

# Surprises in Logic

Catarina Dutilh Novaes\*

## 1 Introduction

In the *Tractatus* (6.1251), Wittgenstein (in?)famously said: “Hence, there can never be surprises in logic.” One way of understanding this claim is to view Wittgenstein as embracing one of the horns of what is often referred to as the ‘paradox of inference’ (which is in fact a dilemma rather than a paradox properly speaking): the tension between the validity and the usefulness of logic, and of deductive reasoning more generally.<sup>1</sup>

If in an inference the conclusion is not contained in the premises, it cannot be valid; and if the conclusion is not different from the premises, it is useless, but the conclusion cannot be contained in the premises and also possess novelty; hence [deductive] inferences cannot be both valid and useful. (Cohen & Nagel, 1934) (p. 173)

In the *Tractatus*, Wittgenstein clearly chooses validity over usefulness in his account of logic. As portrayed by him, logic is essentially uninformative: logical propositions “say nothing” (6.11), as they do not depict (contingent) states-of-affairs; “we can actually do without logical propositions” (6.122).<sup>2</sup> Indeed, his conclusion to the effect that there cannot be surprises in logic follows neatly from the premises he lays down in section 6.1 of the *Tractatus*. So whoever wishes to find a different solution to the dilemma, and in particular to give an account of logic which allows for validity and usefulness to co-exist, must address Wittgenstein’s argument in order to block the conclusion: either at least one of the premises does not hold, or at least one of the inferential steps is not legitimate (so naturally, there are several ways of blocking Wittgenstein’s argument). Here I shall

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\*Thanks to Martin Stokhof for comments on an earlier draft. I must also warn the reader that the ideas presented here are very much work in progress; many of the claims made here shall not receive a full treatment for now.

<sup>1</sup>Notice that the name ‘paradox of inference’ is also often used in connection with Lewis Carroll’s puzzle of Achilles and the Tortoise. This usage of the expression seems to stem from (Clark, 2002), and it concerns a different issue, namely the threat of infinite regress for a rule-following conception of (logical) reasoning.

<sup>2</sup>But in all fairness, Wittgenstein’s position is more subtle than these remarks may seem to suggest. In particular, even though logical propositions are ‘senseless’, logic is a *Spiegelbild* of the world (6.13).

focus on one particular aspect of the argument, namely his characterization of the epistemology of what he calls a ‘mechanical expedient’, the derivation of proofs. I agree with Wittgenstein’s claim that what could be described as a mechanical way of reasoning—calculation—is a significant aspect of logical practice (though I certainly do not wish to imply that it is the only or not even the most important aspect thereof); but I question his characterization of this way of reasoning as delivering no surprises.

For this purpose, I draw on some experimental results from the psychology of reasoning, which suggest that a very pervasive mechanism in our ordinary, everyday life ways of reasoning is a tendency to seek confirmation of previously held beliefs; this mechanism is referred to as ‘confirmation bias’ in the psychology literature. In particular, it is identified as the source of the empirically observed phenomenon of people tending to endorse arguments with plausible conclusions (i.e. conclusions according with their prior beliefs) far more frequently than arguments with implausible conclusions, regardless of the argument’s validity as such. In the case of argument endorsement, the term typically used is ‘belief bias’, which is a special case of confirmation bias. Indeed, in experiments *invalid* arguments with plausible conclusions are more often endorsed than valid arguments with *implausible* conclusions. My suggestion here will be that the ‘mechanical’ manner of reasoning often used in logic (and other deductive fields) in fact acts as a counterbalance to our tendency towards confirmation and belief bias, and that this is one of the reasons why deductive reasoning can be and often is informative after all. The built-in belief bias suppressing effect of deductive reasoning (which is particularly acute in the case of deductive ‘mechanical’ reasoning) makes it in fact particularly apt to deliver surprises.

I shall first discuss the so-called ‘paradox of inference’ and some of the different treatments it received in the literature. Next, I turn to the *Tractatus* in order to spell out the structure of the argument that led Wittgenstein to conclude that there can be no surprises in logic. I then discuss the mechanism of belief bias as described in the psychology of reasoning literature. Finally, I argue that ‘mechanical’ reasoning can serve as a counterbalance to belief bias and thus that its use in logic can partially explain why there seem to be surprises in logic after all.

## 2 The paradox of inference and surprises in logic

The so-called paradox of inference has received quite some attention from logicians and philosophers at different times, and rightly so: it is perhaps the most crucial philosophical issue concerning deductive reasoning in general. The point of deductive reasoning is precisely not to allow for external information to ‘sneak in’, to conduct reasoning solely on the basis of the information explicitly on the table in such a way that no additional information could possibly defeat the conclusion at a later stage. But if all the information that can be used and is relevant is already on the table, how can we learn anything new by reasoning deductively?

In a sense, the conclusion is already contained in the previously available information, the premises. “The existence of deductive inference is problematic because of the tension between what seems necessary to account for its legitimacy and what seems necessary to account for its usefulness.” (Dummett, 1978) (p. 297) (Notice that this discussion intersects directly with the matter of analyticity, which is of course one of the concepts used to explain in more precise terms what it means for the conclusion to be ‘contained’ in the premises—see (Primiero, 2008).)

Awareness of this somewhat paradoxical nature of deductive reasoning can be traced back to Mill (Mill, 1843). Some of the authors who have taken an interest in the issue are Keynes (Keynes, 1884) (p. 414 et passim), Hintikka (Hintikka, 1973) (p. 222 et passim), and more recently D’Agostino and Floridi (D’Agostino & Floridi, 2009), Sequoiah-Grayson (Sequoiah-Grayson, 2008) (the last three refer to the issue as ‘a scandal of deduction’, a term introduced by Hintikka) and Primiero (Primiero, 2008) (section 2.3), among others. Different approaches and solutions to the dilemma have been proposed in order to explain why there seems to be gain of information when one performs a deduction, even though the whole point is precisely not to go beyond what is given by the premises. Hintikka proposed a syntactic approach to the issue, based on the notion of distributive normal form of a sentence  $F$ ; Sequoiah-Grayson criticized Hintikka’s solution and suggested that instead a semantic approach would be required to deal with the puzzle. D’Agostino and Floridi address the issue from the point of view of the computational complexity of different logical systems. They notice that there is a certain tension between the idea that logic does not yield new information and the undecidability of first-order logic, and suggest that, on the basis of some computational properties, a hierarchy of logical systems can be formulated, which would determine the lower or higher degree of ‘analyticity’ of a given system. Primiero addresses the issue from a constructive point of view, arguing that the tension between the validity and the usefulness of logic can be dissipated once one pays sufficient attention to the distinction between proposition and judgment.

I think these different solutions all outline important factors that may be involved in the apparent information gain resulting from reasoning logically (deductively), and outlining yet another one of such factors is the purpose of the present contribution. In other words, I believe that there are different phenomena involved, and thus that different accounts may complement each other rather than compete with each other when it comes to explaining why there seems to be information gain in logic after all. To my knowledge, the ‘paradox of inference’ has never been formulated specifically in terms of the presence or absence of surprises in logic, but some authors (Carnap, Hintikka) come very close to this idea when pointing out that information flow and information gain go hand in hand with unpredictability (e.g. that the measure of content of a proposition is inversely proportional to the probability weight assigned to it). There is information gain in particular when the outcome of some reasoning goes against what was initially anticipated - thus, when the conclusion is unexpected and surprising in one way or another. Indeed, the paradox (dilemma) can also be neatly formulated in terms

of surprises: for deductive reasoning to be legitimate, it must not deliver any surprises; but for deductive reasoning to be useful, it must do just that - deliver surprises.<sup>3</sup>

### 3 Wittgenstein on surprises and ‘mechanical reasoning’

Wittgenstein’s claim that there can be no surprises in logic is of course related to a deeper feature of the philosophy of logic defended in the *Tractatus*: his realist vision of logic, as opposed to what could be described as a Fregean, epistemological account of logic as a tool to acquire new knowledge. The search for an ontological grounding for logic (and in fact for language in general) leads Wittgenstein away from matters such as the potential cognitive role of logical reasoning. So in a sense, it is to be expected that he would be prepared to ‘bite the bullet’ of logic’s uselessness. Still, it is interesting to take a closer look at the argument leading to the conclusion that there can be no surprises in logic in order to see what exactly the conclusion depends on.

The cornerstone of the Tractarian philosophy of logic is stated at the very beginning of the section we will be concerned with here, namely section 6.1:

#### 6.1 The propositions of logic are tautologies.

On the one hand, to limit the scope of logic in this way may seem unwarranted, as logic presumably also deals with hypothetical reasoning starting with open assumptions. On the other hand, this may also simply be a different formulation to the familiar slogan according to which logic (and deductive reasoning more generally) is ‘tautological’ precisely in the sense spelled out above, i.e. in the sense that the conclusion of a logical argument is already contained in the premises. Moreover, by the deduction theorem (which holds in most, but not all, logical systems), any valid argument can be formulated as a conditional having as antecedent its premises and as consequent its conclusion, and such a conditional is indeed a tautology in the sense of ‘true no matter what’. (Notice also that proofs in sequent calculus are trees whose initial nodes are all instances of the identity axiom  $A \Rightarrow A$ .) So there is nothing particularly controversial in Wittgenstein’s claim, even though one could probably offer an account of logic that is not limited to tautological propositions.

That the propositions of logic are all tautological does not yet imply that there shall be no surprises in logic; to be a tautology is a *factual* (albeit necessary) property of propositions, whereas the phenomenon of surprises concerns the *recognition* by an agent that some object  $a$  has property  $P$  (in this case, that a proposition is a tautology). The feature of logical propositions that really excludes

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<sup>3</sup>Notice however that ‘surprise’ is a stronger notion than ‘information gain’: there may be information gain even if the new information is not particularly surprising, i.e. if the agent involved did not have specific expectations concerning it prior to obtaining it.

the possibility of surprises is a different one: for Wittgenstein, every tautological proposition *shows* its own 'tautologyness'. Just as he insists that the truth or falsity of non-logical propositions is a purely contingent matter (determined by the existence or non-existence of the situation that is its sense), a key feature of logical propositions is that their truth (or falsity, in the case of contradictions) can be 'read off' from the propositions directly.

6.113 It is the peculiar mark of logical propositions that one can recognize that they are true from the symbol alone, and this fact contains in itself the whole philosophy of logic. And so too it is a very important fact that the truth or falsity of non-logical propositions cannot be recognized from the propositions alone.

6.127 All the propositions of logic are of equal status: it is not the case that some of them are essentially derived propositions. Every tautology itself shows that it is a tautology.

How can a proposition show itself to be true (and necessarily so)? To understand this claim, one must bear in mind that, for Wittgenstein in the *Tractatus*, validity in logic is purely determined by logical syntax, i.e. by the (internal) properties and possibilities of the signs themselves, viewed as objects as such, thus not in their representative dimension (e.g. as pictures of something else, precisely because logical propositions do not depict possibilities). So in a sense, the objects that a logical proposition 'speaks of' are exclusively signs, in particular those very signs being presented, and this is why its truth can be determined by mere inspection of the proposition. Thus, it would appear that, for Wittgenstein (of the *Tractatus*) just as for Peirce, logic is the science of (the necessary laws of) signs.

6.124 [...] We have said that some things are arbitrary in the symbols that we use and that some things are not. In logic it is only the latter that express: but that means that logic is not a field in which we express what we wish with the help of signs, but rather one in which the nature of the absolutely necessary signs speaks for itself. If we know the logical syntax of any sign-language, then we have already been given all the propositions of logic.

But what about proof and derivation? Isn't the practice of formulating proofs essential for the establishment of the (necessary) truth of a logical proposition? Or does Wittgenstein deny that formulating proofs has always been part and parcel of logic as an enterprise? Well, he does have an account of proofs in logic, but one which significantly downplays their importance:

6.126 One can calculate whether a proposition belongs to logic, by calculating the logical properties of the symbol. And this is what we do when we 'prove' a logical proposition. For, without bothering about sense or meaning, we construct the logical proposition out of others

using only rules that deal with signs. The proof of logical propositions consists in the following process: we produce them out of other logical propositions by successively applying certain operations that always generate further tautologies out of the initial ones. (And in fact only tautologies follow from a tautology.) Of course this way of showing that the propositions of logic are tautologies is not at all essential to logic, if only because the propositions from which the proof starts must show without any proof that they are tautologies.

6.1262 Proof in logic is merely a mechanical expedient to facilitate the recognition of tautologies in complicated cases.

Wittgenstein attributes a ‘mechanical’ character to the operations of transforming propositions into others—i.e. of inferring A from B. Importantly (for my purposes), he says that when conducting a proof one proceeds “without bothering about sense or meaning, [...] using only rules that deal with signs”. This observation fits in well with the idea that logic is the science of signs as such, i.e. not insofar as they are pictures of something else outside them (which would be their potentially meaningful dimension). But if every tautology shows indeed itself to be a tautology, proof is a rather superfluous device, of purely instrumental value. This again confirms Wittgenstein’s realist perspective: logic is concerned with the objective properties of signs, which are all there from the start (just as the internal properties of objects as described in the first section of the *Tractatus*). The ‘merely’ epistemological layer of an agent actually uncovering (unfolding) these properties, which is what happens when she formulates a proof, is unimportant. The properties are already (or should be, in any case) shown in a logical proposition, which shows itself to be a tautology.

6.1265 It is always possible to construe logic in such a way that every proposition is its own proof.

But because the objective properties of signs (or their ‘necessary laws’, as Peirce would say) are a given, i.e. are fully ontologically determined, the class of logical propositions is also fully determined from the start, much before any proof is formulated.

6.125 It is possible—indeed possible even according to the old conception of logic—to give in advance a description of all ‘true’ logical propositions.

And this is indeed the aphorism immediately preceding the claim under scrutiny here:

6.1251 Hence, there can never be surprises in logic.

Thus, from the start, the whole of logic is given to us, since the objective properties of the signs are determined from the outset. It is all there ‘on the table’, as it were, and if we fail to see it immediately, this can only be due to our own inability or perhaps to a defective notation (one which fails to formulate every tautology as showing its own tautological nature). Wittgenstein’s ontic point of view entails a disregard for the actual *process* of ‘unfolding’ propositions and coming to recognize them as tautologies by means of a proof, given that the *result* of a proof, i.e. the conclusion of the derivation, is in itself already a ‘proof’ of its own truth.

6.1261 In logic process and result are equivalent. (Hence the absence of surprise.)

There are of course many aspects of Wittgenstein’s characterization of logic one could object to in order to block the argument leading to the conclusion that there can be no surprises in logic. I shall focus on contesting the following claim: “6.1262 Proof in logic is merely a mechanical expedient to facilitate the recognition of tautologies in complicated cases.” The idea seems to be that what is achieved by means of a proof could be achieved without a proof,<sup>4</sup> and Wittgenstein seems to suggest that it is precisely the ‘mechanical’ nature of this expedient that makes it superfluous. I essentially agree with Wittgenstein’s characterization of proof as a sort of calculation, as a process during which one (often) does not bother “about sense or meaning”,<sup>5</sup> but I will argue that it is precisely the fact of not bothering about sense or meaning and of applying rules that only deal with signs ‘blindly’ that makes this ‘mechanical’ way of reasoning particularly suitable to deliver surprises. So what I object to most of all is Wittgenstein’s account of the *epistemology* of proof; in a Leibnizian vein, I shall argue that proof (and deductive reasoning in general) is in fact a crucial tool for the discovery of new facts, i.e. for information gain. What my argumentative strategy seeks to accomplish is to show that, even if we grant the other premises that Wittgenstein’s argument is based on, it will still not follow that reasoning ‘mechanically’ will yield no surprises.

## 4 ‘Everyday life’ reasoning and belief-bias

Decades of experimental research on the psychology of reasoning have shown that people typically do not reason according to the canons of deductive reasoning. After a long-lasting predominance of what could be described as a Piagetian paradigm, according to which reasoning in general (regardless of the circumstances) essentially follows the canons dictated by (presumably classical) logic, researchers started to conduct experiments whose results suggested significant

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<sup>4</sup>It can be argued that Wittgenstein is actually saying that proof is not superfluous in such complicated cases, but the fact that he uses the term ‘facilitate’ rather than ‘ensure’ or the like at least suggests that even in such cases proof is not essential.

<sup>5</sup>I will, however, highlight the importance of heuristic devices when formulating a proof at a later stage.

discrepancy between ‘everyday life’ reasoning and the deductive canons; the locus classicus for this tradition is (Wason, 1966), where the famous Wason selection task was presented for the first time. The results presented by Wason indicated that subjects simply did not follow the basic logic of conditionals in order to solve the task proposed, namely to validate or invalidate a rule formulated as a conditional.

The ‘fall’ of the Piagetian paradigm has caused and still causes significant discomfort and turmoil, and many possible explanations have been proposed to account for the discrepancy between actual patterns of human reasoning as experimentally observed and the canons of deductive reasoning and of other presumably rational canons. Some have argued that there are fundamental problems with the experimental paradigm; others have concluded that people in general are bad reasoners and ‘irrational’; yet others maintain that it is deductive reasoning instead that has no (natural) place in human cognition. (For an overview of this tradition, see (Evans, 2002).)

Among the many discrepancies studied since then, a group of reasoning mechanisms received the general name of ‘cognitive biases’. The term ‘bias’ (in itself loaded with negative connotations) is used to describe a series of reasoning mechanisms that depart from the norm defined by the canons of ‘rationality’ theoretically defined (i.e. on the basis of deductive reasoning, rational choice theory etc.). Among these are confirmation bias and belief bias. Generally speaking, belief bias refers to the tendency we seem to have to endorse far more arguments as valid if their conclusions also accord with prior belief, and to reject arguments whose conclusions clash with prior belief. The concept was introduced in a 1983 paper by Evans et al. (Evans, Barston, & Pollard, 1983), to account for the results obtained in the following experiment: subjects were presented with syllogistic arguments and asked to indicate whether the conclusion necessarily followed from the premises given. In other words, subjects were asked to make an evaluation of the (logical) validity of the arguments in question. These were valid as well as invalid arguments, featuring plausible as well as implausible conclusions (in all four combinations). Some of the arguments presented to subjects were:

Valid-believable	Valid-unbelievable	Invalid-believable	Invalid-unbelievable
No police dogs are vicious.	No nutritional things are inexpensive.	No addictive things are inexpensive.	No millionaires are hard workers.
Some highly trained dogs are vicious.	Some vitamin tablets are inexpensive.	Some cigarettes are inexpensive.	Some rich people are hard workers.
Therefore, some highly trained dogs are not police dogs.	Therefore, some vitamin tablets are not nutritional.	Therefore, some addictive things are not cigarettes.	Therefore, some millionaires are not rich people.

The results once again clashed with the canons of deductive reasoning: subjects tended to endorse arguments with plausible conclusions (i.e. conclusions according with their prior beliefs) far more frequently than arguments with implausible conclusions, regardless of the argument's validity as such. Indeed, in the experiments *invalid* arguments with plausible conclusions are more often endorsed than valid arguments with *implausible* conclusions, as the table below shows. This suggests that accordance of the conclusion with one's prior beliefs plays a more prominent role in the evaluation of the propriety of an argument than its 'logical' validity.

Percentage of conclusions accepted:

*	Believable	Unbelievable
Valid	89	56
Invalid	71	10

Of course, these somewhat surprising results can be seen as a consequence of problems with the experimental setup; it is unclear, for example, how exactly subjects understand the concept of 'necessity' as presented in the task. Another hypothesis that has been put forward to account for the results is that subjects may be using a parsimonious heuristic mechanism: if the conclusion is already plausible, then there is no point in allocating cognitive and computational resources to evaluate the validity of the argument. (For a discussion of these hypotheses, see (Evans, Newstead, & Byrne, 1993) (pp. 243-255). For a more recent article on belief-bias, see (Klauer, Musch, & Naumer, 2000).)

Be that as it may, belief-bias is a variation of a more general mechanism known as confirmation bias, i.e. a tendency to search for, interpret or remember information in a way that confirms preconceptions. People can reinforce their existing beliefs by selectively collecting new evidence, by interpreting evidence in a biased way or by selectively recalling information from memory. As studied in the literature, however, belief bias concerns confirmation bias specifically in the case of reasoning from premises to conclusion (and in particular concerning syllogistic arguments). True enough, the experiments set up to investigate belief bias typically consist in subjects being asked to endorse or reject previously formulated arguments rather than to draw conclusions themselves on the basis of given premises. Still, it would seem that the results at least suggest the more general pattern of belief bias as also operating when one is actively drawing inferences: one may typically avoid drawing conclusions from given (endorsed) premises if they happen to clash with one's prior beliefs, and may instead choose to draw conclusions that confirm these prior beliefs. These conclusions may actually 'follow' (validly) from the premises in question, but still the behavior of being selective and avoiding the counter-intuitive conclusions would already indicate a form of confirmation and belief-bias. Moreover, the results also suggest that there may be a tendency towards drawing 'conclusions' which do not actually follow from the given premises, but which are themselves plausible; this would amount to a fallacious form of seeking confirmation to one's prior beliefs (on this connection,

see (Floridi, 2009).)

At any rate, what seems to be going on is that subjects let external information in the form of prior beliefs (in particular, their belief in the plausibility of the conclusion) ‘contaminate’ the reasoning process, whereas according to the canons of deductive reasoning, only the information contained in the premises is to be taken into account. For my purposes here, this seems to be the main upshot of the belief bias experiments: we typically call upon external information when reasoning in everyday life, and for good reasons. In everyday life, to make use of deductive reasoning exclusively would be extremely counterproductive, as we typically do not dispose of sufficient information to draw the appropriate conclusions. We would ‘freeze’ most of the time, as the available information would underdetermine the conclusion(s) to be drawn.

Moreover, while the term ‘bias’ suggests that it is a mistake to seek confirmation to one’s prior beliefs, in the literature there are also discussions on why it may be a perfectly ‘reasonable’ mechanism after all, in any case for use in practical situations, where there are constraints of time and cognitive resources (again, see (Evans et al., 1993) (p. 243-255)). If one were to revise one’s beliefs constantly, this would demand a significant allocation of cognitive resources, which would most likely provoke a situation of cognitive overload. We do, of course, perform belief revision regularly, but to suppress confirmation and belief bias completely would probably entail that we would be revising our beliefs more often than would be beneficial given our limited resources.

## 5 Deductive reasoning as a counterbalance to belief-bias

But there are contexts and circumstances where it is in fact not so advantageous to seek confirmation to previously held beliefs, i.e. to be conservative towards one’s own prior doxastic commitments. This is the case in particular of scientific contexts, where the goal is precisely to uncover new information for as much as possible, and constraints of time and resources play a less significant role. So this may be yet another reason (besides the quest for the highest degree of certainty) why deductive reasoning is thought to be the quintessential form of reasoning in scientific contexts, that is, if it serves indeed as a counterbalance to belief bias, as I shall argue now.

In scientific contexts, the paradox of inference with which I started the paper manifests itself in the form of another tension, namely the tension between the certainty and indefeasibility sought after in science and the constant strive to reveal new facts, to produce new information. Typically, the higher the standards of certainty adhered to, the lower the amount of new information likely to be produced and accepted as legitimate. The use of deductive reasoning in science is often thought to be related to the high level of certainty it provides; but if I am correct in identifying deductive reasoning as a way to counterbalance confirmation and belief bias, then deductive reasoning may also play a positive role regarding

information gain.

Let us now go back to Wittgenstein's characterization of proof in logic as a 'mechanical expedient'. The crucial features of this form of reasoning are disregard for 'sense or meaning' and the fact of using only rules that deal with signs. Wittgenstein is effectively saying that proof in logic is ultimately a form of calculation, of blind manipulation of signs by means of rules. While there is definitely more involved in derivations than mere calculation (more on this below), the process of 'de-semantification' (in S. Krämer's fitting terms in (Kramer, 2003)) that seems to be at least one important element of our use of formal languages when doing logic suggests that Wittgenstein is right in identifying a calculatory aspect in the act of formulating a proof. Applying the 'rules that deal with signs' is often done more efficiently precisely if one does not pause to think about the meaning of the expressions involved and instead treat them as 'meaningless signs'.

More importantly, this process of de-semantification also facilitates the suppression of contamination of prior beliefs in the reasoning process. Given that no ingenuity or insight is required to perform the application of the rules that deal with signs (even though some ingenuity may be required to decide *which* rules to apply—see below), it is effectively possible to avoid the interference of external information, in particular of prior beliefs.

How does this 'mechanical' way of reasoning relate to deductive reasoning more generally? The canons of deductive reasoning tell us that we must draw indefeasible inferences solely on the basis of the explicitly accepted premises, but they do not tell us how to accomplish this feat. Mechanical reasoning, or pure manipulation of signs, is one way of ensuring that no extra premises be allowed to sneak in during the reasoning process, and this is indeed one of Frege's crucial insights in the *Begriffsschrift*. While this feature of deductive reasoning is usually associated with the quest for the highest possible degree of certainty, my suggestion here is that it also contributes to the novelty of the conclusions to be drawn by means of purely logical reasoning, precisely because it blocks the possible interference of prior beliefs and thus our tendency to seek confirmation for them.

Even in logic, where one not only uses patterns of deductive reasoning to reason about a specific topic but also investigates these patterns as such, some expectations as to what is likely to be a theorem of a given theory are usually in place. And while not all results in logic are surprising, some are, and my suggestion here is that the 'mechanical way of reasoning' related to the manipulation of formal languages is at least partially responsible for the phenomenon of logicians overcoming their own confirmation bias.<sup>6</sup>

This being said, I must qualify that characterizing proofs in logic as a merely mechanical expedient does not tell us the whole story either. If nothing else, in most (interesting) logical systems the possibilities of combinations of 'the rules that deal with signs' amounts to a combinatorial explosion, and most of these

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<sup>6</sup>Here is one example of a logical-mathematical result which very much surprised its own discoverer: the Paris-Harrington incompleteness theorems, which came as a total surprise to Jeff Paris (personal communication). For a broader discussion of surprising mathematical results, see <http://rjlipton.wordpress.com/2009/09/27/surprises-in-mathematics-and-theory/>.

combinations are utterly uninteresting and trivial. Proof in logic is not a merely mechanical expedient also because it takes insight to identify the promising paths, i.e. those leading to non-trivial results among the many possible combinations. Indeed, even automated theorem-provers typically operate on the basis of heuristic mechanisms rather than on ‘brute force’ alone, i.e. mere combinatorial possibilities.

But ultimately, Wittgenstein’s claim that there can be no surprises in logic stems from an undue disregard for the epistemic act of actually unpacking the information contained in the premises when drawing a (deductive) inference. Before the act of unpacking, the information contained in the premises is merely ‘virtual information’ (a term used by D’Agostino and Floridi), which must be actualized in order to become truly available, and this is exactly what the act of drawing an inference is able to accomplish. In a sense, the information is indeed contained in the premises, but in a sense it is not, i.e. in the sense of actually becoming available to us for future use. (It is not very different from telling a child who has just received a present that she need not open it, as the toy is already ‘there’ even though she cannot see it or play with it; the present must be unpacked in order to become ‘real’ for the child.)

As for surprises: the act of unpacking may reveal something that confirms what one already believes or at least suspects, but it may also reveal something that had not been taken notice of even though it was there all along, so to say, and which in fact clashes with one’s prior beliefs. Deductive reasoning ought to be neutral with respect to prior beliefs not directly involved in a given deductive inference, and a certain degree of mechanization in one’s reasoning can certainly contribute to this neutrality.

Catarina Dutilh Novaes  
 Philosophy Department and ILLC, University of Amsterdam  
 Nieuwe Doelenstraat 15, 1012 CP Amsterdam, The Netherlands  
 c.dutilhnovaes@uva.nl  
<http://staff.science.uva.nl/~dutilh/>

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