is the adage 'The absence of evidence is not evidence of absence'. This paper analyzes the rationale hidden behind such statement and it offers a structural way to approach the analysis of this particular adage throughout a careful analysis of four different scenarios.

1. Introduction

The adage 'The absence of evidence is *not* evidence of absence' is widely used and commonly illustrated with reference to the writings of Conan Doyle.[1] The dictum has also attracted interest among scientists. Their analyses of the rationale hidden behind the statement led some scientists to support it, others to criticized it. Recently, Thompson and Scurich [1] addressed the question 'does the absence of evidence constitute evidence of absence?'. Through their comments and illustrative examples, they provided an affirmative answer.

In this note, we will argue that the positive reply to the above question can also be based on what is known as Bayesian Confirmation Theory, an approach that offers theoretical bases. Note that the question of interest refers to the term 'absence of evidence'. Thus, we will also seek to clarify some terminology associated with the term 'evidence' that is commonly used in inferential contexts. Moreover, some case examples of likelihood ratio calculation when 'absence of evidence' is reported by a forensic scientist will be introduced and discussed.

2. Terminology related to the term 'evidence'

Start by considering some clarifying notes on terminology. Legal and forensic science publications, including experts' claims in court, commonly make use of a specialist terminology that may seem self-explanatory at first sight, but can be tricky upon further scrutiny. Examples of terms that are often used, sometimes as synonyms, are *absence of* evidence, *negative* evidence, or even *missing* evidence.

Thompson and Scurich defined *negative* evidence as 'the failure to find a trace after looking for it' [1 at p. 1]. In turn, Hicks et al. [2] use the term *absence* of DNA in a case where a scientist searches extraneous biological material on the T-Shirt of a person of interest: here, the event of absence of any DNA profile other than that of the T-shirt owner is referred to as *absence* of evidence.

The term *missing* evidence can be found in Schum [3] who calls evidence *missing* if it is expected, but it is neither found nor produced on request. Lindley and Eggleston [4] present the example of a collision between two motor cars, with no paint flakes being recovered *after search* by an investigator. Their case is as follows and will help us in clarifying the multiple terms used:

"The plaintiff sues the defendant, claiming that it was his car that collided with the plaintiff's. The evidence of identification is weak, and the defendant relies on the fact that, his car being

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[1] As mentioned by Thompson and Scurich [1], in Conan Doyle's novel 'The Silver Blaze', the following dialogue can be found: Inspector Gregory: Is there any other point to which you would wish to draw my attention? Sherlock Holmes: To the curious incident of the dog in the night-time. Inspector Gregory: The dog did nothing in the night-time. Sherlock Holmes: That was the curious incident.

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red, the plaintiff has produced no evidence that any paint, red or otherwise, was found on the plaintiff's car after the collision."

If this case example uses the term *missing* evidence, then what is *negative* evidence and *absence* of evidence?

Kadane and Schum [5] defined those terms as follows:

"Evidence of the occurrence of an event is sometimes described as *positive evidence*; evidence of the nonoccurrence of an event is said to be *negative evidence*." (at p. 59)

Schum [3] previously noted that:

"It is often common to focus on evidence regarding the occurrence of events and easy to overlook evidence regarding the nonoccurrence of events. In any inferential context it is just as important to inquire about what did not happen as it is to inquire about what did happen." (at p. 96)

An example of this line of reasoning will be presented in Section 3 of this commentary when we will provide a formal analysis using the Bayesian framework.

Schum [3] also distinguishes between the adjectives *negative* and *missing*, used to charaterize evidence. He notes:

"It is quite important to note that having no evidence about an event E is not the same as having evidence that E did not occur. The distinction between negative evidence and missing evidence is not always made." (at p. 97)

How does this relate to the *absence* of evidence? Absence of evidence can be considered as a generic term for negative and missing evidence. Kadane and Schum [5] clarified the point by affirming that:

"[. . .] negative evidence is frequently missing because the nonoccurrence of events is not always reported or recognized. In the construction of arguments [. . .] there will be instances in which we note the *absence of evidence* on a particular matter." (at p. 59)

Differences exist in legal terminology. The notion *absence of evidence* can be considered as a generic term that encapsulates two aspects: on one side, the adjective *negative* evidence that specifies the non-occurrence of an expected event in cases where the scientist looks for a given item of evidence and he or she did not observe it (i.e. the scientist did not observe the presence of a given DNA profile of interest on a receptor, but he observed another DNA profile or nothing at all). On the other side, *missing* evidence can be used to characterize the absence of information about the state of the expected evidence because the scientist did not report it. The reason not to report seems not to play a fundamental role. Schum [3] and Kadane and Schum [5] agreed on the fact that the information is not acquired after a search of the evidence. But the use of the same adjective can also occur in situations in which the scientist did not even looked for evidence. Here, by consequence, there is uncertainty about the presence (or not) of *positive* evidence and about the existence of a situation involving *absence* of evidence. This situation will be analyzed in Section 3 and developed throughout some case examples in Section 4.

3. How can Bayesian theory help us to reply to the question?

In this Section we will analyze some assumptions related to the analysis of the probabilistic relationship between what is called 'absence of evidence' (either *negative* or *missing*) and the notion of 'evidence of absence'.

Following standard forensic and legal terminology and notation, let E denote the evidence and let H denote an hypothesis (i.e., proposition) of interest. The negation of E and H are denoted by $\overline{E}$ and $\overline{H}$, respectively. The sentence 'when does absence of evidence constitute evidence of absence' may then be expressed as 'when does $\overline{E}$ imply $\overline{H}$ as true?'. Stated otherwise, under which conditions is it legitimate to affirm that the absence of evidence, $\overline{E}$, implies evidence of absence, $\overline{H}$? Note that the term 'implication' characterizes here a support for or the strengthening of $\overline{H}$.

Consider again the forensic scenario involving DNA traces that was mentioned above as a case study. The following question may be of interest: under which conditions does the fact of not finding expected evidence (say, a given DNA profile corresponding to a person of interest (the victim) on a given receptor item, such as the suspect's T-shirt) implies or, provide evidence for the proposition that person of interest did *not* commit a given action?

Bayesian theory [6] can help us in the understanding of these matters. The analysis of the dictum 'The absence of evidence is not evidence of absence' can easily find a justification within a logical framework of reasoning. Let us introduce this point more formally.

As it is well known to readers of judicial and forensic science journals, Bayesian reasoning proceeds as follows. Before an item of information — generically called finding, evidence or even observation — is collected (or is known by the person in charge of the inferential reasoning), one starts with initial (prior) probabilities assigned to each of a list of hypotheses of interest, given the knowledge collected until the probabilistic assignment is being made.[2] Available knowledge is usually denoted by the letter B (or I), and the prior probability of the hypothesis of interest H can be formalized as $Pr(H|B)$.

After acquiring a new item of observation, one's prior probabilities assigned to the hypotheses are revised in the light of the new information. Note that such an item of information could be scientific, such as features of a stain or mark, or non-scientific, such as eyewitness testimony. The probabilities assigned before knowing the new information are called *a priori* probabilities, and the probabilities updated with the new information are said *a posteriori* probabilities. The transition from the prior to posterior probability is operated by the Bayes' theorem, which allows one to update prior uncertainty as new information become available.

Note that Bayes' theorem is a natural consequence or the third law of probability and, mathematically, it is not controversial at all [8]. Using the previous introduced terminology — letter E for evidence, letter B for the background knowledge and letter H for the hypothesis — the posterior probability of a hypothesis H can be computed according to Bayes's theorem as:

$$\Pr(H|E,B) = \frac{\Pr(H|B) \times \Pr(E|H,B)}{\Pr(E|B)}.$$

The Bayes theorem provides a qualitative response to the question whether a piece of evidence confirms, or disconfirms, an hypothesis of interest H. In fact, it is possible to consider an item of information E also in terms of its influence on the prior beliefs about the truth or otherwise of a hypothesis H, that is:

1. E confirms or supports H if and only if $Pr(H|E,B) > Pr(H|B)$;
2. E disconfirms or undermines H if and only if $Pr(H|E,B) < Pr(H|B)$;
3. E is neutral with respect to H if and only if $Pr(H|E,B) = Pr(H|B)$.

[2] Note that Hicks et al. [2] and Thompson and Scurich [1] suggest an analysis using hypotheses that are said to be at the 'activity level' [7] because they put forward propositions based on the information given by the parties at trial who are interested in a series of activities (legitimate or not) committed by a given person of interest. In fact, absence of evidence cannot be assessed under 'source level' hypotheses simply because to proceed to an assessment given source level propositions one needs to observe trace material. Here, the scientist is faced to an absence of trace material and that event can only be assessed in relation to activities.

According to Bayesian confirmation theory, it is further possible to provide a quantitative response to the question whether one piece of evidence confirms, or disconfirms, a hypothesis of interest H. One can in fact interpret the difference $Pr(H|E,B) - Pr(H|B)$ as a measure of the degree with which E supports H, and Bayes' theorem constitutes a logical scheme to understand how an item of information supports or undermines given hypotheses. On a conceptual account, Jeffrey [9] has noted the following:

> "Bayesianism does not take the task of scientific methodology to be that of establishing the truth of scientific hypotheses, but to be that of confirming or disconfirming them to degrees which reflect the overall effect of the available evidence — positive, negative, or neutral, as the case may be." (at p. 104)

Note that conditions 1, 2 and 3 can also be formulated in terms of odds. Consider condition 1 for sake of illustration. If $Pr(H|E,B) > Pr(H|B)$ holds, it is immediate to verify that $Pr(H|E,B)/Pr(\overline{H}|E,B) > Pr(H|B)/Pr(\overline{H}|B)$. Conditions 2 and 3 can be reformulated analogously. Recall now the odds form of Bayes' theorem, according to which the posterior odds $Pr(H|E,B)/Pr(\overline{H}|E,B)$ if favor of an hypothesis of interest H can be expressed as the product of the prior odds $Pr(H|B)/Pr(\overline{H}|B)$ and the likelihood ratio $Pr(E|H,B)/Pr(E|\overline{H},B)$. This latter term measures the value of evidence [10], where $\overline{H}$ is also called 'alternative hypothesis' and, in forensic contexts, generally represents the events from the defense's point of view. The three conditions previously introduced can be reformulated as:

1. E confirms H if and only if $Pr(E|H,B) > Pr(E|\overline{H},B)$;
2. E disconfirms H if and only if $Pr(E|H,B) < Pr(E|\overline{H},B)$;
3. $E$is neutral with respect to H if and only if $Pr(E|H,B) = Pr(E|\overline{H},B)$.

How can these conditions help us to contrast the common saying 'The absence of evidence is *not* evidence of absence'?

Consider, for sake of illustration, the example described above where a person of interest is accused of having attacked a victim. Call this contested event the hypothesis, H. DNA corresponding to the victim is expected — assuming H — to be found upon searching the suspect's T-shirt. Forensic scientists do not detect any extraneous biological staining on the suspect's T-shirt. Call this event the results (or observations) $\overline{E}$, the *absence of evidence*. In fact, no evidence of biological staining corresponding to the victim is found on the T-shirt.

Recall that the adage also refers to the 'evidence of absence'. So, the saying 'the absence of evidence is evidence of absence' should have the formal equivalent that an item of evidence, say $\overline{E}$,*decreases* the probability of the hypothesis of interest after such evidence is recorded. In the case considered here, the absence of DNA corresponding to the victim, on the suspect's T-shirt, should decrease the probability of the hypothesis regarding a physical assault committed by the suspect against the victim.

Consider, for the sake of our analysis, that the above-mentioned condition 1 relates to evidence. It states that E confirms H if and only if $Pr(E|H,B) > Pr(E|\overline{H},B)$. Analogously, it follows that $\overline{E}$ disconfirms H (and so $\overline{E}$ confirms $\overline{H}$) if and only if $Pr(\overline{E}|\overline{H},B) > Pr(\overline{E}|H,B)$. So, under this logical framework, and if the numerical assignment for the denominator of the likelihood ratio is greater than that of the numerator, the absence of evidence supports the hypothesis that the suspect did not assault the victim. This, in turn, validates the conclusion that the absence of evidence constitutes evidence of absence. Numerical examples are presented in Refs. [1,2]. Section 4 analyses four different scenarios.

Some particular situations might be encountered. Consider the following one.

Note that the three conditions that have been previously illustrated refer also to the role of the background information B. The background information conditions the probability of the item of information E. It may happen that the absence of evidence is no longer evidence of absence, i.e. the evidence E is neutral with respect to the hypothesis H, depending on the information conveyed by B. Imagine, for example, that the background information relates to the fact that the suspect immediately changed his T-shirt after the alleged facts. Under such a conditioning, we would consider the absence of evidence as uninformative: $Pr(\overline{E}|\overline{H},B)$ would not be assessed to be greater than $Pr(\overline{E}|H,B)$, and so there would be no greater support for hypothesis $\overline{H}$. More detailed examples follow in the next section.

4. Practical examples of likelihood ratio calculation with so called «absence of evidence»

In the present section, four case examples will be introduced and the likelihood ratio will be quantified. Example 1 was originally presented in Hicks et al. [2], while the further three examples cover variations of the first one.

Example 1. Single DNA profile corresponding to the suspect (who is the wearer of the garment).

At first, recall the scenario under study. A crime is committed, and DNA is searched on Mr Smith, here a potential aggressor, arrested 20 min after the alleged event. The prosecutor's view is that Mr Smith attacked Ms Johnson who spat several times on Mr Smith's face and T-shirt. Mr Smith said that he had never met Ms Johnson. From the case information, it is known that Mr Smith was arrested in a bar, which he entered a few minutes after the incident and that he had not changed his T-shirt all day.

The T-shirt of Mr Smith is searched for DNA and the forensic scientist noticed that there was only one single profile that corresponded to its owner (no extraneous DNA).

We can thus define the finding E as *no extraneous DNA*.

In order to evaluate this result, one needs to assign the probability of these results under the competing propositions.

(a) Consider first the prosecution's proposition. If Ms Johnson spat on Mr Smith, and that the forensic scientist observed only a single DNA profile that corresponds to the T-shirt wearer (Mr Smith), then this means that there was no DNA transferred from Ms Johnson when she spat on his t-shirt or that none was recovered. Call this probability t_0. It also means that there was no background (extraneous DNA from some unknown source) on Mr Smith's T-shirt. Call this probability b_0.

(b) Consider the alternative proposition. If Ms Johnson never spat on Mr Smith, then the observation of the single profile that corresponds to him (and so no extraneous background) is simply due to absence of background. We call this probability b_0 as before.

The likelihood ratio formula equals $t_0 b_0 / b_0 = t_0$, a value that has to be larger than 0 (there is no reason to search for DNA if the probability of recovering it is 0) and less than 1. As the LR is smaller than 1, the result "E" supports the alternative proposition representing the case information given by the defense.

Example 2. Single DNA profile corresponding only to the victim (the victim is the wearer of the garment).

Now imagine a variation of the scenario described in Example 1. It is not the victim who spits on the aggressor, but the aggressor who spits on Ms Johnson. It is not contested that the aggressor spat on Ms Johnson, but Mr Smith says he has nothing to do with the incident. DNA corresponding to Ms Johnson only (the wearer of the T-shirt) is recovered. Let E denote the evidence *no extraneous DNA*.

In order to evaluate this result, one needs to assign the probability of these results under the competing propositions.

(a) If Mr Smith spat on Ms Johnson, and the forensic scientist observed only a single DNA profile that corresponds to the T-shirt wearer (Ms Johnson), then this means that there was no DNA transferred from Mr Smith when he spat on her t-shirt or that none was recovered. Call this probability t_0. It also means that there was no background (no extraneous DNA from some unknown source) on Ms Johnson's T-shirt. Call this probability b_0.
(b) If an unknown person spat on Ms Johnson, and no extraneous DNA is found (in fact, a single profile that corresponds to her is recovered), then this means that there was no DNA transferred from the unknown aggressor when he spat on her T-shirt or that none was recovered. Call this probability t'_0. It also means that there was no background on Ms Johnson T-shirt. Call this probability b_0 as before.

The likelihood ratio becomes $t_0b_0/t'_0b_0 = 1$ (if it is assumed that the transfer probabilities are the same for the suspect and the unknown offender, that is if $t_0 = t'_0$). In this particular case, the evidence E is neutral and supports neither proposition.

Example 3. Single DNA profile recovered on the victim corresponding to an unknown person.

Imagine now that the case circumstances are the same as those described in Example 2: the aggressor spits on Ms Johnson. It is not contested either that the aggressor spat on Ms Johnson, and as before Mr Smith says he has nothing to do with the incident.

Here, however, the results are different and on the victim's t-shirt, one recovers a single non matching DNA profile. This single DNA profile corresponds to neither the victim nor the suspect, but to an unknown individual.

Let E denote the evidence that now is *single non-matching DNA profile*.

In order to evaluate this result, one needs to assign the probability of these results under the competing propositions.

(a) If Mr Smith spat on Ms Johnson, then how can we explain that the forensic scientist observed one single profile that does not correspond to anyone (i.e., there is extraneous DNA)? This means that there was no DNA transferred or recovered from Mr Smith on Ms Johnson. This happens with probability t_0. The extraneous DNA corresponds to an unknown individual, so the numerator of the likelihood ratio becomes $t_0b_1\gamma$, where γ refers to the probability of observing the DNA profile of the recovered DNA in a relevant population and b_1 is the probability of observing a DNA profile as background.
(b) If it is some unknown person who spat on Ms Johnson, then the observation of the single profile that corresponds to an unknown individual can be explained by two possibilities. Either there was no transfer from this unknown person to Ms Johnson and the DNA is due to background, this happens with probability $t'_0b_1\gamma$. The second explanation is that there was transfer from this unknown person to Ms Johnson, this unknown's DNA profile occurs with probability γ, and there was no DNA due to background. This happens with probability $t'\gamma b_0$, where t' denotes the transfer from an alternative aggressor.

If the transfer probabilities of the unknown offender is similar to Mr Smith's (which seems a reasonable assumption), then one can see that the numerator is smaller than the denominator, as the LR simplifies to:

$$LR = \frac{t_0b_1\gamma}{t'_0b_1\gamma \ + t'\gamma b_0} = \frac{t_0b_1}{t'_0b_1 \ + t'b_0}.$$

This result (a single non-matching DNA profile from a trace recovered on the victim) will support defence's proposition.

Example 4. Single DNA profile corresponding to an unknown person recovered on the clothing of the suspect (the wearer of the garment).

As a last example, consider a situation similar to that described in Example 1 (victim spits on offender). However, in this latter case example a single DNA non matching profile that corresponds to none of the known persons involved is recovered on the suspect's T-shirt. What is the probability of this result given the two propositions?

(a) If Ms Johnson (the potential victim) spat on Mr Smith, then how can we explain that the forensic scientist observed a single non matching profile on the suspect's T-shirt? This would mean that there was no DNA transferred or none was recovered on Mr Smith's T-shirt (this happens with probability t_0) from Ms Johnson but there was background (with probability b_1), with occurrence γ. So, the probability at the numerator of the likelihood ratio can be quantified as $t_0b_1\gamma$.
(b) If Ms Johnson never spat on Mr Smith, then the DNA is present as background. The probability at the denominator of the likelihood ratio can be quantified as $b_1\gamma$.

The likelihood ratio simplifies to $t_0b_1\gamma/b_1\gamma = t_0$. This is similar to the first example, recovering non-matching DNA on the suspect supports defence proposition.

The above examples show that different situations involving what has been called *absence of evidence* has no fixed evidential value. However, if the alternative hypothesis does not imply a similar activity as prosecution's, then both recovering no DNA or a non-matching DNA will generally support the alternative hypothesis given by the defence.

If the activities are similar (the suspect or an alternative offender spat on the victim), then finding no extraneous DNA on the victim is neutral, but recovering non matching DNA supports the alternative. It is thus of paramount importance to define what is 'absence of evidence', to specify the activities (or lack of it) and to assess the probability of the results in the given case.

5. Conclusion

In forensic science it is not rare that common sayings are used to support particular inferences. A typical example is the adage 'The absence of evidence is *not* evidence of absence'. This paper analyzes the rationale hidden behind such statement and it offers a structural way to approach the analysis of this particular adage throughout a careful analysis of four different scenarios.

Bayesian theory offers a justification within a logical framework of reasoning to affirmatively answer — under peculiar situations — to the question 'does the absence of evidence constitute evidence of absence?'

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