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An Argumentation Interface for Expert Opinion Evidence

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Abstract

Tribunals have come to depend increasingly on expertise for determining the facts in cases. However, current legal methods have proved problematic to work with. This paper argues that, as a special model of public understanding of science, assessing expertise should consider source credibility of expertise from internal aspects, including scientific validity and reliability, and external aspects involving the credibility of experts. Using the Carneades Argumentation System we show that the internal and the external aspects are mediated by the structure of the argument from expert opinion with its matching set of critical questions.

Keywords: expert opinion testimony; evidence; source credibility; internal credibility; external credibility; argumentation scheme; scientific inquiry

1. Introduction

Because the factual truths in dispute often go beyond what the fact-finders can be expected to know, tribunals have come increasingly to depend on expertise for determining the facts in cases. It is important to know whether jurors can be trusted to properly assess expertise, and what decision aids might assist them in this task. For more than four decades, researchers have studied the ways that people process witness testimony on the model of judicial decision-making based on evidence (Pennington and Hastie, 1993), but few of these studies focus on the intrapersonal status of fact-finders to process expertise in a rational manner. The *Daubert* criteria have proved problematic to work with, and even though subsequent rulings have made further modifications, the whole area of expert testimony evidence remains in an unsatisfactory state (Walton, 2008, 265). This paper provides a different analytic framework for fact-finders to assess and respond to expertise in the courtroom. In Part 2, the paper critically reviews current methods and their quandaries in the assessment of expertise and argues that assessing expertise requires a special model of public understanding of science. Based on this presumption, Part 3 elaborates the source credibility of expertise from internal aspects, which includes scientific validity and reliability, and external aspects, which involve the credibility of an expert. In Part 4, a model for the revision and justification of beliefs about expertise is developed. It shows how a rational response to expertise is belief revision based on the fact-finders' subjective intrapersonal assessment of argument from expert opinion in the given case.

2. Current Legal Methods for Assessing Expertise in the Courtroom and their Quandaries

2.1 From Frye *to Post-*Daubert

The first systematic attempt to set out requirements for the admissibility and acceptance of evidence based on expert opinion testimony had not been established until 1923 in *Frye v. United States*, and the subsequent *Daubert* trilogy of cases extending this method. In *Frye v. United States*, which involved a murder trial in which the defendant sought to demonstrate his innocence through the admission of a lie detector test that measured systolic blood pressure, the court announced that a novel scientific technique "must be sufficiently established to have gained general acceptance in the particular field in which it belongs". In *Daubert v. Merrell Dow*

Pharmaceuticals, Inc., the Supreme Court explained that in order for expert testimony to be considered reliable, the expert must have derived his or her conclusions from the scientific method. In explaining this evidentiary standard, the *Daubert* Court pointed to several factors that should be considered by a trial judge: (1) whether a theory or technique can be (and has been) tested; (2) whether the theory or technique has been subjected to peer review and publication; (3) the known or potential rate of error of a particular scientific technique; (4) the existence and maintenance of standards controlling the technique's operation; and (5) a scientific technique's degree of acceptance within a relevant scientific community. A critical difference between *Daubert* and *Frye* is the shift from proxy criteria for assessing scientific evidence to a direct judicial inquiry into scientific validity (Black et al, 1994, 715). *Fry*e, on its face, does not ask the judge to decide whether the evidence is reliable, but whether the expert community deems it reliable, while *Daubert* requires the judge to personally assess the reliability of the evidence (Mnookin, 2007, 764).

In *Kumho Tire Co. v. Carmichael*, the Supreme Court shifted the question whether an instance of expert testimony is "scientific" to whether it is "reliable". In the post-*Daubert* era, when the new FRE 702 was written, the key term is "knowledge", not "scientific".

2.2 The Quandaries of Current Legal Methods

The notion of a quandary is an epistemic concept relating to evidence-based knowledge in conditions of uncertainty where the given evidence is insufficient to know what to do. In the sense we use the term in this paper, a *quandary* is a given evidential situation of difficulty or perplexity in which there is a difficult decision or choice where the evidence is insufficient to know what to decide. Our definition of this key term is based on an argumentation framework, that is, a situation where (1) there is a conflict of opinions between two (or more, in some cases) propositions P_1 and P_2 (or P_1, P_2, . . . P_n), (2) there are persuasive arguments (based on evidence) supporting each proposition, but (3) where the evidence, as things stand at that point in the collection of evidence, is insufficient to meet the appropriate standard of proof to prove the one proposition and disprove the other. What one has to do in such a case is to identify, analyze and evaluate the arguments on both sides to determine which side has the more defensible claim. We aim to show that applying Daubert has led to a series of quandaries.

It is not so easy to apply *Daubert* standard in practice because it sets up an unrealistic requirement in epistemic competence for judges or fact-finders to assess expertise. Academics, practitioners, and trial judges all have complained that the standard is unclear, is difficult to interpret, leads to inconsistent results, and requires hearings that cost time and money, or is too confusing to the jury (Browne *et al*, 1998, 5). For example, Mason (2001, 902) argues that the *Daubert* standard is inappropriate because it does not aid in the search for truth, and the uncertainty model contained in the *Daubert* standard only takes into account a particular *theory* of knowledge. So *Daubert's* shortcomings suggested the need for an alternative. Friedman (2003, 1047-48) even argues that reliability is an inappropriate, misleading standard for testing the admissibility of expert evidence and that hence it ought to be discarded because it does not reflect the way we should think about admissibility issues. Why are these methods subject to such powerful criticisms? In our opinion, there are several reasons.

First, the common tendency to conflate of validity with reliability has proved logically confusing. For example, in *Daubert*, Justice Blackmun wrote: "in a case involving scientific evidence, *evidentiary reliability* will be based upon *scientific validity*." Some scholars think the reliability of evidence derived from a scientific theory or principle depends upon three factors: (1) the validity of the underlying theory; (2) the validity of the technique applying the theory; and (3) the proper application of the technique on a particular occasion (Ginannelli and Imwinkelried, 1999; Gianelli, 2003). Judge Blackmun wrote: "On one hand, the difference between accuracy, validity, and reliability may be such that each is distinct from the other by no more than a hen's kick". On the other hand, he said "we note that scientists typically distinguish between validity (does the principle support what it purports to show?) and reliability (does application of the principle produce consistent results?).[1] However, he continued to say that "in a case involving scientific evidence, evidentiary reliability will be based upon scientific validity". More surprisingly, he wrote in the text, "The inquiry envisioned by Rule 702 is, we emphasize, a flexible one. Its overarching subject is the scientific validity - and thus the evidentiary relevance and reliability - of the principles that underlie a proposed submission". Does he mean that scientific validity is relevance and reliability? (*Daubert v. Merrel Dow Pharm., Inc*. (Daubert Ⅲ), 509 U. S. 579, 590 n.9 (1993)). *Daubert* equated "scientific" with "validity", "reliability". As such it said: in order to qualify as "scientific knowledge", an inference or assertion must be [derived by the scientific method.] Proposed testimony must be supported by [appropriate validation] - i.e., "good grounds," based on what is known. In short, the requirement that an expert's testimony pertains to "scientific knowledge" establishes a standard of evidentiary reliability. (*Daubert v. Merrell Dow Pharm. Inc.*, 509 U.S. (1993) 579, 590). Erica Beecher-Monas (2007, 35) took the view that *Daubert* clarified "relevance" as "scientific validity" in the context of expert testimony. However, relevance is quite different from validity. Scott Brewer (1998) articulated the four-factor test in *Daubert* as for "scientific validity". This view appears to imply that validity can be equated with reliability.

Second, gaining general acceptance in the particular field in which some claim belongs can be problematic. Many scientific techniques do not fall within the domain of a single academic discipline or professional field, especially in the current multidisciplinary era. For example, DNA involves several disciplines such as molecular biology, genetics, environmental biology, physical anthropology, evolutionary biology, population genetics, and statistics. What's more, that something has been generally accepted in a field does not mean it is scientific.

Third, the limits of peer review and publication make it very difficult to apply in a trial. Where there are substantial differences of approach or in adversarial contexts, peer review may become a less reliable mechanism (Edmond, 2000, 231). As pressures on the journals and their staffs increase, the hope of prestige and profit has caused further distortions (Haack, 2007, 801-802). For example, some journals suspend the peer-review process when they publish symposia sponsored by pharmaceutical companies. Some reap large sums from the sale of large numbers of reprints to the companies concerned. Some put pressure on authors to cite other papers in the same journal, thus raising its "impact factor" and boosting library orders. By now it should hardly need saying that the mere fact that work has passed pre-publication peer review is no guarantee that it is not flawed or even fraudulent. Also, the fact that work has been rejected by reviewers is no guarantee that it is not an important advance (Haack, 2007, 808). In theory, the process of peer review offers protection against scientific errors and bias. In reality, it has proven incapable of filtering out the influence of government and corporate funders, whose biases too often affect research outcomes (Rampton and Stauber, 2001, 199).

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[1] See Black, 56 Ford.L.Rev. at 599. http://caselaw.lp.findlaw.com/cgibin/getcase.pl?court=US&vol=509&invol=579#t9t9

Fourth, there is a matter of "error rates". The rate may be known with some precision, but that does not mean that application of the technique yields a "yes" answer to this component of the reliability inquiry (Nance, 2003, 200). The error rates are very difficult to calculate in deciding admissibility of scientific evidence, so it is unrealistic to regard it as one of the conditions of admissibility of expertise. And the error rates which people can accept depend on the mission or the questions that must be answered.

In short, the standard of reliability is not free of difficulties as a method for assessing expertise in real cases. Fact-finders are normally not experts in the scientific fields in which testimony is now so often offered as evidence in court. Then how are fact-finders to understand and assess expertise in the courtroom? An answer to this question will be given and defended in the following sections using an argumentation model of transmission of expert opinion evidence from a scientific inquiry to a different procedural setting, that of a legal trial.

These problems have been reviewed in the notes of the advisory committee that formulated rule 702 of the Federal Rules of Evidence, the rule for testimony by expert witnesses, found at: http://www.law.cornell.edu/rules/fre/rule_702 (30/12/2011). Rule 702 is formulated as follows.

A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:
(a) the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
(b) the testimony is based on sufficient facts or data;
(c) the testimony is the product of reliable principles and methods; and
(d) the expert has reliably applied the principles and methods to the facts of the case.

An extensive discussion of how the standard of reliability is to be met has been given in Godden and Walton (2006, 273-276). Note that this rule applies to the admissibility of scientific evidence, but in this paper we are also concerned with the evaluation of scientific evidence.

2.3 Assessing Expertise as a Special Model of Public Understanding of Science

The rise of the "public understanding of science" movement of the 1980s brought an expression of positive attitudes toward popularizing activity by scientists (Bodmer, 1986). Public understanding of science was taken to include not only "the man and woman in the street" but also groups whose expertise lies in fields such as history, philosophy, sociology, culture studies, or other academic disciplines that bring expertise to bear on science (Gregory and Miller, 1998, 52). Science in the courtroom is sometimes called Litigation-Driven Science (Haack, 2008, 1070) or Litigation-Generated Science (Boden and Ozonoff, 2008, 117). Therefore, expertise used in the courtroom can be regarded as popular science because it captures the public imagination and presents cases that change public attitudes. In order to let fact-finders understand expertise effectively, experts have to testify and communicate with them in the courtroom, and the communication has to take place in a language all participants can understand.

In a world divided into sometimes overlapping sets of laypeople and experts, each distinct group needs some point of contact with the other if they are to communicate meaningfully. For the public as well as for the scientific experts, the mass media are often the only point of contact (Gregory and Miller, 1998, 103). In trials, some widely publicized, many scientific experts have become accustomed to using the media via word of mouth, documents, photographs and videos in the courtroom to explain scientific testing, results and conclusions.

According to Gregory and Miller (1998, 86-88), there are three models of the communication process, the linear model, the diffusion model and the web model. The testimony of a forensic scientist in the courtroom best fits the web model, because it offers a more integrated approach to communications and their interactions without privileging any medium. However, there is a difference between models for truth-seeking in science and law. This can be summed by saying that truths are discovered by inquiry in science (even though they are proved as well), but determined by advocacy in the legal system (and also proved, but by different standards and methods). Inquiry is a very different setting for argumentation and proof than advocacy. Inquiry is an attempt to discover the truth of some questions and the obligation of a scientist is to seek out all the evidence he can, to assess its worth as impartially as possible, and to draw conclusions only if the evidence warrants doing so (Walton and Zhang, 2013). Advocacy is an attempt to make a case for the truth of some questions and the obligation of an attorney is to find and present evidence favoring the proposition to be proved (Haack, 2003, 207).

3. The Source Credibility of Expertise

3.1 Source Credibility in the Legal Context

According to source credibility theory, people are more likely to be persuaded if the person doing the persuading is seen as being credible, expert and trustworthy (Gilbert *et al*, 1998). A study by Carl Hovland and Walter Weiss (1952, 642) concluded that subjects changed their opinion in the direction advocated by the communicator in a significantly greater number of cases when the material was attributed to a high credibility source than when attributed to a low credibility source. Fact-finders are constantly surrounded by expert opinions offered by parties, and it is not always easy to know which sources are to be trusted when there is a disagreement. Being able to evaluate the credibility of expertise is an important skill used in factual decision-making. But we should note some differences in considering source credibility in the legal context.

First, in the study of "sleeper effect" undertaken by Hovland, Lumsdaine and Sheffield (1949, 101), only a single source was used, so no test was available of the differential effects when the source was suspected of having a propagandistic motive and when it was not. However, experts authorized by parties in the courtroom usually have a propagandistic motive more or less to help their clients.

Second, Hovland and Weiss (1952, 650) did not distinguish credibility from trustworthiness of source. For example, the immediate reaction to the "fairness" of the presentation and the "justifiability" of the conclusions drawn by the communication is significantly affected by both the subject's initial position on the issue and by his evaluation of the trustworthiness of the source. "Credibility" and "trustworthiness" in expertise in the courtroom have different implications. "Trustworthiness" is mostly used as the same meaning as "reliability" and we will see in the next section that it is a subordinate category of credibility.

3.2 The Structure of Source Credibility of Expertise

Nijiboer (1995) defines expertise as the possession of special qualities - quantity and reliability of knowledge - acquired through special education and training. The term 'expertise' in this article is taken to refer to the derivation of a scientific conclusion that is obtained by scientific method or scientific instruments based on scientific theories and used to prove a specific scientific claim in a case in a field of application of science. For example, DNA analysis of crime scene evidence essentially consists of three stages. The first stage is to collect samples at the crime scene and then transporting them to a forensic lab; the second stage is to compare the collected samples to determine if there are any matches in DNA types; and the third stage is to use statistical procedures to establish the probability that a particular sample came from a specific individual (Bradley, 2004, 156-60). Generally, the first question that the fact-finders must answer when they face expertise in the courtroom is “do I trust or believe this expertise?”

Definitions of trust vary but a widely accepted one is that it is “a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another” (Rousseau, *et al*, 1998). Experimental work on trust has been carried out in various contexts, including behavioral game theory, on-line commerce, and risk communication. Psychological research has shown that factors that determine trust can be broadly categorized into two groups. The first concerns the competence of the trustee (ability, competence, expertise, knowledge). The second concerns the motives of the trustee (benevolence, integrity, honesty, fairness) (Twyman *et al*, 2008, 111).

3.3 Internal Credibility

However, only considering competence and motives of the trustee is not enough for assessing the source credibility of expertise in the courtroom. In answering this “trust” question, fact-finders have to consider more questions from internal and external aspects. The internal question concerns scientific validity and reliability of evidence itself. Scientific validity, which depends on scientific principles and methods, aims at answering the question: does the principle support what it purports to show? Reliability aims at answering the question: does application of the principle produce consistent results?

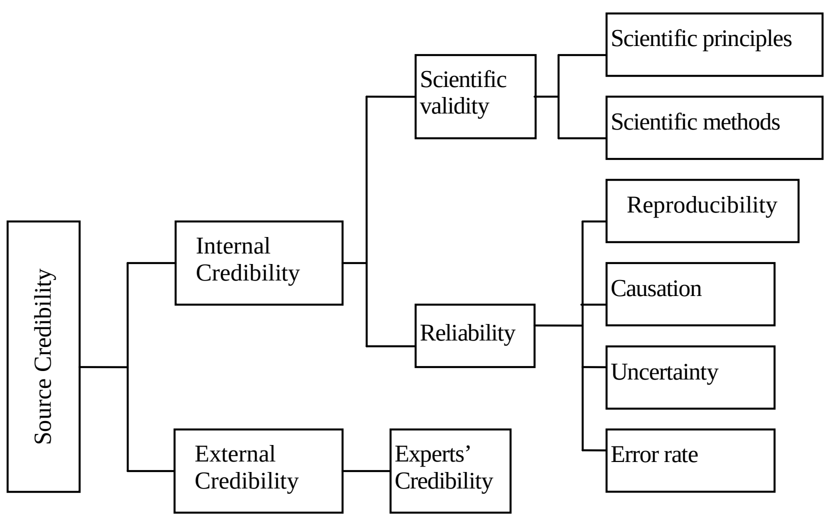

Figure 1: Source Credibility

There are many factors, such as reproducibility, causality, uncertainty and error rate, that can account for the reliability of expertise. External credibility aims at answering the question “do I believe the expert who proffers the expertise?” which is called experts’ credibility (see Figure 1). Internal credibility of expertise comes from scientific validity and reliability. Scientific validity aims at finding out whether the truth provided by the evidence provides an answer to the question? When fact-finders are considering the validity of any piece of science, they need to examine the scientific principles and methods it is based on. To scientists, reliability involves the competence of applying the same method to the same thing and obtaining the same result each time. There are many factors that account for the reliability of scientific evidence, most notably reproducibility, causality, uncertainty and error rate (see Figure 1).

The difference between validity and reliability is that validity reflects accuracy, the closeness of a measurement to the true value, and reliability reflects the precision which is the variation between repeated readings (Gott and Duggan, 2003, 118-20). There are many different ways of looking at the relationship between validity and reliability. Usually, an investigation can be invalid but still reliable; it cannot be unreliable and valid. If it is unreliable then it is always invalid because the measurements cannot be trusted and therefore the interpretation of the results and conclusion cannot be trusted. Another way of looking at the relationship between validity and reliability is to think of validity as including reliability (Gott and Duggan, 2003, 8). In our opinion, there are many connections between validity and reliability.

3.4 External Credibility

Scientists work behind closed doors. How can fact-finders trust them when they sit in the witness box? The current legal methods to assess expertise in the courtroom only focus on validity and reliability. For example, Forinash (1993, 237-38) claims that scientific evidence requires a two-step analysis. First, the court must ascertain if the theory is valid. Once proven, the trier of fact must determine if the theory if reliable. On this view, fact-finders should consider only the scientific evidence that passes this two-step approach. This paper, however, argues that one more external factor that is concerned with the credibility of scientists themselves should be considered in this process (see figure 1). It is well known that witness testimony is fallible evidence and appeal to expert opinion has traditionally been treated as fallacy in logic (Walton, 2008, 24). In part, fallibility of expertise stems from the variability of credibility of expert witnesses. Schum (2001, 103) identifies three factors that need to be taken into account in assessing the credibility of a witness: veracity, objectivity, and observational sensitivity.

For an expert witness, however, misconduct and bias can be even more important factors in assessing the credibility of an expert. For example, in West Virginia, the former head serologist of the State Police crime laboratory, Trooper Fred Zain, falsified test results in as many as 134 cases from 1979 to 1989. Dwyer (2007, 427) argues that the causes of expert bias fall into three categories: personal interest, financial interest and intellectual interest. On the other hand, many experts are closely tied to powerful interest groups - typically government, industry, or professional bodies. These interest groups provide them with jobs, access to power and status, training, ability to publish their work in professional and academic journals, and other benefits. Affiliation with these organizations also serves to accredit the expert, enhancing his or her credibility in the eyes of the media and the public. Rampton and Stauber (2001, 94-95) argue that money can buy the best science. In the adversarial legal system, experts, just like attorneys, are hired to advocate the point of view of their clients. This factor distinguishes use of expertise in the courtroom from uses of expertise in other public fields. As Tanford (2002, 549) stated, if there is one area in which the evidence seems overwhelming that money corrupts witnesses and makes their testimony unreliable, it is the area of experts.

4. Response of Fact-finders to Expertise: How to Revise and Justify Beliefs

4.1 Epistemology and Psychology

The assessment of expertise itself is both a question of epistemology and psychology. In some cases, it is not necessary for jurors to fully understand the basic theory underlying evaluation of expertise, because they can be instructed by courts by way of judicial notice. For example, matters such as the molecular structure of DNA, the presence of highly polymorphic VNTR loci, and the existence of methods to produce VNTR fragments and measure their lengths, can be understood externally, rather than in the way a trained expert understands these matters. It is proposed by Dwyer (2008, 6) that the fact-finders' epistemic competence to assess expert evidence can be justified, at least on the ground that expert fact-finding is the product of the same common investigative methods as everyday fact finding. After assessing expertise based on credibility as indicated above, fact-finders will form a response to the presentation of expert testimony. This response is based on the fact-finders' subjective intrapersonal assessment of source credibility, as explained above.

Studies have examined how people adjust their beliefs when testimony is discredited. For example, in three studies, Lagnado and Harvey (2008, 1166-1173) asked mock jurors to read simplified criminal cases and then judged the probability that a suspect was guilty on the basis of sequentially presented evidence. Their studies showed an extension effect: when two items of incriminating evidence were presented, a subsequent discrediting of the second item also lessened belief in the first item, irrespective of whether it was directly related to the discredited item. When the discrediting evidence was presented early, rather than late in the sequence, there was no extension to unrelated items.

This paper focuses on a formal and theoretical model of the revision and justification of belief when fact-finders face expertise. It is well known that Bayes' Theorem is a precise way to describe the dynamic revision process of belief scientifically. After the 1970s, theories about belief revision made progress in computer science, artificial intelligence, and psychology, and became a heated issue in these areas. One of the most influential belief revision theories is AGM developed by Alchourrón, Gardenfors and Makinson (1985, 510-30). The AGM theory is based on certain assumptions that make it applicable using first-order logic to formally encode common intuition about the properties that a rational belief change operator should satisfy. The AGM framework is characterized with three ways of changing the belief state: expansion, contraction and revision. Each of these operations models an idealized rational choice of belief in the light of new information which may or may not be consistent with current belief. These three fundamental operators of belief change were defined, as well as a set of rationality postulates (commonly referred to as the AGM postulates) that should apply to each belief change operation. The importance of the above model lies in the fact that AGM defined some widely accepted properties that any rational belief change operator should satisfy.

In our opinion, both expansion and contraction belong to revision. Thus, there should be two ways of revising fact-finders' belief: expansion and contraction. In the external quantity of belief, on the one hand, when the new information which the fact-finders received is consistent with the prior belief set, the belief set will be expanded, and results in the quantity of elements in the belief set will be increased. Conversely, when the new information which the fact-finders received contradicts the prior belief set, the belief set will be contracted, and results in the quantity of elements in the belief set will be decreased. As Quine and Ullian (1978, 16) wrote, when a set of beliefs is inconsistent, at least one of the beliefs must be rejected as false. In the internal degree of belief, on the other hand, when the new information which the fact-finders received supports the proposition that prior belief depends on, the belief set will be expanded, and results in an enhanced degree of belief. Similarly, when the information which the fact-finders received goes against the proposition on which prior belief depends, the belief set will be contracted, and results in a reduction of degree of belief. The revision of belief can take place simultaneously in both external quantity and internal degree. Below we will show how belief expansion and contraction can be modeled in a different way using argumentation tools that are compatible with AGM.

Generally speaking, there are two forms of justification for beliefs: direct justification and inferential justification. Direct justification rests on the explanation from observational facts, founded on a hypothesis. Inferential justification implies to justify by reliable reasoning based on justified belief (BonJour, 1988, 90). The basic assumption about this justification is that reasoning plays a fundamental role in epistemic justification. We begin with some propositions which we are somehow initially justified in believing. Pollock (1983, 232) calls these propositions comprise the *epistemic basis.* Reasoning from the epistemic basis, we become justified in believing some new propositions, and become justified in rejecting some propositions which we were originally justified in believing (Pollock, 1983, 232). Regardless whether it is direct justification or inferential justification, they both use a kind of induction which can be called “intrapersonal induction” in mind. The intrapersonal inductive method derived from a mental model theory of psychology. The idea that people rely on mental models can be traced back to Kenneth Craik’s (1943) suggestion that the mind constructs “small-scale models” of reality that it uses to anticipate events. Through intrapersonal induction, fact-finders establish one or more mental characterizations for the factual conclusions which expertise supports that will be proved by scientific evidence and use them to judge whether the conclusion is true or false.

4.2 Transfer of Evidence to a Different Procedural Setting

Haack (2004, 15) observed that the problem of expert testimony evidence in the courts “arises from the tension between the adversary system of the American legal culture and the open-ended fallibilism of scientific research”. This observation encapsulates the essential theoretical and epistemological nature of the problem, which is the transfer of evidence from one context to a different one, where the methods and standards for evaluating evidence are not the same. Godden and Walton (2006, 269-270) expressed the nature of this transference as a shift from one type of investigative procedure to another, where each procedure has its distinctive standards of evidence and burdens of proof. Godden and Walton (2006, 270) offered an explanation of this transfer of evidence by diagnosing it as a shift from one context of investigation to another, “a shift from a scientific inquiry dialogue to a persuasion dialogue of the kind that takes place in a trial”. The difference here between the two evidential settings is that the goal of a scientific inquiry is to prove a hypothesis, or alternatively to disprove it, if that is what the evidence indicates. In inquiry there is also a third alternative. An inquiry may show that the hypothesis cannot be either proved or disproved, because there simply is not enough evidence that can be collected to either prove or disprove it according to the standard of proof appropriate for the investigation. The aim of an inquiry is to collect all the evidence that carries probative weight one way or the other and to assemble and use this evidence to prove an ultimate claim to such high standard that it will not need to be retracted in the future. The aim of proving something beyond all possibility of retraction is impossible, given that every scientific finding must be seen as falsifiable, and therefore scientific proof of a proposition, while it may be definitive to establish knowledge, must always be seen as resting on defeasible reasoning.

Nevertheless, the goal of the scientific inquiry is to investigate the evidence so thoroughly, and test it so precisely by experimental means, that the need for retraction is minimized (Black, 2007). The reasoning in this investigative setting has the formal property of cumulativeness, meaning that the line of verification ideally moves forward with the result that once a proposition is accepted as knowledge, there is no need to retract it (Walton and Krabbe, 1995).

In contrast, persuasion dialogue needs to much more freely allow for retractions (Walton and Krabbe, 1995; Prakken, 2006). It is part of the rationality of argumentation in a persuasion dialogue that if one party proves that the other party has accepted a statement that has been refuted, the other party has to immediately retract commitment to that statement. In contrast, in the inquiry, the default position is to control the retraction of commitments much more tightly by having a higher standard of proof. An inquiry is always supposed to be a forward-moving sequence as it goes through the argumentation stage in which the foundations are firmly established. In a persuasion dialogue setting participants often need to change their positions, and the general aim of the procedure is to resolve the initial conflict of opinions in a situation where there is inconsistency and lack of knowledge.

There are several points of contrast between the setting of the scientific inquiry and the adversarial setting of legal argumentation in a trial. At the opening stage of the trial, a burden of persuasion is set in place that specifies what each side needs to prove in order to win, and standard of proof appropriate for the type of trial, whether it be a criminal or a civil case. During the argumentation stage each side presents the strongest possible arguments to prove its ultimate claim, and also puts forward the strongest possible arguments attacking the ultimate claim made by the other side along with its supporting arguments. This setting is very different with regard to the kind of evidence that is admitted to the procedure, the methods used to evaluate that evidence, the standards of proof used to determine whether a claim is accepted or not, and the ultimate outcome of the procedure as a finding.

We will now show how argumentation and artificial intelligence can provide a method of constructing an argumentation model that someone confronted with evidence based on expert testimony can use to provide a framework into which this testimony can be fitted. This framework takes into account the shift from an inquiry setting to one of persuasion dialogue.

5. The Argumentation Approach

5.1 Argument from Expert Opinion

The argumentation approach to analyzing an argument, or to dealing with problems that arise in connection with arguments, typically goes through a series of four initial steps. First, the analyst makes a list of all the premises and conclusions explicitly expressed as propositions in the text of the argument. Second, the analyst marshals the textual evidence available in the case in order to identify implicit premises or conclusions that may be found in the text and that are necessary to compose a recognizable argument. Third, the analyst creates an argument map, a diagram that links the statements together into a sequence of reasoning. This argument diagram represents the structure of the argument as a tree where each premise or conclusion is a node of the tree and the ultimate claim to be proved by the argument is the root of the tree (Prakken, 2005). Fourth, the analyst labels each argument with an argumentation scheme representing a particular type of argument that has a known structure.

The study of argumentation schemes representing defeasible forms of argument began with the tradition in the logic textbooks of studying informal fallacies, kinds of arguments that can be misleadingly erroneous, or can even be used as deceptive argumentation tactics to get the best of the speech partner unfairly. Through the study of many examples of such fallacies, it became apparent that fallacious instances of such arguments can only be properly identified by recognizing that in many instances the same kind of argument can be used as a heuristic that is a quick but nonetheless often reasonable way of arriving at a tentative conclusion. Through the study of many examples of such tricky arguments, the logic textbooks begin to identify some of these reasonable forms of argument used as heuristics in different settings, including legal argumentation in everyday conversational argumentation. These forms of defeasible argument are called argumentation schemes. Schemes are currently proving to be practically useful in artificial intelligence to recognize, analyze and evaluate common forms of argument used in everyday conversational argumentation and legal reasoning (Prakken, 2005).

The basic argumentation scheme for argument from expert opinion has been analyzed as having two premises and a single conclusion (Walton, 1997, 210). The variable *E* stands for an expert source of knowledge. It can represent a human expert or a database that can be accessed to obtain information, like an expert system. *A* is a propositional variable. We use the term 'proposition' as being equivalent to the term 'statement'.

Major Premise: Source *E* is an expert in subject domain *D* containing proposition *A*.
Minor Premise: *E* asserts that proposition *A* (in domain *D*) is true (false).
Conclusion: *A* may plausibly be taken to be true (false).

Argument from expert opinion in this form is best seen as a form of argument that leads by defeasible reasoning to a tentative conclusion. The assumption behind the scheme is that it is not justifiable to take the word of an expert as infallible, or to defer to an expert without questioning what she says, but nevertheless since experts tend to be more right than laypersons in a given field, there can be reason on balance to accept what an expert says is right. To accept what an expert says as having to be right absolutely, beyond all questioning or possibility of doubt, is a fallacious form of reasoning. But accepting expert advice in a cautious and qualified manner can be a reasonable heuristic under conditions of uncertainty and lack of direct access to scientific knowledge. As a practical matter, you can do much better if you tentatively accept what an expert says unless you have reason not to accept it, so long as you are prepared to critically question the advice given by the expert. Thus it is vital to see appeal to expert opinion as defeasible, as open to critical questioning.

Each argumentation scheme has a matching set of critical questions that can be used to find the weak points on which the argument can be questioned and cast into doubt. An expert opinion put forward as evidence in a trial setting can be questioned and examined in many ways. However, it is helpful to have a set of basic or standard critical questions that can provide an entry point into where to begin in examining expert testimony. The following six standard critical questions have been given as the basic ones for the argumentation scheme for argument from expert opinion (Walton, 1997, 223).

1. *Expertise Question*: How credible is *E* as an expert source?
2. *Field Question*: Is *E* an expert in the field *F* that *A* is in?
3. *Opinion Question*: What did *E* assert that implies *A*?
4. *Trustworthiness Question*: Is *E* personally reliable as a source?
5. *Consistency Question*: Is *A* consistent with what other experts assert?
6. *Backup Evidence Question*: Is *E*'s assertion based on evidence?

One can critically question an appeal to expert opinion by raising doubts about any of the premises. The first question concerns the depth of knowledge the expert supposedly has. Is the expert a master or only a beginner, even though he or she is qualified? This factor corresponds to the perceived expertise of the source, cited as one of the two most factors by Gilbert *et al*. (1998). The second question asks whether the field of the expert matches the field into which the proposition *A* falls. The third question probes into the exact wording of what the expert said (whether quoted or paraphrased). The fourth question raises doubts whether the expert is personally reliable as a source, for example, if she is biased, or has something to gain by making the statement. This factor corresponds to the trustworthiness of the source cited as the other of the two most important factors cited by Gilbert *et al*. (1998). The fifth question asks what kind of evidence the expert's pronouncement is assumed to be based on. If asked what evidence the pronouncement is based on, an expert should be willing to provide such evidence, and if she does not, the argument based on her expert opinion defaults.

Each of the basic critical questions has a number of critical sub-questions beneath it. For example critical question 1., the expertise question, has the following five critical sub-questions attached to it (Walton 1997, 223).

1. What is *E*'s name, job or official capacity, location, and employer?
2. What degrees, professional qualifications or certification by licensing agencies does *E* hold?
3. Can testimony of peer experts in *F* be given to support *E*'s competence?
4. What is *E*'s record of experience, or other indications of practical skill in *F*?
5. What is *E*'s record of peer-reviewed publications or contributions to knowledge in *F*?

These lists of critical questions and critical sub-questions were collected and systematized by research analyzing numerous examples of fallacious arguments from expert opinion, to see where these erroneous arguments went wrong (Walton, 1997). Once the errors were identified, sets of critical questions designed to pinpoint and cope with these errors were built.

The recognition that argumentation skills can benefit greatly from the use of computational tools to support and teach argumentation has led to the development of argumentation software. One of these tools, called Carneades, is domain-independent, but primarily aimed at legal argumentation. Carneades is an Open Source software project that provides tools for supporting a variety of argumentation tasks including argument mapping and visualization, argument evaluation, applying proof standards respecting the distribution of the burden of proof, and argument construction from rules and precedent cases. Carneades supports and uses argumentation schemes, including the one for argument from expert opinion.

5.2 The Carneades Argumentation System

Carneades is a computational model of argumentation and proof consisting of mathematical structures that has been implemented using a functional programming language (Gordon, 2010), and has a graphical user interface: (http://carneades.github.com/). The graphical user interface can be employed to draw an argument map that models the inferential relationships among statements that represent items of factual evidence in a case (Gordon, 2007). The result is a Wigmore-style diagram of the kind used by Schum (2001) to portray the logic we use when thinking about evidence in a legal case. Tillers (1989, 1237) showed how these kinds of diagrams are rich enough to represent a kind of problem faced by the trier confronting a mixed mass of evidence. How the Carneades graphical user interface can help us to analyze an argument that depends on the use of expert opinion as evidence in a trial setting can be shown by using it to draw argument maps using the scheme for argument from expert opinion in some examples.

In figure 2, each premise and conclusion in the sequence of argumentation is shown in a text box. The claim to be proved, the proposition that X killed Y, shown in the text box at the far left of the argument diagram. It is the root of the tree. There are four nodes in the tree representing arguments. Each node contains a plus symbol, indicating a pro-argument that offers positive support, or what could be called probative weight, in favor of the conclusion that the arrow from the node points to.

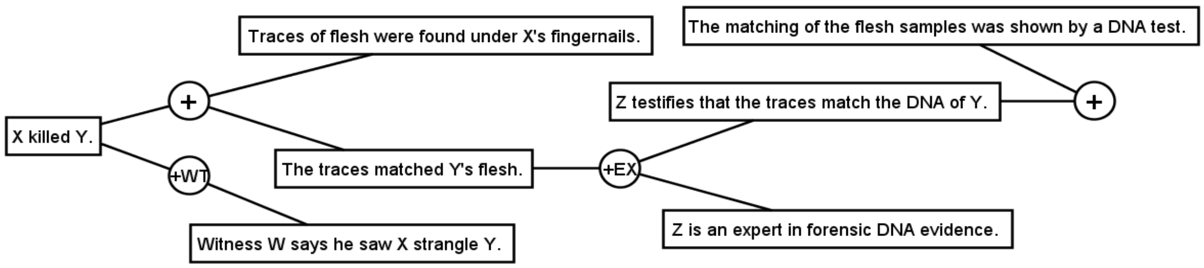

Figure 2: Carneades Map of an Example of Corroborative Evidence

At the top left we have what is called a linked argument, an argument with two premises that each go together to support a conclusion. The two premises are the proposition that traces of flesh were found under X's fingernails and the proposition that the traces matched Y's flesh. Below this we have another argument with a single premise, the proposition that witness W says he saw X strangle Y. This witness testimony evidence corroborates the evidence provided by the linked argument just referred to. So far we have two arguments, in addition to the argument based on the argumentation scheme for argument from expert opinion. One of the premises of this linked argument, the proposition that Z testifies that the traces matched DNA of Y, is itself the conclusion of another argument that supports it as evidence citing a DNA test.

The next example is an instance of the type of argumentation that could be called the battle of the experts. The structure is shown in figure 3.

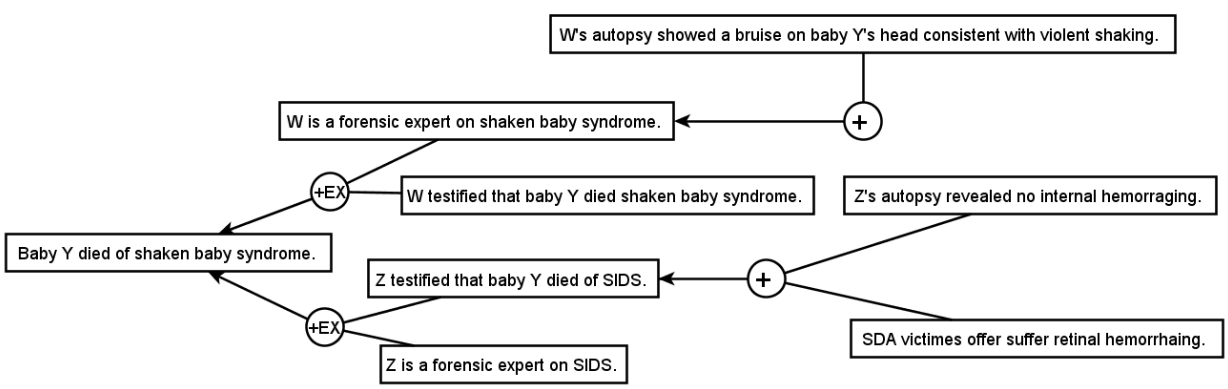

Figure 3: Conflicting Expert Testimony in Shaken Baby Case

In this evidential structure, we have one expert testifying to a particular conclusion by means of a pro-argument that has the form of argument from expert opinion. But we also have the testimony of the second expert that takes the form of a contra argument also taking the form of argument from expert opinion. In the example shown in figure 3, the one forensic expert testifies that the baby died of shaken baby syndrome. The testimony of the other expert provides evidence against the claim that the baby died of shaken baby syndrome because of the experts testimony that the baby died from sudden infant death syndrome (SIDS). Presumably the baby could have only died from the one or the other because there is an incompatibility in these diagnoses. However, in each instance, the argument is based on a premise that is backed up by additional evidence, shown in the form of the two arguments at the extreme right of the diagram.

Looking at these two diagrams we can see how Carneades provides a way of visualizing the structure of the evidence in typical legal cases relating to expert opinion testimony. One especially noteworthy feature of this way of representing the structure of the argumentation is that the diagram shows how argumentation schemes can be applied to particular arguments in the stream of argumentation. Argument from expert opinion is a defeasible form of argument, and the diagram shows instances where it can be questioned, as applied in a particular case, using the critical questions matching this scheme. A particular advantage of the Carneades system is that the critical questions matching an argumentation scheme can be represented on an argument diagram. The critical questions are represented as additional premises that act as assumptions that can be questioned (Gordon, 2010). This is an important advantage, as only propositions can be represented as text boxes in an argument diagram, not questions.

How this works can be illustrated using the scheme for argument from expert opinion. The two assumptions that the expert is trustworthy and that what she says is consistent with what other experts say, are assumed to be false. The two assumptions that the expert is credible as an expert and that what she says is based on evidence, are assumed to be true, until such time as new evidence comes in showing they are false. Also assumed as true are the four assumptions that the expert really is an expert, that she is an expert in the field of the claim, that she asserts the claim in question, and that the claim is in the subject domain in which she is an expert. How this device of representing critical questions as additional premises of an argument works is more fully explained in (Walton, 2007). Counter-arguments are modeled as arguments in the opposite direction for the same conclusion. For example if one argument is *pro* the conclusion, its rebuttal would be another argument *con* the same conclusion. Premise defeat is modeled by an argument *con* an ordinary premise or an assumption, or *pro* an exception (Gordon, 2005, 56).

5.3 How Carneades Models the Transition from Internal to External

In the Carneades model, an inquiry is defined as an ordered 3-tuple $<O, A, C>$ where O is the opening stage, A is the argumentation stage, and C is the closing stage (Gordon and Walton, 2009, 5). Protocols define (1) what types of speech acts are allowed at each move in the sequence of argumentation, and (2) set pre-conditions and post-conditions for each type of move (Gordon, 2007). Commitment rules determine how propositions are accepted or rejected at each move, and how retractions can take place (Walton and Krabbe, 1995). Carneades models the procedure of inquiry based on acceptability of statements, burdens of proof, and proof standards. In the Carneades model, what is accepted as scientific knowledge varies with the standards of proof appropriate for kinds of inquiry in a field of knowledge and with criteria for it to be considered to be evidence in a given field (Gordon and Walton, 2009). Whether a proposition is accepted as knowledge in an inquiry depends on the standard of proof and the data that has been collected in the inquiry (Gordon, Prakken and Walton, 2007). Whether a proposition can justifiably be classified as knowledge or not depends on its rational acceptance, given the evidence supporting its acceptance, weighed against the evidence supporting its rejection, at a given point in an inquiry. In this model, knowledge is based on the evidence collected at a given point in the inquiry, on the kinds of arguments that can properly be used to justify a claim in that type of inquiry, and on the standard of proof set for knowledge in that type of inquiry.

Whether a given proposition is accepted by a group of investigators in a scientific field as knowledge, or whether it should be treated as a hypothesis subject to further investigation and testing, depends on a scientific convergence effect. In this effect a mass of evidence comes together to decisively support the proposition has acceptable to the appropriate standard of proof (Peirce, 1931). This standard of acceptance is internal to the scientists in a particular field of knowledge (Black, 2007). But the external question of how the proposition is presented to outsiders as knowledge that has been scientifically established is another issue. How such a claim to knowledge is treated depends on the perceived credibility of the source.

Anderson (2007) pointed out that the argumentation scheme, along with its matching set of critical questions standardly used in argumentation theory to represent arguments from expert opinion, fails to take into account the special requirements of the use of this form of argument in legal contexts in trials. A better approach to formulating these requirements (Schum, 1994, 107) treats factors like previous convictions related to dishonesty, other misconduct related to dishonesty, character evidence regarding honesty, and testimonial bias, under the heading of credibility. Schum treats objectivity as a separate factor in assessing witness credibility. He distinguishes between two primary categories of assessing witness testimony called competence and credibility. Factors such as being in a position to observe, understanding of what was observed, and ability to communicate are treated under the category of competence. Factors such as veracity, objectivity, and observational sensitivity are treated under the heading of credibility. As Anderson pointed out, this method of classification is based on judicial wisdom regarding witness testimony accumulated in the common law legal system since the year 1352 (Schum, 1994, 106). Utilizing these observations Walton (2007) formulated a new version of the argument from expert opinion specially designed for use in legal contexts.

The expertise premise of the previous scheme is now called the competence premise. It assumes that the source cited is a genuine expert, meaning that his opinion will be based on appropriate sources of knowledge, and that he is in a position to be not only aware of these sources and to understand them at an appropriate level of technical competence, but also has the ability to communicate them so that they can be understood by laypersons. The premise formerly called the trustworthiness critical question is now called the credibility question. ‘Credibility’ refers not to the mastery of the domain of knowledge by the source said to be an expert, but to the expert’s reliability as a source who can be relied upon to convey it to others in a balanced way. These reformulations led to the following 2007 version of the scheme for the legal argument from expert opinion (Walton, 2007, 128).

Competence Premise (Ordinary Premise): *E* is an expert in knowledge domain *D*.
Statement Premise (Ordinary Premise): *E* said the sentence *S**.
Interpretation Premise (Ordinary Premise): *S* is a reasonable interpretation of *S**.
Domain Premise (Assumption): *S* is in *D*.
Depth of Knowledge Premise (Assumption): The knowledge of *E* about *D* is deep enough to know about *S*.
Careful Analysis Premise (Assumption): *E*’s testimony *S** is based on his own careful analysis of evidence in this case.

Other Experts Premise (Exception): *S* is inconsistent with what other experts in *D* say.
Credibility Premise (Exception): *E* is not credible.
Conclusion: *S* may plausibly be taken to be true.

Under ‘credibility’ are included matters of veracity, that is, matters of whether the witness is telling the truth, or at least attempting to do so within the confines of what he or she knows or does not know. The issue of bias comes under this category.

The latest version of Carneades treats exceptions in a different way. Instead of treating an exception as a special kind of premise that is assumed to be false, in the new version, Carneades treats an exception as an undercutter. An undercutter can most easily be explained as an exception to a rule. Pollock (1995) drew a distinction between two kinds of counter-arguments called rebutters and undercutters. A rebutter gives a reason for denying a claim by arguing that the claim is a false previously held belief (Pollock, 1995, p. 40). An undercutter attacks the inferential link between the claim and the reason supporting it by weakening or removing the reason that supported the claim. So, for example, consider this argument: if Tweety is a bird, Tweety flies; Tweety is a bird; therefore Tweety flies. Although this argument generally holds in the sense that the premises normally provide support for the conclusion, it fails or defaults in a particular instance where Tweety is a penguin. But in order for the argument to be shown not to hold, evidence has to be offered by the proponent of the argument that Tweety is in fact a penguin. To show graphically how an undercutter works using Carneades in a case of an argument from expert opinion, let us consider the argument shown in figure 4.

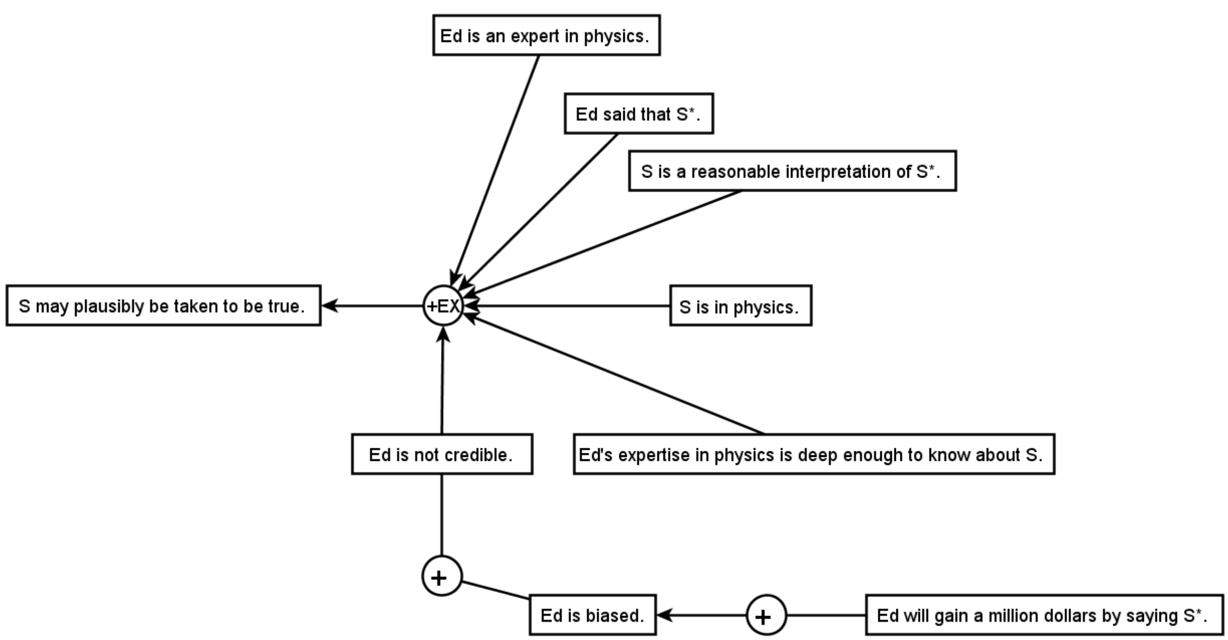

Figure 4: Example of Undercutting of Legal Argument from Expert Opinion

This example contains three arguments, two pro arguments and one contra argument. The pro-argument is shown in figure 4 as an instance of the scheme for argument from expert opinion. The five assumptions shown to the right of the node for the argument from expert opinion represent the first five premises of the 2007 version of the scheme. At the bottom part of the diagram, the credibility critical question is represented. The statement that Ed is not credible is represented as an undercutter attacking the conclusion that S may plausibly be taken to be true. The specific allegation made was that Ed is biased, shown as premise supporting the conclusion that it is not credible. Finally, to the bottom right of figure 4, some evidence is shown to support the claim that Ed is biased, by the statement that he will gain a million dollars by saying S*. If we look at figure 4 carefully, we can see how the way that Carneades represents the credibility critical question as an undercutter is highly intuitive. There are two reasons for this. The first is that the statement that Ed is biased represents a sub question of the credibility critical question, and the relationship of this sub question as a pro argument as shown on the argument diagram. The other reason is that is shown how this sub-question defeats the argument from expert opinion as an undercutter only once it is backed up by evidence. In this case the evidence given is the statement that Ed will gain $1 million by saying S*.

There are several general features shown in the argument diagram in figure 4 that help us to understand how Carneades represents structure of legal argument from expert opinion better once the notion of exception as undercutter has been introduced, especially in regard to how it manages critical questions. We now proceed to explain some of these features. First, the previous version of Carneades was somewhat counterintuitive for the reason that it represented an exception as a negative premise, a kind of premise that was assume not told. The double negation involved in this feature tended to make it somewhat difficult for the average user to apply to real examples of expert opinion evidence of the kind frequently encountered in legal argumentation. Second, Prakken and Sartor found some technical problems concerning how Carneades handled exceptions. Third, once Carneades moved to this new method of managing critical questions as exceptions by using Pollock's notion of an undercutter, the resulting system was shown by a technical result (Prakken and Sartor, 2011) to converge with the system ASPIC+, another AI and law argumentation system that makes use of defeasible argumentation schemes like argument from expert opinion.

6. Conclusions

There are great differences between the quest for truth in the courtroom and the quest for truth in the laboratory, but fact-finding based on expertise integrates both models of truth-seeking. The problem is that current legal methods are not free of difficulties in assessing expertise. As we have shown, the area is full of quandaries. This is not surprising. It really is very difficult to judge the worth of scientific evidence without substantive knowledge of the appropriate field. However, as we have also shown, understanding scientific evidence in the proceedings of fact-finding by using defeasible reasoning based on data given by expert testimony does not require a judge or jury to learn domain-specific scientific knowledge like scientists. Rather what it does require is the capability to assess the source credibility of expertise and justify their beliefs based on their reasoned assessment of the evidence presented by means of intelligent critical questioning. Fortunately there are tools available from argumentation models developed in artificial intelligence to help deal with this problem. As we saw above, fact-finders need to approach the problem assessing the source from both an internal and an external viewpoint.

We now put forward the thesis, based on our investigations in this paper, that the interface between these two viewpoints has the structure of the argument from expert opinion of the kind laid out in the previous section along with its matching set of critical questions. The solution to the problem, the way that we can use to move forward through the succession of quandaries described in this paper towards a better way of formulating procedures for evaluating expert testimony as a form of legal evidence used in trials lies on the interface between the internal scientific inquiry and the external uses of the results of scientific inquiry in a legal setting, along with different standards of proof appropriate for argumentation in that setting. The inquiry is undertaken by a group of scientific experts in a particular field of science using the methods and standards of proof appropriate in the field to prove the proposition at issue. However, in a trial setting, or other legal application, this proposition has to be translated into terminology that is comprehensible by the jury or other fact-finder, who must try to assess the evidence from expert opinion testimony. Internal credibility is concerned with scientific validity and reliability.

The general structure of the relationship between the internal and the external aspect of expert opinion evidence is shown in figure 5. In a scientific inquiry, there will be an appropriate standard of proof set for the investigation is underway that will help participants determine when the ultimate claim can be said to have been proven, or alternatively where the outcome of the inquiry is that the claim is not provable given the available evidence. In a trial, standards of proof, like preponderance of the evidence, clear and convincing evidence or beyond reasonable doubt will be set by law, and in the case of the jury trial will be explained to the jury, during the opening stage of the trial. How these two different contexts of argumentation can work together in a constructive argumentation framework, requires the integration on the interface provided by the argumentation scheme for argument from expert opinion, as shown in figure 5.

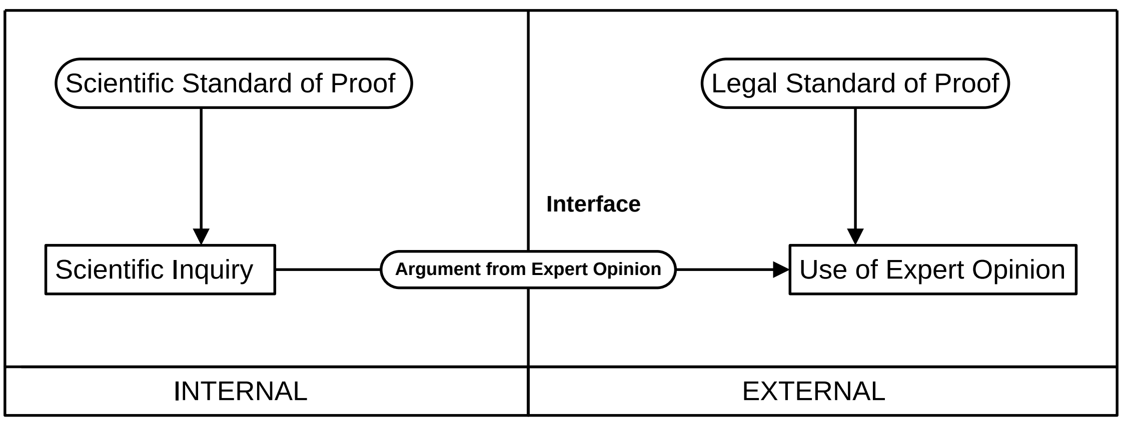

Figure 5: Interface between Internal and External Viewpoints

Finally, we showed how moving ahead towards a better way of dealing with the quandaries posed in this paper requires a clarification of the terminology concerning validity and reliability. Scientific validity is decided by scientific principles and methods. Reliability is influenced by reproducibility, causes, uncertainty and error rate. External credibility concerns with the credibility of scientific experts themselves. The response of fact-finders to expertise is to revise and justify their beliefs, based on their subjective intrapersonal assessment to expertise. The procedure in which this process of belief revision takes place is different from that of a scientific inquiry. We need to understand that the primary arena where these problems need to be solved and better understood by moving forward through the existing quandaries is that of the adversarial setting of the common law system, where the issue is an initial conflict of opinions second place at the opening stage, and where the succeeding argumentation of the one side is opposed to that of the other. In this setting, the testimony of the witnesses is examined by a process of critical questioning that probes into the weak points of the testimony, and in some instances even looks for finding of inconsistencies during examination as a reasonable way of casting doubt on the credibility of the expert witness testimony.

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References

Alchourrón, C. E., Gärdenfors, P. and Makinson, D. (1985). On the Logic of Theory Change: Partial Meet Contraction and Revision Functions. *Journal of Symbolic Logic*, 50 (2), 510-30.

Anderson, T. (2007). Visualization Tools and Argumentation Schemes Revisited, *Law Probability and Risk*, 6, 2007, 97-107.

Beecher-Monas, E. (2007). *Evaluating Scientific Evidence: An Interdisciplinary Framework For Intellectual Due Process* (Cambridge University Press, 35.

Black, E. (2007). A Generative Framework for Argumentation-Based Inquiry Dialogues. PhD thesis, University College London.

Boden, L. I. and Ozonoff, D. (2008), Litigation-Generated Science: Why Should We Care?, *Environmental Health Perspectives*, 116, 117-122.

Bodmer, W. (1986). *The Public Understanding Of Science*. London: Royal Society.

BonJour, L. (1988), *The Structure of Empirical Knowledge*. Cambridge: Harvard University Press, 90.

Bradley, R. C. (2004). *Science, Technology, & Criminal Justice*, New York: Peter Land Publishing, 156-60.

Brewer, S. (1998). Scientific Expert Testimony and Intellectual Due Process, 107 *Yale Law Journal*,1547.

Browne, M. N. *et al* (1998). The Epistemological Role of Expert Witnesses And Toxic Torts, *Am. Bus. L. J.*, 36, 5.

Craik , K. (1943). *The Nature of Explanation*. Cambridge: Cambridge University Press.

Dwyer, D. (2007), The Causes and Manifestations Of Bias In Civil Expert Evidence, *Civil*

Justice Quarterly, 26, 427.

Dwyer, D, (2008). *The Judicial Assessment of Expert Evidence*. New York: Cambridge University Press, 6.

Edmond, G. (2000). Judicial Representations of Scientific Evidence. *Modern Law Review*, 63, 231.

Forinash, R. A. (1993). Analyzing Scientific Evidence: From Validity to Reliability with a Two-Step Approach, *St. Mary's Law Journal*, 24, 237-38.

Friedman, R. (2003). Squeezing Daubert Out of the Picture, *Seton Hall L. Rev*iew, 33, 1047-48.

Giannelli, , P. C. (2003). Admissibility of Scientific Evidence, 28 *Oklahoma City University Law Review*, 3.

Giannelli, P. C. and Imwinkelried, E. J. (1999). *Scientific Evidence* ch. 1 (3d ed.).

Gilbert, D. T., Fiske, S. T. and Lindzey, G., eds (1998). *The Handbook of Social Psychology*. Oxford: Oxford University Press.

Godden, D. M. and Walton, D. (2006). Argument from Expert Opinion as Legal Evidence: Critical Questions and Admissibility Criteria of Expert Testimony in the American Legal System, *Ratio Juris*, 19(3), 261-286.

Gordon, T. F. (2010). The Carneades Argumentation Support System, *Dialectics, Dialogue and Argumentation*, ed. C. Reed and C. W. Tindale, London: College Publications.

Gordon, T. F. (2007). Visualizing Carneades Argument Graphs. *Law, Probability and Risk*, 6(1-4), 109–117.

Gordon, T. F., Prakken, H. and Walton, D. (2007). The Carneades Model of Argument and Burden of Proof, *Artificial Intelligence*, 171, 875-896.

Gordon, T. F. and Walton, D. (2009). Proof Burdens and Standards, *Argumentation and Artificial Intelligence*, ed. I. Rahwan and G. Simari, Berlin: Springer.

Gott, R. and Duggan, S. (2003). *Understanding And Using Scientific Evidence: How To Critically Evaluate Data*, London: SAGE Publications, 8.

Gregory, J. and Miller, S. (1998). *Science in Public: Communication, Culture, and Credibility*. New York: Plenum Press.

Haack, S. (2003), Inquiry and Advocacy, Fallibilism and Finality: Culture and Inference in Science and the Law, *Law, Probability and Risk*, 2, 207.

Haack, S. (2004). Truth and Justice, Inquiry and Advocacy, Science and Law, *Ratio Juris*, 17, 15-26.

Haack, S. (2007). Peer Review and Publication: Lessons for Lawyers, *Stetson L. Rev.*, 36, 801-802.

Haack, S. (2008), What's Wrong with Litigation-Driven Science? An Essay in Legal Epistemology, *Seton Hall Law R*eview, 38, p.1070.

Hovland, C. and Weiss, W. (1952). The Influence of Source Credibility on Communication Effectiveness，*Public Opinion Quarterly*, 15: 642.

Hovland, C. I., Lumsdaine A. A. and Sheffield, F. D. (1949). *Experiments on Mass Communication*. Princeton: Princeton University Press, p. 101.

Lagnado, D. A. and Harvey, N. (2008). The Impact of Discredited Evidence, *Psychonomic Bulletin & Review*, 15 (6).

Mason, M. C. (2001). The Scientific Evidence Problem: A Philosophical Approach, *Arizona State L. Rev.*, 33, 902.

Mnookin, J. L. (2007). Idealizing Science And Demonizing Experts: An Intellectual History Of Expert Evidence, *Villanova Law Review*, 52, 764.

Nance, D. A. (2003). Reliability and the Admissibility of Experts, *Seton Hall Law Review*, 34, 200.

Nijboer, H. (1995). Expert Evidence, In R. Bull & D. Carson (Eds), *Handbook of Psychology in Legal Context*, Chichester: Wiley.

Peirce, C. S. (1931). *Collected Papers*. Edited by C. Hartshorne and P. Weiss. Cambridge: Harvard University Press.

Pennington, N. and Hastie, R. (1993). Reasoning in Explanation-Based Decision Making. *Cognition*, 1993, 49(1-2), 123-63.

Pollock, J. L. (1983). Epistemology and Probability, *Synthese*, 55, 232.

Pollock, J. L. (1995). *Cognitive Carpentry*. Cambridge, Mass: MIT Press.

Prakken, H. (2006). Formal Systems for Persuasion Dialogue. *The Knowledge Engineering Review* 21, 163-188.

Prakken, H. (2005). AI & Law, Logic and Argument schemes. *Argumentation* 19, 303-320.

Prakken, H. and Sartor, G. (2011). On Modelling Burdens and Standards of Proof in Structured Argumentation. In K.D. Atkinson (ed.), *Legal Knowledge and Information Systems. JURIX 2011: The Twenty-Fourth Annual Conference*. Amsterdam etc, IOS Press, 83-92.

Quine, W. V. and Ullian, J. S. (1978). *The Web of Belief*, New York: McGraw-Hill, Inc., 10.

Rampton, S. and Stauber, J. (2001). *Trust Us, We're Experts!: How Industry Manipulates Science and Gambles with Your Future*. New York: Penguin Putnam Inc.

Rousseau, D., Sitkin, S., Burt, R., & Camerer, C. 1998, Not So Different After All: A Cross-Discipline View of Trust, *Academy of Management Review*, 23: 393-404.

Schum, D. (2001). *The Evidential Foundations of Probabilistic Reasoning*, Evanston: Northwestern University Press, 103.

Tanford, J. A. (2002). The Ethics of Evidence, *American Journal of Trial Advocacy*, 25, 549.

Tillers, P. (1989). Webs of Things in the Mind: A New Science of Evidence. *Michigan Law Review*, 87(6), 1225-1258.

Walton, D. (1997). *Appeal to Expert Opinion*. University Park: The Penn State Press.

Walton, D. (2007). Visualization Tools, Argumentation Schemes and Expert Opinion Evidence in Law, *Law, Probability and Risk*, 6, 119-140.

Walton, D. (2008). *Witness Testimony Evidence: Argumentation, Artificial Intelligence, and Law*. New York: Cambridge University Press.

Walton, D. and Krabbe, E. C.W. (1995). *Commitment in Dialogue*. Albany, N.Y.: State University of New York Press.

Walton, D. and Zhang, N. (2013). The Epistemology of Scientific Evidence, *Artificial Intelligence and Law*, 21(2), 173-219