1. Introduction

Testimony is our greatest source of belief. Most of the things we believe have been acquired from other people’s words, not from evidence directly collected in the world through observation. Facts about the past or about remote places are obvious examples of testimonial beliefs, but so are very personal facts such as the place and date of my birth, or the names of my great-grandparents. Scientific discoveries and theories are accepted by most of us on the basis of what others say. That smoking causes cancer or that the anomalies in observed galactic rotation can be explained by the theory of dark matter are claims which are impossible to verify by any one individual. In many cases I can neither imagine or understand the means by which my testimony-based beliefs could be directly verified, but I believe them nonetheless.

Most testimony is accepted as a matter of course, without any conscious deliberation. It might be, as Fricker (1995) has pointed out, that our apparent gullibility is actually underpinned by steady, sub-conscious mechanisms that monitor for plausibility. Or perhaps all human beings possess, as Thomas Reid claims, “a disposition to confide in the veracity of others, and to believe what they tell us” (1764/2000: 194). Thagard (2005) asserts in a similar vein that there is a “default pathway” in which people more or less automatically respond to a claim by accepting it, as long as the claim made is consistent with their beliefs and the source is credible. Whatever the explanation, the fact remains that there is a greater tendency to accept a given testimony than to reject, withhold our ascent, or assign some intermediate degree of belief to it. Our trust in the words of others is a requirement not only for the collective construction of knowledge, but also for social interaction in general.

1 Associate Professor and Chair, Department of Philosophy, Universidad de los Andes, Bogotá
But our natural tendency to accept testimony sometimes leads us into trouble, especially when the unguarded acceptance of false testimony has significant negative consequences. In business, law, science, and daily life important decisions are made and crucial policies are implemented based solely or mostly on other people’s claims. In these contexts testimony ought to be accepted as the result of a rational decision process. The acceptance of testimony requires an evaluation according to two different criteria, one to determine which testimonies qualify as evidence, and another one to determine their probative value in different contexts.

Finding criteria to evaluate the epistemic merits of testimony is no easy task. There are two main objections to any attempt to analyze testimony in terms of more basic criteria. They were initially raised by Coady (1973, 1992) against Hume’s reductive approach to testimony in his famous essay “Of Miracles,” included as chapter X of his Enquiry Concerning Human Understanding (1743/1975). The first is the charge of circularity due to the fact that most testimonies will be supported by evidence mostly consisting of more testimony; the second, the claim that our inferences regarding the truth of certain kinds of testimony will never have sufficient inductive support because the cases in which testimony can be verified directly in the world will never be numerous enough.

Most accounts of testimony have opted for a non-reductive approach. Shapin (1994), for example, tries to transform the issue from one about justification to one about the trustworthiness of the person offering testimony. Since judgments of trustworthiness are always moral judgments, the institution of testimony would be moral in nature. The problem is that the sources of false testimony include not only mendacious intentions but also honest incompetence. Shapin’s approach is ill equipped to deal with this latter fundamental aspect of testimony. Hardwig (1985, 1991) also argues that trust is the basis of the epistemic authority that supports the advancement of science. His argument is that researchers cannot be independent and self-reliant, not even in their own fields of specialization, if they want to have access to the best evidence available. In his view, a researcher can have good reasons to believe a testimony if he has good reasons to believe that the source has good reasons to believe it. In other words, we trust certain testimonies because we have evidence that the source is an expert in the field. There are several other
non-reductive approaches, but my interest here is not to diagnose their failures but rather to show that a reductive account can overcome Coady’s objections.

In this paper I offer an account of testimony which shows that warranted testimonial belief is based on rules of inference or mechanisms of belief acquisition that apply to non-testimonial beliefs, but that also does justice to the peculiar characteristics of testimonial evidence. The basic idea is that the deliberate acceptance of testimony is a two-step process. In the first step a justification for the testimony is sought by considering all the facts that raise the epistemic probability that a given testimony is true, that is, that the witness is truthfully reporting a fact. The set of relevant facts can be determined from the content of the testimony and from the context in which the claim is made, including the identity of the witness or source. The acceptance of these facts and probabilistic relations is based on a trade-off between their credibility and their informational value. The second step is to determine whether the justification obtained is sufficient for the acceptance of the testimony as evidence in a given context, trying to obtain a similar trade-off between its credibility and the usefulness of the information in promoting the cognitive interests and goals of an inquiring agent.

The structure of the paper is as follows. In the following two sections I will present the main objections to a reductionist account of testimony, focusing in particular on the claim that any attempt to justify testimony is hopelessly circular. In the remaining sections I will present my own approach to the problem of testimony. From the outset I should indicate that the following analysis does not take into account many of the complications that arise in the analysis of testimony within legal contexts. My idea is to offer an epistemological analysis of the problem which indirectly might shed some light on the problem of legal testimony.

2. The Trouble with Reductive Accounts of Testimony

In the opening pages of “Of Miracles,” Hume notes “that there is no species of reasoning more common, more useful, and even necessary to human life, than that which is derived from the testimony of men and the reports of eye-witnesses and spectators” (1748/1975: 88). Seeking the source of our confidence in the testimony of others, he states that “our

---

2 See e.g. Burge (1993) and Dummett (1993).
assurance in argument of this kind is derived from no other principle than our observation of the veracity of human testimony, and of the usual conformity of facts to the reports of witnesses” (88). Hume’s claim seems to be that if someone makes a claim of kind \( p \), which reports a state of affairs, we believe it because we have directly verified in the past that claims of kind \( p \) regularly correspond to the states of affairs they describe. Testimonial inference is thus reduced to simple enumerative induction.

Coady finds this proposal defective on two counts: “We are told by Hume that we only trust in testimony because experience has shown it to be reliable but where experience means individual observation and the expectations it gives rise to, this seems plainly false and, on the other hand, where it means common experience (i.e., the reliance upon the observations of others) it is surely question-begging” (1973: 150).

As Coady points out, textual evidence seems to indicate that Hume has in mind the common experience of mankind and not the observations of an individual as the basis for testimonial inference. But since we can only know what others have observed by means of their testimony, the account is clearly circular. If we circumscribe Hume’s account to the sphere of individual observation, we might find some examples in which his account works, but these would be restricted to the testimony of one’s friends and family, and to everyday situations where the events reported are directly observable. In most cases, however, there are very few opportunities to verify whether a certain kind of report is reliable, and therefore I believe Coady is right in claiming that our testimonial inferences lack the type of justification that Hume claims for them.

Coady also points out that Hume does not even offer an indication about how we should classify the kinds of reports for which we search justification. “Hume wants these conjunctions to be something like the kinds of conjunctions he thinks are required to establish causal laws and even laws of nature. In such matters the decisive constant conjunctions are between one kind of object and another kind of object. But whatever we think about the idea of a kind of object, the notion of a kind of report surely requires some explanation in this context” (151).

There are two natural ways of classifying reports: by the kind of reporter and by the kind of content. In the former case, the relevant kinds would be determined by the area of expertise: weather forecaster, art historian, biochemist, and so on. In order to determine if a given reporter belongs to one of the relevant kinds, we must rely on additional information, most of which is not directly observable and which must be gathered from the testi-
mony of others. We thus end up again with the problem of circularity. The main problem in the latter case is that one and the same content can be classified in too many different ways, making it unclear how to set up our inductive inferences. “...some sort of decision would presumably be required as to whether or not the report ‘There is a sick lion in Taronga Park Zoo’ belonged to the kind medical report or geographical report or empirical report or existence report” (152). In addition, the decision would also rely on the testimony of others.

Coady goes on to offer a third argument against Hume, which amounts to a *reductio ad absurdum* of Hume’s argument. This last argument is not very relevant for the purpose of this paper and I will leave it aside. Instead, in the next section I want to focus on the problem of circularity in the justification of testimony.

3. Rule-Reductive Accounts of Testimony

As Peter Lipton points out, Hume’s description of our inductive practices is too rudimentary and does justice to almost no aspect of our non-demonstrative inferences. “This weakness of Hume’s general account of our inductive practices may also however create a weakness in Coady’s own line of argument, for it seems to me that Coady is too quick to move from the failure of Hume’s attempt to reduce testimony to primitive enumerative induction to the conclusion that there is no general account of inductive warrant that might subsume inferences to the reliability of testimony” (1998: 17).

Lipton argues that there are two possible reductionist accounts of testimony, a premise-reductive account and a rule-reductive account. “The former is an attempt to show how every testimonial belief the agent is warranted to accept can be justified in terms that do not themselves appeal to beliefs based on testimony” (23). This is the kind of account that Coady rejects, and it seems clear that it is a hopeless enterprise given the feeble empirical base on which any inductive testimonial inference would be based. And it would be not only hopeless but also undesirable, since it would not do justice to our scientific and everyday practice, where testimony not directly verified by observation is used in the justification of all sorts of claims.

Lipton believes that there are better prospects for a rule-reductive account, “an account which would show that warranted testimonial beliefs are based on rules of inference or mechanisms of belief acquisition that apply to the beliefs from various sources, not just
the source of testimony‖ (24). The possibility of such an account draws support from the idea that there is not only a vertical but also a horizontal dimension to the justification of belief in general, in which coherence and cohesion play a fundamental role, and in which testimonial beliefs are combined with beliefs from different sources, such as perception and memory. Lipton concludes: “This holistic mechanism strongly suggests that, insofar as acquisition of belief from testimony is based on inference, the rules of inference are not specific to testimony” (24).³

The inferential mechanism adopted by Lipton is Inference to the Best Explanation (IBE), a full account of which can be found in his book of the same name (2004). According to IBE, we ought to infer the hypothesis that would provide the best explanation of our evidence. “In the case of testimony, the most straightforward application of Inference to the Best Explanation would be to say that the agent infers that what the informant said is true just in case the truth of what was said is (part of) the best explanation of (among other things) the fact that the informant said it” (27). His idea is that explanation in the case of testimony refers to the psychological explanation of a verbal behavior in which judgments about sincerity and competence play a central role. “When we explain why a person says something, the explanation need not rest on a prior determination whether what was said is true. Thus we may judge that the best explanation of her saying what she did is that she is unlikely to be deceived or deceiving on that sort of matter, without first independently knowing whether what she says is true” (29).

Lipton does not offer any further details about the use of IBE in the case of testimony. He simply assures us that IBE is well suited to provide us with an epistemology of testimony for two reasons. On the one hand, the features of testimonial inferences are shared by many inductive inferences generally; in particular, IBE sanctions vertical inferences and emphasizes the role of coherence. On the other hand, IBE captures two features that only belong to testimony, namely, the two different sources of error in testimonial inference: mendacity and honest incompetence.

A complete analysis of IBE in general and of how it would apply to the case of testimony would take us too far afield. I will only point out why I think that IBE and abductive strategies in general are ill suited to account for testimonial inferences. The main problem

³ There remains of course the question of whether testimonial beliefs are inferential. I will return to the problem below.
is that what testimonial inferences require is not an explanation but a justification, The search for an explanation takes us in the wrong direction. Consider the explanandum of an IBE and the why-question that sets the inference in motion. The fact that has to be explained is that an individual a said that p, and the question is “Why did a say that p?” The best explanation of why a said that p clearly involves all sorts of different information. Alvin Goldman’s analysis of testimony makes evident the variety of elements involved:

First, the communicator must select which of the observed facts to communicate. If she just observed ten truths but it is not feasible to communicate each of them, she must decide which subset to report. Second, for each of the observed truths, there is the option of reporting it sincerely versus the option of distorting or falsifying it. The third dimension is “how” to communicate. More than one medium of communication may be available, and the media may differ, for instance, in terms of their likelihood of reaching the intended audience. So choices must be made. Finally, on the “to whom” dimension, the observer needs to select the targeted audience for the selected messages. To which individuals should the various messages be directed? Are there potential receivers that the reporter wants to prevent from receiving the messages? Choices along the four dimensions may be interdependent. The chosen medium or manner of transmission might constrain how many messages can be sent. The audience targeted for the messages may influence their contents, and vice versa (1999: 104).

All of these aspects are part of the complete psychological explanation of why a said that p. Interesting as they may be, most of these partial explanations are useless to someone who wants to accept a testimony as evidence and seeks a warrant for it. On the one hand, many of them cannot be verified by the receiver of the testimony because they make reference to decisions and psychological processes that are inaccessible to the receiver. On the other, the receiver wants to know if the witness was in a position to observe the facts she reports, or if she has the necessary knowledge or training to make the claims she makes, or if she has a good track record in making true claims, and so on. None of these facts belong to the psychological explanation of why she said what she said, but they belong to the justification that the receiver can offer in deciding whether to believe the testi-
mony. An appeal to IBE as the basis for an epistemology of testimony fails because explanatory reasons are not justificatory reasons.

In this paper I want to adopt an entirely different route towards a rule-reductive account of testimony. I agree with Lipton that such an account should be “based on rules of inference or mechanisms of belief acquisition that apply to the beliefs from various sources, not just the source of testimony” (1998: 24), and also that the account should do justice to the specific features of testimonial inference. The basis of my account will be the theory of belief revision, developed by Isaac Levi (1967, 1980, 1991), and in particular his approach to scientific inquiry as a decision problem.

4. Inquiry as a Decision Problem

In The Fixation of Belief and Its Undoing (1991), Levi offers an account of inquiry inspired in the doubt-belief model of inquiry first proposed by Peirce (1877/1998). According to the doubt-belief model, an inquiring agent presupposes that everything he is currently committed to fully believing is true. This does not mean that truth or falsity is relative to what the agent believes. But the agent’s judgments of what is true and what is false are relative to what he currently believes.

Levi treats inquiry as a decision problem. Two desiderata guide an inquiring agent’s decisions to modify her present state of belief: (i) the acquisition of valuable new information, and (ii) the avoidance of error. Inquiry proceeds from a background of firmly held beliefs, the agent’s state of full belief, which the agent regards as error-free. Given the agent’s cognitive goals, an optimal change in belief is one that provides new error-free information. But the avoidance of error and the acquisition of new information are goals that pull in different directions. On the one hand, error is best avoided by remaining in the original state of full belief. On the other, a maximum amount of information is acquired by shifting to states that might not be error-free. “The moral of the story is that those shifts that increase informational value incur risk of error” (1991: 12).

In order to provide an account of how these two conflicting cognitive goals can be balanced, Levi begins by clarifying what a state of full belief is. When an inquiring agent

---

4 The theory of belief revision was independently developed in a different direction by Alchourrón, Gärdenfors & Mackinson (1985). Appendix 1 explains the basic aspects of the AGM approach.
consciously accepts a set of propositions at any given time, he commits himself to the consequences of these propositions. The agent may not recognize all the consequences of his beliefs at the time, but he cannot rationally deny them if made aware of them. By consciously accepting the consequences of his beliefs, the agent fulfills his doxastic commitment. But in virtue of his limited reasoning abilities, his doxastic performance will always fall short of his doxastic commitment. The set of propositions to which an agent is committed at any given time is the agent’s state of full belief $K$.

According to the doubt-belief model, inquiry begins with the presence of doubt. “Doubt is an uneasy and dissatisfied state from which we struggle to free ourselves and pass into the state of belief; while the latter is a calm and satisfactory state which we do not wish to avoid, or to change to a belief in anything else. … I shall term this struggle inquiry” (Peirce 1877/1998: 114). To be sure, not all doubts force us to engage in inquiry. Some doubts are regarded as more important than others, and there is no other principle directing our inquiries than our own interests and cognitive goals.

As I mentioned in the beginning, most testimonies are accepted and believed as a matter of course. The only requirements are that the testimony should be consistent with the agent’s set of beliefs and that there should be a previous commitment to the reliability of the witness or the source of information. This automatic acceptance of testimony corresponds to what Levi calls a “routine expansion” of $K$ (1991: ch. 3). The search for the justification of a testimony only arises when the issue at hand is important to the inquirer and decisions ought to be made without a reasonable doubt; or simply when her particular interests find doubt in a claim made by others and her intellect will not be satisfied until the claim has been justified by further evidence. If someone’s testimony is tautological, or if it states something that an inquiring agent already believes, it would be foolish, from the point of view of the doubt-belief model, to undertake the task of finding a justification for it.

The account that I present here thus assumes that an inquiring agent believes that a given testimony is not beyond a reasonable doubt, but also that she regards undertaking the task of reaching a firm belief about it as a useful enterprise in view of her cognitive interests and goals. If a testimony is doubtful but no decision or further inquiry depends on it, or if a testimony will be used as important evidence and there is no reasonable doubt

---

5 Appendix 2 contains the rationality postulates for the expansion of a state of belief set forth in Gärdenfors (1988: 48-52). The acceptance of a testimony in $K$ must obey these postulates.
about it, the agent will not make an effort and commit important cognitive resources finding a justification for it.

5. Finding a Justification for Testimony

Once inquiry has been set in motion by a doubtful testimony, my suggestion is that the agent will face two separate tasks. The first one will be to find a justification for a testimony by considering all the facts that raise the probability that the testimony is true, that is, that the witness is truthfully reporting a fact. The set of relevant facts can be determined from the content of the testimony and from the context in which the claim is made, including the identity of the witness or source. The evidence cannot be restricted to observable facts. Otherwise the account would become a premise-reductive account. Factual information can be gathered from what others say and the assessment of the credibility of their testimony will be part of the justification process. Naturally the testimony that serves as justification cannot be weaker than the original testimony on pains of an infinite regress. The acceptance of these facts and probabilistic relations will be based on the best trade-off between their credibility and their informational value relative to the agent's belief set $K$.

The second task is to determine whether the justification obtained is sufficient for the acceptance of the testimony in a given context. That task will be analyzed in the next section.

To motivate the account, I will present a series of examples of testimony and some of the facts that make it likelier that the testimony is true. A formal treatment will follow.

Example 1: A witness reports that the getaway car in a bank robbery was blue. The following is a partial list of facts that increase the probability that the witness is telling the truth:

- The witness was in the close vicinity of the bank
- The lighting conditions were such that the color of the car could be easily determined
- The witness is a respected school teacher
- The witness is not colorblind.

Example 2: A series of experimental results are published in a highly reputed journal by Dr. G. The following facts increase the probability that the report is true:
Dr. G. holds a doctoral degree in the field
Dr. G. is a tenured professor in a research university
The journal uses a double-blind peer review process
Previous experimental results obtained by Dr. G have been replicated by other independent researchers.

In both of these examples, the background beliefs required to accept that the information listed increases the probability that the witness is telling the truth are not very sophisticated. If the information comes from reliable sources, the agent can accept it and use it to reach a final decision about whether to accept the testimony, as we will see in the next section.

**Example 3:** Some stranger approaches you on the street and tells you that Michael Phelps, the fourteen-time Olympic gold swimming medalist, drowned this afternoon. Your first reaction is of disbelief, and you decide to investigate the issue. You are able to verify that Michael Phelps was scheduled to use the local pool this afternoon, but you have no other information. Although this fact slightly increases the probability that the report is true, you decide not to believe the report.

**Example 4:** In an Internet bulletin board about publicly-traded company X, pumpers, dumpers, and reliable sources offer information about events that have the potential of affecting the price of the company’s stock. Since there is little or no information about the identity, background, context or motivation of the participants, it is very difficult to give any credibility to the possible factors that might increase the probability that the testimony offered by any of the participants is true. Assuming the claims are not intrinsically unbelievable, an inductive strategy of the type described by Hume would be the only available one. One should only believe the claims of those participants who regularly inform about events that one has later confirmed. But if there is no pattern in the information provided, it would be irrational to take any of these testimonies as evidence for further reasoning since they lack any sort of justification.⁶

---

⁶ It is interesting to note that if the claims made in the Internet bulletin board are about the price of the stock, Hume’s inductive strategy would be unavailable because there is no direct way of
In all of these cases it is very important to keep in mind that the facts that increase the probability of the truth of a testimony are not necessarily the same facts that increase the probability of the state of affairs being reported. In the first example, the fact that the witness is a respected school teacher neither increases nor decreases the probability that the getaway car was blue, but it increases the probability that his testimony is true. The same goes for the fact that the journal in the second example uses a double-blind peer review process, a fact that has no causal connection whatsoever to the experimental results obtained by Dr. G. in his lab.

Thagard (2005: 298) identifies four triggers for doubt about testimony: lack of credibility of the source, non-credible behavior of the source, incompatibility of the claim with the hearer’s goals, and inconsistency of the claim with other beliefs. Now, according to the doubt-belief model, if a testimony is inconsistent with the agent’s state of belief \( K \), it must be rejected outright. However, there are cases in which the agent might want to hypothetically contract her state of belief in order to give the testimony a fair hearing.\(^7\) In what follows I will assume that the testimony is not inconsistent with \( K \), either because the negation of the testimony is not entailed by \( K \) or because \( K \) has been contracted to hypothetically eliminate the inconsistency. The initial epistemic attitude of the agent will be a suspension of judgment regarding the truth of the testimony.

Suppose \( K \) is the state of belief of a person considering whether to accept the testimony offered by a witness, \( \psi \) is a sentence that states that the testimony is true, and \( p(\psi) \) is the epistemic probability\(^8\) in \( K \) that the witness is telling the truth. A set of sentences \( \Psi \) is a potential justification of \( \psi \) relative to \( K \) just in case:

\[
\begin{align*}
(i) & \quad K \cup \Psi \text{ is consistent.} \\
(ii) & \quad \Psi \not\subseteq K \\
(iii) & \quad \text{There is a sentence } \psi \in \Psi.
\end{align*}
\]

verifying the price. The only possible verification is through an official report from the stock exchange.

\(^7\) For a formal treatment of the contraction of a state of belief, see Levi (2004) and Gärdenfors (1998).

\(^8\) By the “epistemic probability” of a sentence I understand its degree of confirmation or support provided by the total available evidence, in this case, by the sentences in the belief set \( K \).
(iv) There is a sentence \( p(\phi \mid \psi) > p(\phi) \in \Psi \)
(v) There is no \( \gamma \in K \) such that \( p(\phi \mid \psi \land \gamma) = p(\phi \mid \neg \psi \land \gamma) \).
(vi) \( \phi \) and \( \psi \) are logically independent.
(vii) Nothing else is an element of \( \Psi \).

A potential justification is thus a set containing a singular sentence \( \psi \) and a probability sentence that states the probabilistic relevance of the fact described by \( \psi \) to the fact that the witness is offering a true testimony. Let us examine each of the conditions in turn.

The first condition states that a potential justification must be consistent with the corpus of beliefs in which the testimony is to be accepted. To be sure, there are many testimonies whose acceptance leads to a radical change in our beliefs. However, the effect of the acceptance of the testimony on one’s belief state is independent of the acceptance of the beliefs which raise the probability of that testimony. Suppose I believe that John, who works for Company X, is guilty of embezzlement. I am then confronted with the testimony of a detective who has been tracing the bank accounts of all the employees and working in close connection with the accountant of the company. According to the detective’s testimony, John is innocent and the real culprit is Mary. The testimony will turn out to be highly credible in light of facts that I come to accept and that I consider relevant to the truth of the detective’s version. The testimony will force me to revise my belief set, but the acceptance of the testimony itself is based on information consistent with my initial belief set.\(^9\)

The second condition states that the potential justification cannot be already accepted in \( K \). It might seem that there are cases in which the potential justification is already included in \( K \), in violation of this condition. Although it might happen that the relevant fact \( \psi \) is already believed, the probability sentence cannot be already in \( K \) because the testimony is new to the agent. She cannot antecedently believe anything about it, in particular, that there are facts that increase its probability of being true. Since \( \Psi \) is a conjunction that includes the probability sentence, the violation of this condition is only apparent.

The third and fourth conditions can be analyzed together. The former says that the potential justification must include a singular sentence \( \psi \) that describes a relevant factor.

\(^9\) It might happen, of course, that a testimony that was rejected relative to \( K \) might be accepted later on due to a revision of \( K \) consistent with new potential justifications.
The fourth condition states that $\psi$ is positively or negatively relevant to the truth of the testimony. The relevance of $\psi$ is relative to $K$. Most testimonies will only require common sense knowledge in order to determine the facts that increase the probability that the testimony is true, although in some cases the contextual conditions might be too sophisticated and will require expert knowledge. In these cases the non-expert will end up with an impoverished or weak set of potential justifications which might lead to the rejection of testimonies that the experts accept. Ignorance can get in the way of finding warranted evidence.

It is obvious that a testimony that states that $\beta$ is the case will always be made more probable by the fact that $\beta$. Provided that $\beta$ is consistent with $K$, my account allows for a potential justification containing a sentence describing the fact that $\beta$ and a probability sentence to the effect that $\beta$ raises the probability that the testimony is true. Since the agent does not want to beg the question in favor of the testimony, this potential justification will be assigned the lowest informational value. Furthermore, if the testimony contains an outlandish claim, the credal probability of $\beta$ will be extremely low. In both cases the potential justification that includes $\beta$ will not qualify as a bona fide justification (see below).

The fourth condition does not impose any restrictions on the value of $p(\phi)$ in $K$. This allows for cases in which the epistemic probability of $\phi$ is high, say $> \frac{1}{2}$. It would be a mistake, however, to set an upper limit to the epistemic probability of $\phi$ in $K$. Even if a testimony seems very plausible to an agent, the agent might ponder if she can use it as evidence in settling a very important matter and just wants to make sure. Since one of the desiderata in expanding a state of belief is the avoidance of error, the agent’s confidence that a given testimony is true should be weighted against the value of the information it contains. If the risk of error is low, but the information turns out to be almost useless, it might not be worth the risk.

The fifth condition guarantees that $\phi$ and $\psi$ will not be spuriously correlated. Again, this can only be guaranteed relative to $K$ and in some cases common sense knowledge will not be sufficient to rule out potential justifications where $\phi$ and $\psi$ are in fact, spuriously correlated.

The sixth condition prevents the inclusion of trivial cases in which $p(\phi | \psi) = 1$ because $\psi \parallel \phi$. 
The last condition ensures that each potential justification contains only one relevant factor. A strong justification of a testimony will typically mention several relevant factors.

Using our definition of a potential justification, we can now characterize the notion of an *justification space*. An justification space can be understood as the subset of the set of sentences by which \( K \) can be consistently expanded that contains all the potential justifications of \( \phi \), regardless of whether the agent is aware of them or not.

\( (J_{\text{S} \phi}) \quad \text{For every sentence } \phi \text{ in } K, \text{ there is a set } \{\Psi_1, \Psi_2, \ldots, \Psi_k\} \text{ such that } \Psi_i \text{ is an element of the set iff it is a potential justification of } \phi. \text{ The set, denoted } J_{\text{S} \phi}, \text{ is the *justification space* of } \phi. \)

The justification space will contain logically equivalent and empirically equivalent potential justifications. On the one hand, if \( \Psi_1 = \{\psi, p(\phi|\psi) > p(\phi)\} \) and \( \Psi_2 = \{\eta, p(\phi|\eta) > p(\phi)\} \), where \( \psi \) and \( \eta \) are logically equivalent, then \( \Psi_1 \) and \( \Psi_2 \) are logically equivalent potential justifications. If an agent accepts \( \Psi_1 \), she is thereby committed to \( \Psi_2 \). On the other hand, if \( \psi \) and \( \eta \) contain coextensive singular terms or predicates that occupy the same places in \( \psi \) and \( \eta \), \( \Psi_1 \) and \( \Psi_2 \) will be empirically equivalent potential justifications. However, the informational value and the credibility of \( \Psi_1 \) and \( \Psi_2 \) will not be assessed in the same way unless the agents who assess them are aware that the singular terms or predicates are coextensive.

The justification space provides all the possible justifications of a testimony relative to a given knowledge situation, from the most recondite to the most obvious. However, rarely are we in a position to identify all of its elements. Our options are usually restricted to those potential justifications that can be gleaned from the context and from the content of the testimony. We must therefore restrict the options available for expansion to a subset of the justification space. This subset will be the basis for our assessment of the risk of error incurred and of the informational value obtained when we accept a potential justification.

A set of justificatory options relative to \( J_{\text{S} \phi} \), denoted \( O_{\phi} \), is the subset of the justification space of \( \phi \) that contains all the potential justifications of \( \phi \) that the agent has been able to identify. To simplify the analysis, each potential justification \( \Psi_i \) in the justification
space will be represented in $O_\psi$ by the conjunction of its elements, that is, by the conjunction of a singular sentence and a probability sentence, and denoted $J_i$.

Since $O_\psi$ will contain quite disparate potential justifications, the agent must divide the justifications into those that seem credible, those that seem controversial, and those that seem outlandish. In other words, the agent must assign a credal probability distribution to the sentences in $O_\psi$. The resulting credal probability function $C$ determines the risk of error incurred in accepting a potential justification in $O_\psi$. For every potential justification $J_i$, the risk of error is $1 - C(J_i)$.

The risk of error incurred in accepting an justification in the set of justificatory options must be compensated by the informational value thereby obtained. The potential justifications in $O_\psi$ will be more or less valuable to the cognitive agent depending on how much information they contain and on how valuable that information is. How should we evaluate the informational content of a potential justification? The idea that I will adopt here was first presented by Popper in *Logik der Forschung* (1935), and it has been defended in one way or another by Carnap, Bar Hillel, Levi, and others. Popper claimed that the content of a hypothesis, its “degree of falsifiability,” should be measured by how many other hypotheses it rules out. Likewise, I will argue that the informational content of a potential justification in $O_\psi$ should be measured by how many other potential justifications it rules out. Content alone will not be sufficient to obtain a complete ordering of the elements of $O_\psi$ with respect to informational value, but it will provide an objective basis for the ordering.

Popper’s idea can be made more precise in the following way. Levi (1984, ch. 5) proposes a method to measure the informational content of the potential expansions which captures the idea that the content of a justificatory hypothesis should be measured by how many other justifications it rules out. Levi’s proposal can be adapted without modification to the case of potential justifications. To measure the informational content of an justification, we introduce a measure $M$ that assigns nonnegative values to the elements of $O_\psi$ summing up to 1 and such that the $M$-value of a disjunction of elements of $O_\psi$ is equal to the sum of their individual $M$-values. The increment in informational content in expanding by adding $J_i$ to $K$ is the sum of the $M$-values of the elements of $O_\psi$ that are rejected. In other words, the informational content of $J_i$, denoted $\text{Cont}(J_i)$, is $1 - M(J_i)$. As Levi points out, the $M$-function has the formal properties of a probability function.
Carnap, Bar Hillel, and others also used probability based notions of content. But the $M$-function was interpreted by these authors either as a credal probability function or as a measure of the degree of confirmation of the hypotheses. What is new in Levi’s approach is that he rejects these interpretations and introduces a distinction between expectation and content determining probability. The latter is based on the partial ordering of the potential expansions of $K$ introduced by a classical consequence relation. The set of potential expansions of $K$ is a boolean algebra in which the maximum is $K$ and the minimum is 0, the inconsistent state. If $M$ is defined over this set, it will generate a partial ordering of its elements, and if the only element that has probability zero is 0, potential expansions will strictly increase in probability with a decrease in strength. When the $M$-function is defined over the set of potential expansions of interest to the inquirer, i.e., over an ultimate partition, in Levi’s jargon, we obtain a measure of the informational content of the relevant potential expansions. In the case of the potential justifications of testimony, I have transformed the $M$-function into a measure of the informational content of the potential justifications in $O_\phi$.

Levi establishes a distinction between informational content and informational value, a distinction that is captured by the weak monotonicity requirement. I will adopt an analogous requirement in the case of potential justifications:

(WMR) If a potential justification $J_1$ in $O_\phi$ carries at least as much new information as another potential justification $J_2$ in $O_\phi$, $J_1$ carries at least as much new informational value as $J_2$.

The weak monotonicity requirement generates a quasi-order of the potential justifications in $O_\phi$ which is based on the partial order generated by the $M$-function, but is not necessarily identical to it. Thus an agent might consider that a potential justification $J_1$ that is a consequence of another potential justification $J_2$ according to the partial order carries the same informational value than the stronger potential justification because the additional information in $J_2$ has no value to him. But the stronger potential justification cannot carry less informational value than the weaker one. Although some information is useless, it is never worthless.

Here we encounter the crux of the problem of informational value. On the one hand, even though the quasi-ordering generated by the weak monotonicity condition is
based on the partial order generated by the $M$-function, different agents might assess informational value in different ways, all compatible with the $M$-function and in accordance with weak monotonicity. On the other hand, typically there will be elements in $O_\phi$ that are not comparable in terms of strength. Thus they are not partially ordered by the $M$-function. They are examples of residual potential justifications.

Since the agent wants to adopt the best justification available to her, she might invoke further criteria in order to assess the informational value of the elements of $O_\phi$. Levi regards the criteria that are usually invoked to judge the epistemic virtues of a hypothesis or theory "as considerations that complete, to some degree, the quasi-ordering with respect to informational value generated by the [weak] monotonicity condition from the partial ordering with respect to information carried" (1991: 83). The question is to what degree can the quasi-ordering be completed and what considerations would be relevant in the case of justifying testimony.

There are many epistemic values that are usually mentioned in the context of theory choice: explanatory power, predictive power, simplicity, accuracy, fruitfulness, and so on, but they cannot always be used in judging the epistemic value of potential justifications of testimony. We need not decide on a set of general criteria. If the criteria are such that the agent has a clear idea of their importance relative to her interests and epistemic purposes, and on how they should be applied in particular cases, she can incorporate them into her belief state. She will then be able to complete, to some degree, the quasi-ordering generated by the monotonicity condition with respect to the $M$-function.

Let $O^*_\phi$ be a set of justificatory options such that $O^*_\phi \subseteq O_\phi$ and such that the $M$-value of each element of the set has been determined. Combining the credal probability function $C$ that determines the risk of error incurred in accepting a potential justification in $O^*_\phi$ with the $M$-function defined over the elements of $O^*_\phi$, we obtain a value that the agent can use to select the acceptable justifications of $\phi$. I will call this result the epistemic value of a potential justification:

$$(EV) \quad EV(J) = \alpha C(J) + (1 - \alpha)M(J).$$

If we assume that $q = (1 - \alpha)/\alpha$, we obtain the following positive affine transformation of $EV$:

$$(EV) \quad EV(J) = C(J) - qM(J).$$
where \( q \) is the index of boldness. Since the justifications that the agent wants to accept should not be false regardless of how much epistemic value they have, we must require that \( \alpha \geq 0.5 \), and thus that \( 0 \leq q \leq 1 \). Once an index has been adopted, the agent should reject a potential justification in \( O^*_{\phi} \) if \( EV(J) \) is negative, remain uncommitted if it is 0, and accept it if it is positive. Any potential justification in \( O^*_{\phi} \) with positive epistemic value is an justification of \( \phi \) in \( K \). The disjunction of all such justifications is the justification of \( \phi \) in \( K \):

\[
(J_{\phi}) \quad \text{The justification of } \phi \text{ in } K, \text{ denoted } J_{\phi}, \text{ is the disjunction of all the potential justifications in } O^*_{\phi} \text{ with positive epistemic value.}
\]

If no justification is found for a testimony, the original doubt that motivated the agent to engage in inquiry has not been eliminated. The agent should continue to suspend her judgment until further information is available and the testimony cannot be used as evidence for the time being.\(^{10}\) On the other hand, the existence of a justification for \( \phi \) does not lead to its automatic acceptance. As we shall see in the next section, the question of whether a testimony should be accepted is not entirely dependent on the existence of a justification for it.

6. The Acceptance of Testimony as Evidence

Finding and accepting the justification of \( \phi \) in \( K \) is only the first stage of the decision process. The acceptance of \( \phi \) is a different story. Not every justified testimony ought to be accepted as evidence by the agent. It could happen that even the best justification in \( J_{\phi} \) offers very weak support to the testimony. In such cases, a weak justification might leave our epistemic attitude towards the testimony unchanged.

The decision to accept a testimony must be based on the same strategy that was used in the acceptance of its justification. In other words, the acceptance of \( \phi \) ought to be based on its informational value and on its credal probability relative to a belief set \( K + J_{\phi} \), which I will denote \( K^* \).

\(^{10}\) This does not apply to those cases in which the agent has hypothetically contracted her state of belief in order to give the testimony a fair hearing. I will discuss such cases towards the end of the paper.
Let us begin with the credal probability of $\phi$. The role of $J_\phi$ is to provide good reasons to believe that the testimony is true. If it does so effectively, then it should not provide good reasons to believe that it is false. More precisely, $J_\phi$ provides good reasons to believe $\phi$ only if $C(\phi) > C(\neg \phi)$ in $K^*$. Now, since there is no restriction on the value of $C(\phi)$ in $K$, the original belief set where the search for justification was undertaken, it could happen that $C(\phi)$ was already greater than $C(\neg \phi)$ in $K$. In such cases, the role of $J_\phi$ is to lower the risk of error in accepting $\phi$ by increasing its credal probability. However, the final decision to accept $\phi$ will have to be weighted against its informational value, as we will see below.

If $C(\phi) = C(\neg \phi)$ in $K^*$, the agent should suspend judgment regarding the truth of $\phi$, and if $C(\phi) < C(\neg \phi)$ in $K^*$, she should reject it. The former case would occur if $\neg \phi$ was initially more credible in $K$, and the justification made $\phi$ equally credible. The latter case would occur in the Michael Phelps example, where the agent accepts a probability raising fact, namely, that Michael Phelps was in the pool, but that fact fails to change his epistemic attitude towards the stranger’s testimony.

The fact that $C(\phi) > C(\neg \phi)$ in $K^*$ is only a necessary but not a sufficient condition for the acceptance of $\phi$. There are two reasons why having good reasons to believe does not warrant the acceptance of testimony. The first one is that the justification found for $\phi$ might not be sufficient to remove all reasonable doubt. This could happen if there was not enough information available in the context or the testimony was obscure or the inquirer was not very competent in finding strong possible justifications. For whatever reason, a justified testimony might still generate reasonable doubts in the agent. The second reason is that the decision to accept $\phi$ must also take into account the informational value of the testimony. Even if the testimony is more credible than not, the agent might decide not to accept it if its informational value is not very high, as we shall see below.

Let us turn now to the informational value of testimony. If the question regarding the truth of a testimony arises in the course of inquiry, the informational value of $\phi$ will depend on how well the testimony promotes the agent's cognitive or practical goals. Thus formulated, informational value is a comparative measure. Testimony can be seen as (part of) an answer to a what-, a how-, or a why-question, and as such, it can be compared to other potential answers to the same question. The mechanism to judge its content would proceed as in the previous section by means of the $M$-function, which measures the informational content of the relevant potential expansions.
In such cases, once the informational content and the credibility of $\phi$ in $K^*$ have been assessed, we proceed to find the epistemic value of the truth of the testimony.

\[(EV) \quad EV(\phi) = C(\phi) - qM(\phi)\]

The index of boldness $q$ should be the same one used in selecting the potential justifications of $\phi$ because the epistemic context is identical. As before, the agent should reject $\phi$ if $EV(\phi)$ is negative, remain uncommitted if it is 0, and accept it if it is positive.

The foregoing analyses has an additional complication in those cases in which the agent has hypothetically contracted her state of belief in order to give the testimony a fair hearing. When an agent contracts her state of belief, there is a principle that guides the process: the principle of informational economy. "Information is in general not gratuitous, and unnecessary losses of information are therefore to be avoided" (Gärdenfors 1988: 49).

If an agent wants to contract her state of belief by $\sim\phi$, the state $K - \sim\phi$ must contain as much as possible from $K$ without entailing $\sim\phi$. The problem is that typically there will be several possible ways of forming a contraction that does not entail $\sim\phi$. How should we determine exactly which beliefs should be given up?

Several solutions have been suggested in the literature, including finding maximal subsets of $K$ that fail to imply $\sim\phi$ (Alchourrón & Makinson 1982), minimal subsets of $K$ that contain $\sim\phi$ (Alchourrón & Makinson 1985). The solution that I want to briefly examine here was suggested by Gärdenfors (1988) and Gärdenfors & Mackinson (1988). It is based on the intuitive idea that not all the beliefs in an agent's state of belief are equally epistemically entrenched. When forced to choose between two beliefs, an agent will give up the less entrenched one.

The epistemic entrenchment of a sentence is not connected to its subjective probability. If a sentence has been accepted in $K$, it is judged to be maximally probable. Nonetheless, an individual does not regard all of her beliefs as having equal epistemic entrenchment. The informal criterion to determine the degree of epistemic entrenchment of a sentence is "how useful it is in inquiry and deliberation" (Gärdenfors 1988: 87). Some true sentences are central to our cognitive endeavors and others are just epistemically inert.

---

Entrenchment is connected to explanatory and predictive power, and to overall informational value. According to the definition offered by Gärdenfors, it is possible to determine the relative epistemic entrenchment of all the beliefs in a belief state $K$, but the definition is purely qualitative and offers no procedure to assign numerical values to individual beliefs. Nonetheless, Gärdenfors presents a series of postulates for epistemic entrenchment that serve as the basis for the construction of a contraction function. The technical details are presented in Appendix 3.

Now suppose that an agent has contracted his state of belief to $K - \sim \phi$ using epistemic entrenchment to minimize the loss of information. Let $K^\dagger = K - \sim \phi$ and $K^{**} = (K - \sim \phi) + (J_\phi + \phi)$. There are three possible outcomes of shifting from $K$ to $K^\dagger$:

1. The agent may decide that $\sim \phi$ was true after all because no justification was found for $\phi$. The agent returns to $K$ without going to the second stage of the decision process. There is no loss or gain of informational value.

2. The agent may decide that $\phi$ is true because its EV is positive relative to $K^\dagger$. The informational value of $K^{**}$ can be greater than, lesser than, or equal to that of $K^\dagger$.

3. The agent may not make up his mind because $EV(\phi) = 0$ in $K^{**}$, and thus refuses to add $\phi$ or $\sim \phi$ to his corpus. The agent suffers a loss of informational value.

From a decision theoretical point of view, the best option is to refuse to contract to $K^\dagger$, unless $K^{**}$ carries more informational value than $K$. “There is no sense in incurring the risk of ending up with $K^\dagger$ unless there is a chance of benefiting by ending up with $K^{**}$” (Levi 1991: 156). Informally, one should not give up a state of belief unless there is another state of belief that has the potential to be more informationally valuable.

A final problem remains. The analysis presented in this section assumes that a testimony can be compared to other potential answers to research questions in order to determine its comparative informational value. But not all testimonies are answers to research questions and it will not be possible to analyze all of them in this fashion. If I am reading a magazine and come across a dubious assertion, there is no previous question involved. I might undertake the task of finding out if the claim can be justified simply to quell my curiosity, not because the claim is part of an inquiry or because it serves any practical purpose. But how should I assess the informational value of the claim in these cases?
My suspicion is that when doubt about testimony arises in isolation from any cognitive or practical context, when it will not be used as evidence for further inquiry or deliberation, its informational value is quite low. Doubt in these contexts might be an example of what Thagard calls “hot doubt,” a doubt that “involves an attitude toward a proposition that is emotional as well as cognitive” (2004: 391). If the informational value of the testimony is very low, the decision to accept it will be based mostly on its credibility in the light of the possible justifications that the agent might find for it.

7. Conclusion

In this paper I have presented a rule-reductive account of testimony in Lipton’s sense, that is, an account based on rules of belief acquisition that apply to beliefs generally, and not just to testimony. The acceptance or rejection of testimony follows the same decision-theoretical principles that guide the acceptance or rejection of any other belief. At the same time, the account takes into account the specific characteristics of testimonial belief. Firstly, it provides tools to detect the main sources of error in testimony: mendacious intentions and honest incompetence. Both are detected in the justificatory stage by identifying the factors that promote the truth of the testimony. By examining whether there are reasons to trust a witness, or whether the spatiotemporal location of the witness makes it likely that he observed the event reported, my account minimizes the chance of error in accepting a testimony. Secondly, by focusing on doubt as the trigger of any inquiry, my account also explains the difference between testimony accepted as a matter of course and testimony accepted as the result of a decision process. Finally, my account provides a criterion to determine which testimonies can be used as evidence.

The account might strike some as overly subjective. On the one hand, the assessment of the risk of error and of the informational value both of testimony and of its justification is always relative to the belief state of an individual agent; on the other, what triggers an inquiry seeking a warrant for testimony is always the doubt of an individual inquirer. Concerns about the first point can be assuaged by pointing out that it is fairly easy to extend the account presented here in such a way that the assessment of risk of error and informational value is done relative to a corpus of beliefs that represents the shared agreements of a scientific community. I have offered such an account for the concept of explanation elsewhere (Páez 2006).
Regarding the issue of individual doubt, following Peirce I will reply that the starting point of individual inquiries is irrelevant to the settlement of common opinion: “Different minds may set out with the most antagonistic views, but the progress of investigation carries them by a force outside of themselves to one and the same conclusion. … The opinion which is fated to be ultimately agreed to by all who investigate, is what we mean by the truth, and the object represented in this opinion is the real (1878/1998: 138-139).

Appendix 1: Basic Aspects of the AGM Theory of Belief Revision

This appendix presents the basic aspect of the theory of belief revision developed by Alchourrón, Gärdenfors & Mackinson (1985). The account is roughly similar to Levi’s and in the main text I have mostly used the notation used by AGM.

The linguistic representation of an epistemic state is a belief set, also referred to as a state of belief. A belief set is the set of sentences in an object language $L$ that a person accepts at time $t$. Accepting a sentence $\phi$ in a belief set $K$ entails full belief, in the sense that in $K$ there is no doubt about the truth of $\phi$ at $t$.

Since the main use of belief sets is to represent rational epistemic states, two conditions of rationality are imposed on belief sets: the set should be consistent, and it should be closed under logical implication. Both of these criteria presuppose a logic for the language $L$. Besides containing expressions for the standard truth-functional connectives, the language $L$ is governed by a consequence relation $\models$ between a set of sentences in $L$ and a sentence in $L$. A sentence $\phi$ is logically valid iff it is a consequence of the empty set. The relation is assumed to satisfy the following conditions:

\begin{enumerate}
    \item [(\models 1)] If $\phi$ is a truth-functional tautology, then $\models \phi$.
    \item [(\models 2)] Modus ponens. That is, if $\models \phi \rightarrow \psi$ and $\models \phi$, then $\models \psi$.
    \item [(\models 3)] Not $\models \bot$. That is, $\models$ is consistent.
\end{enumerate}

It follows that $\models$ contains classical propositional logic. It is assumed that $\models$ satisfies the deduction theorem and that it is compact. A belief set is defined thus:

\begin{enumerate}
    \item [(Def BS)] A set $K$ of sentences is a (nonabsurd) belief set iff (i) $\bot$ is not a logical consequence of the sentences in $K$ and (ii) if $K \models \phi$, then $\phi \in K$.
\end{enumerate}
An *absurd* belief set, denoted $K_{\bot}$, is the set $L$ of all sentences. A *maximal* belief set $K$ is a belief set such that, for every sentence $\phi$ in the language, either $\phi \in K$ or $\sim \phi \in K$.

The set of all logical consequences of a set $K$ is denoted $Cn(K)$. From (Def BS) it follows that all belief sets satisfy the following condition:

(Cn) \[ K = Cn(K). \]

Belief sets thus include both the beliefs that a person explicitly accepts at a given time, and all of the consequences of those beliefs.

There are only three epistemic attitudes associated with any sentence $\phi$ and any belief set $K$:

(i) $\phi$ is accepted: $\phi \in K$.
(ii) $\phi$ is rejected: $\sim \phi \in K$.
(iii) $\phi$ is indetermined: $\sim \phi \notin K$ and $\phi \notin K$.

A change of belief concerning $\phi$ consists in changing one of these epistemic attitudes into one of the others. The six possible change operations are usually organized into three groups: expansions, revisions, and contractions.

In an *expansion*, the epistemic attitude ‘$\phi$ is indetermined’ is changed into either ‘$\phi$ is accepted’ or ‘$\sim \phi$ is accepted’. The expansion of $K$ by $\phi$ is denoted $K + \phi$. Such changes are the result of epistemic inputs—information added to an epistemic state, either through observation or justified testimony. None of the beliefs accepted in an expansion can contradict any belief in the epistemic state, i.e., expansion into inconsistency is forbidden.

*Revisions* occur when either ‘$\phi$ is accepted’ is changed to ‘$\sim \phi$ is accepted’, or ‘$\sim \phi$ is accepted’ is changed to ‘$\phi$ is accepted’. A revision of $K$ by $\phi$ is denoted $K * \phi$. A revision is the result of an observation or testimony that contradicts one’s current epistemic state. As in expansion, legitimate revisions of our epistemic states can only be represented as changes from one nonabsurd belief set to another. The central rationality criterion on revisions is that the revision of $K$ by $\phi$ should be the minimal change of $K$ that is consistent and includes $\phi$.

In a *contraction*, the epistemic attitude ‘$\phi$ is accepted’ or ‘$\sim \phi$ is accepted’ is changed into ‘$\phi$ is indetermined’. In other words, in a contraction the belief that $\phi$ (or that $\sim \phi$) is given
up and is not replaced by its negation. The contraction of \( K \) by \( \phi \) is denoted \( K - \phi \). The main problem concerning contractions is that, when retracting a belief \( \phi \) from \( K \), there may be other beliefs in \( K \) that jointly entail \( \phi \). In order to maintain closure, we must therefore give up some of those beliefs as well. The problem is then to determine which beliefs should be given up since we do not want to give up beliefs unnecessarily.

These three belief change operators are essentially functions taking a belief set \( K \) and an epistemic input \( \phi \) to a new belief set \( K + \phi \), \( K * \phi \), or \( K - \phi \). Gärdenfors provides rationality postulates that specify the requirements that the respective operators should satisfy. The postulates are then related to the belief change operations via representation theorems.

**Appendix 2: Rationality Postulates for Expansion**

\((K^*1)\) For any sentence \( \phi \) and any belief set \( K \),
\[ K + \phi \text{ is a belief set.} \] (closure)

\((K^*2)\) \[ \phi \in K + \phi. \] (success)

\((K^*3)\) \[ K \subseteq K + \phi. \] (inclusion)

\((K^*4)\) \[ \text{If } \phi \in K, \text{ then } K + \phi = K. \] (vacuity)

\((K^*5)\) \[ \text{If } K \subseteq H, \text{ then } K + \phi \subseteq H + \phi. \] (monotonicity)

\((K^*6)\) For all belief sets \( K \) and all sentences \( \phi \), \( K + \phi \) is the smallest belief set that satisfies \((K^*1) - (K^*5)\). (minimality)

The first postulate expresses the fact that + is a function from \( K \times L \) to \( K \), where \( K \) is the class of all belief sets and \( L \) the class of all sentences. \((K^*2)\) states the acceptance of \( \phi \) in \( K + \phi \). \((K^*3)\) says that no beliefs are retracted in an expansion. In the abnormal case in which \( \neg \phi \in K \), adding \( \phi \) produces an inconsistency. In that case \( K + \phi \) is \( K_{\perp} \), the absurd belief set, which is a superset of all belief sets. \((K^*4)\) states that no expansion is necessary if the epistemic input is already believed. Monotonicity says that if one belief set contains at least the same information as another belief set, then the expansion of the former will contain at least the same information as the expansion of the latter with respect to the same sentence. \((K^*6)\) is an expression of the criterion of informational economy. These postulates lead to the following representation theorem:
THEOREM 1  The expansion function + satisfies \((K+1) - (K+6) \iff K + \phi = \text{Con}(K \cup \{\phi\})\).

The postulates for expansion uniquely determine the expansion of \(K\) by \(\phi\) as the set of all logical consequences of \(K\) together with \(\phi\), and thus lead to an explicit definition of the expansion process.

**Appendix 3: Epistemic Entrenchment**

The epistemic entrenchment of a sentence is relative to the belief set in which it occurs. Different belief sets are associated with different orderings of epistemic entrenchment, even if some of the sentences in the sets overlap. If \(\phi\) and \(\psi\) are sentences in \(L\), the notation \(\phi \leq \psi\) is used as shorthand for ‘\(\psi\) is at least as epistemically entrenched as \(\phi\)’, and \(\phi < \psi\) for ‘\(\psi\) is epistemically more entrenched than \(\phi\)’. The relation \(\leq\) is defined only in relation to a given belief set \(K\). Gärdenfors (1988: 89-91) offers the following postulates for the relation \(\leq\):

\[
\text{(EE1)} \quad \text{For any } \phi, \psi, \text{ and } \chi, \text{ if } \phi \leq \psi \text{ and } \psi \leq \chi, \text{ then } \phi \leq \chi. \quad \text{(transitivity)}
\]

\[
\text{(EE2)} \quad \text{For any } \phi \text{ and } \psi, \text{ if } \phi \models \psi, \text{ then } \phi \leq \psi. \quad \text{(dominance)}
\]

\[
\text{(EE3)} \quad \text{For all } \phi \text{ and } \psi \text{ in } K, \phi \leq \psi \text{ or } \psi \leq \phi. \quad \text{(conjunctiveness)}
\]

\[
\text{(EE4)} \quad \text{When } K \neq K_\perp, \phi \notin K \text{ iff } \phi \leq \psi \text{ for all } \psi. \quad \text{(minimality)}
\]

\[
\text{(EE5)} \quad \text{If } \psi \leq \phi \text{ for all } \psi, \text{ then } \psi \models \phi. \quad \text{(maximality)}
\]

(EE1) is a minimal requirement for any ordering relation. The justification for (EE2) is that, if \(\phi\) entails \(\psi\) and either \(\phi\) or \(\psi\) must be retracted from \(K\), it is a smaller change to retract \(\phi\). If we retracted \(\psi\), \(\phi\) would have to be retracted anyway in order to retain closure, so we lose less by retracting \(\phi\). (EE3) says that, since we must retract either \(\phi\) or \(\psi\) to retract \(\phi \& \psi\), the informational loss incurred by retracting \(\phi \& \psi\) is at least the same as that incurred by giving up \(\phi\) or \(\psi\). (EE4) states that when a sentence is not contained in \(K\), it is not entrenched at all and is thus minimal in the ordering. (EE5) states the opposite, namely, that when a sentence is logically valid, and thus contained in every nonabsurd belief set, it is maximal in \(\leq\). Logical truths have the highest degree of epistemic entrenchment because they will never be given up.
The following condition relates ≤ to contraction functions:

\[(C\leq) \quad \psi \leq \phi \text{ iff } \psi \notin K - \phi \& \psi\]

The intuitive idea is that if \(K\) is contracted by \(\phi \& \psi\), either \(\phi\) or \(\psi\) must be given up. \(\psi\) should be retracted just in case \(\phi\) is at least as epistemically entrenched as \(\psi\). \(\phi\) and \(\psi\) are equally entrenched only when they are both logically valid.

References


