

REASON NATURALIZED (AN EMPIRICAL JUSTIFICATION OF LOGIC)*¹

LA RAZÓN NATURALIZADA (UNA JUSTIFICACIÓN EMPÍRICA DE LA LÓGICA)

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ABSTRACT

The question of rationality is approached from the justification of logic, considering the existence of alternative systems. I delimit this topic to the justification of our criteria for rationality, focusing on inferential rationality. In light of this, I suggest *a posteriori* solution to recognize logical systems as reasonable, given the absence of an infallible notion of rationality. This proposal is pluralistic, acknowledging multiple valid systems, and normative, establishing that not all have the same value: some are more suited for inferences than others.

Keywords: rationality; logical pluralism; logic; normativity; logic *a posteriori*.

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RESUMEN

Se aborda la cuestión de la racionalidad desde la justificación de la lógica, considerando la existencia de sistemas alternativos. Delimito este tema a la justificación de nuestros criterios de racionalidad, centrándome en la racionalidad inferencial. Ante esto, sugiero una solución *a posteriori* para reconocer sistemas lógicos como razonables, dada la inexistencia de una noción infalible de racionalidad. Esta propuesta es pluralista, reconociendo múltiples sistemas válidos, y normativa, estableciendo que no todos tienen el mismo valor: algunos son más aptos para inferencias que otros.

Palabras clave: racionalidad; pluralismo lógico; lógica; normatividad; lógica *a posteriori*.

1. THE PROBLEM OF JUSTIFYING REASON

...if we separate all the knowledge that we must obtain from objects and reflect upon the use of understanding in general, then we discover those rules of it which are quintessentially necessary for any purpose and independently of all particular objects of thought, because without them we would not think at all. Hence, these rules can be comprehended a priori (...) That science of the necessary laws of understanding and reason in general... we thus call logic. (Kant 2000 79-80).²

² *Lógica. Un manual de Lecciones*, is the name, in its Spanish version, of the work that, as a product of Kant's own class notes, was edited by G.B. Jäsche, under the title of *Lógica de Kant*, on his behalf.

That was said by Immanuel Kant in the year 1800. Logic, as the science of the laws of thought, was considered necessary and a priori.

The apriorism of logic allowed it to maintain the certainty that Kant would question for metaphysics. Logic was, therefore, considered a reliable source of knowledge. That certainty, in turn, resulted in the normativity of logic, conceived as the science of "correct" thinking.

Logic is... an a priori science of the necessary laws of thought... a science, therefore, of the correct use of understanding and reason in general, but not in a subjective sense, that is, not according to psychological (empirical) principles: how the understanding thinks, but in an objective sense, that is, according to a priori principles: how it ought to think. (Kant 2000 84, author's italics).

Kant's text immediately raises several questions: (1) How does apriority guarantee the correctness of logic? And why would it? (2) If the error inherent in human use of reason has been eliminated, why still trust in reason itself? (3) How would reason define itself, apart from its use?

To justify the existence of reason, distinct from its use (responding to question 3), we can consider it as a human capacity. Although I will later argue that it is not limited only to humans, this attribution is sufficient to distinguish between a faculty and its use. Thus, there could exist a faculty that not only allows but also guides certain uses. Just as we assume, without adding too much ontological weight, that we have an ability to utter grammatical statements (which even an infant uses to form sentences without being aware of it), we can believe that we possess a faculty that guides our inferences.

It is necessary to pause for a moment to point out that we might find other candidate faculties that, if not to be identified with rationality, should at least be considered part of it. Perhaps there are actions that we also consider rational although they do not stem from an inference. For example, it could be considered rational to cross the street when the traffic light is green, even if we do so automatically and without inferring it. It might even be argued that our instincts are, in a

certain sense, rational. For instance, it would be rational to flee if we come across an uncaged tiger. That would not be rational in the sense of a decision motivated by a correct inference, but rather an action that is better to take than not, with the natural objective of surviving. In an objective sense, one that evaluates the action rather than its causes, fleeing from a giant feline is rational, whether it is instinctive or the result of deliberation. If we wish to judge the rationality of our actions from a third-person viewpoint, it could be considered sensible to find rational both the actions that are the product of our inferences and those that are the result of any other mechanisms if they lead to the correct end. But that kind of rationality would not be, of course, the rationality associable with a logical system, since logical systems only deal with inferences and not with other links between ideas, such as free association or imagination, nor with instincts and actions motivated by non-inferential means. In the following discussion, I will focus solely on the problem of the normativity of logic. Specifically, I will examine the extent to which normative systems present, and potentially govern, inference. The concern for the normativity of logic arises as the concern for the normativity of a system that describes not the “reason”, a term that can refer to many things, but the faculty of reasoning.

Gilbert Harman (1986) refers to the logic whose normativity we are considering, as what he calls a *theory of inference*, and contrasts it with a *theory of reasoning*.³ The theory of inference states what follows from what,⁴ not what we can or should infer, we human beings. Harman emphasizes that there are constraints, such as short-term memory capacity and limited time to make decisions, that restrict certain uses. However, in specific situations, Harman considers that it's not only that we cannot

³ “Logic is the theory of implication, not directly the theory of reasoning” (Harman 1986 10).

⁴ Harman asserts that “A judgment that S ought to do A, according to the law, is not the judgment that this conclusion follows deductively from certain legal principles together with the facts of the case.” (Harman 1986 134) Logic, the theory of implication, would deal with what is deductively followed; the theory of reasoning would deal with the former, with someone's judgment: “...such judgments are judgments about decisions that would be made by someone...” (Ibid. 135) The theory of reasoning deals with that, however, it does not describe actual inference, which includes cases of error, but rather “...decisions that would be made by someone who accepts law as binding

infer according to logical laws due to our limitations, but often we should not do so.⁵ His proposal suggests a middle ground between logic and concrete uses. According to the author, these concrete uses would be guided not by the theory of inference, but by the theory of reasoning. This theory, although not identified with logic, is not simply a description of uses; it is distinguished from them in such a way that it has a normativity over them.

Harman's delineation between logic as an abstract construct and the practical norms of reasoning prompts the author to scrutinize the extent to which logic is normative in the context of daily reasoning: "According to Harman, once we realize that principles of deductive logic are not norms of reasoning in and of themselves, a gap opens up between the two" (Steinberger 2017a 2).

From this distinction arises the issue of the normativity of logic, which has thus been framed as a challenge to Harman's position: "[the] influential skeptical challenge to the thesis that logic and norms of reasoning are indeed interestingly related" (Steinberger 2017a 1-2).

Since they are different, it is essential to connect them if logical normativity is based on guiding common inference. This connection could be achieved by linking logic with the theory of reasoning, using something akin to the 'bridge principles' that John MacFarlane (2004) mentions.⁶

and who reasons without error in the light of all the relevant facts." (Ibid. 135. Italics added). Just as Harman distinguishes between the two theories, he seems to acknowledge only the existence of two theories in relation to the notion of consequence: deductive logic, on one hand, and the theory of reasoning, understood as the theory of rational decision, on the other. Other non-classical logics (which, evidently, already existed in 1986) are not taken into account.

⁵ He claims, for example that "...the Logical Closure Principle is not right either. Many trivial things are implied by one's view which it would be worse than pointless to add to what one believes." (1986 12).

⁶ The *bridge principle* is, for MacFarlane, y Steinberger's words, "...a general principle articulating a substantive and systematic link between logical entailment and norms of reasoning" (Steinberger 2017a 2). More specifically, "Bridge principles are general principles that articulate the ways in which a valid argument (or our attitudes towards such an argument) normatively constrains doxastic attitudes towards the relevant propositions" (Steinberger 2019 3). See the notion and clarification in MacFarlane's work in (2004) and (2014).

The controversy regarding the normativity of logic, posed in this way, has led to a considerable bibliographic development that,⁷ one way or another, fills that gap by offering more encouraging answers than Harman's skeptical conclusion. Although these solutions do not follow exactly the original approach of the author,⁸ all of them conform to his general framework: logical normativity depends on bridging the gap between logic and our inferences.

However, in this line of argument, there is an assumption of the correctness of logic itself as a theory of correct inference, which is not questioned. But why trust in logic? If it no longer reflects the rationality of the ordered cosmos of the Greeks or the omniscient mind of God, but a human capacity, and if we are only facing rules created by humans, how can we be sure that it actually shows 'what follows from what'?⁹

⁷ Field (2009a, 2009b, 2015), MacFarlane (2004; 2014), Steinberger (2017a, 2017b, 2019), among others.

⁸ "(...) the type of first-personal normative role Harman is concerned with differs from the third-personal normative roles other contributors to the debate have in mind (Field (2009a, 2014), MacFarlane (2004), Milne (2009), Streumer (2007) (...). Consequently, the proposals of MacFarlane and others cannot be said to meet Harman's skeptical challenge" (Steinberger 2017a 2). The normative roles proposed in the debate can be classified into three: "Norms can fulfill at least three distinct functions. Norms can have the purpose of providing first-personal guidance in the process of practical or doxastic deliberation. I call norms that play this role *directives*. Alternatively, norms might serve as objective, third-personal standards of evaluation. I call norms playing this role *evaluations*. Finally, norms might serve as the basis for our (equally third-personal) criticisms of our epistemic peers and so underwrite our attributions of praise and blame. I call norms that play this role *appraisals*." (Steinberger 2017a 13, *Itálicas del autor*). See also (Steinberger 2019 2). Although the challenge of the authors that Steinberger mentions as the 'other contributors' is different from Harman's, in the sense that it confronts different normative roles, it can still be affirmed that they would have found, within the general scheme, a normative role for logic.

⁹ "An account of logical consequence is an account of what follows from what—of what claims follow from what claims (in a given language, whether it is formal or natural)." (Beall & Restall 2005 3).

Logic, conceived as the formal system that defines our notion of deductive consequence, which we know today as classical logic, was defended by Carnap and Hempel as *a priori* knowledge. In it, what Descartes called in his time 'truths of reason' is reduced to the laws of a logic considered universal, that of Russell and Whitehead's *Principia Mathematica*. These statements have the virtue of analyticity. The response of these authors to the problem of the correctness of logic is that its analyticity guarantees its truth independent of experience. If this is true, there is still one more step to take to infer 'what follows from what' from the logical truths of the system. This step is indeed taken in Russell's logic, since for every conditional logical truth it is possible to demonstrate, in turn, the inference of the consequent, given the antecedent as a premise. The rules of inference can, then, be demonstrated from the logical truths, with the introduction of at least one rule.¹⁰ A rule can also be considered analytic. Its analyticity does not lie in its necessary truth (rules are not true, as they are not statements), but in that, if the premises were true, the conclusion would also always be true. The 'correctness' of the system would consist in guaranteeing that.

For logical positivism, as long as logic is correct in the indicated sense (that is, due to the analyticity of its inferences), it has, just as for Kant, a normative character. This normativity is based on its *a priori* nature, which is derived from its analyticity.

The bridge that Harman requires remains necessary, but the crucial point here is that, before considering logic as normative in the context of the mismatch between logic and reasoning, we must first justify why to accept logic itself. This more basic and fundamental challenge is addressed by logical positivism through the argument of analyticity.

However, the difficulty arises again with the advent of new logics. While some logics alternative to the classical suggest different laws and rules, in other systems the

¹⁰ If there weren't at least one basic rule of inference, we could not infer anything from logical truths. In fact, without rules, we could not infer anything from truths or any statement.

validity of the principles does not always ensure the validity of the linked rules.¹¹ Moreover, not all systems maintain truth; there are values that deviate from truth, such as acceptability, probability, among others, and designated/undesignated values that lack clear meaning. Given this diversity in logic and the fact that each system, from its semantic perspective, sees certain principles and rules as analytically true or valid, how to decide which system is the 'appropriate' one? To think that all are 'correct', as if they represented valid forms of argumentation, is not viable if we want a unified notion of validity, given that many are inconsistent with each other.

Nelson Goodman, as early as 1979, clearly outlined the reasons why the certainty of logical truths poses an unsolvable problem: we take theorems for granted because of their inferential guarantee. But why consider valid axioms that, by definition, do not follow from anywhere else? Their analyticity, it should be added to Goodman's idea (1979), constitutes a circular argument. A semantics leading to the analyticity of a set of formulas, which is precisely the basis of its construction, simply confirms that the analytical statements are exactly what they were expected to be. Likewise, the validity of an argument presupposes the correctness of its structure, taking the justification *ad infinitum*.

If the analyticity of a system constitutes a circular argument and, moreover, different logical systems have their own criteria of analyticity that lead to different conclusions, then the alternative of analyticity to evaluate any logic no longer remains. Thus, only an *a posteriori* justification remains. Willard Van Orman Quine (1953) reached a similar conclusion in other terms, by more radically denying even the possibility of defining analyticity. Whether we regard the distinction between analytic and synthetic statements as untenable, or we choose to define analyticity

¹¹ I define a rule α as linked to a law β when the antecedent of β is the conjunction of the premises of α and has the consequent of β as its conclusion. To give some examples, Priest's LP system validates all the laws of classical logic but not all its rules of inference: it accepts the propositional version $(\alpha \& \neg \alpha) \rightarrow \beta$ but not the rule $(\alpha \& \neg \alpha) / \beta$; the FDE system (First Degree Entailment) and Kleene's strong system, L3, do not accept any tautologies, though they have, of course, rules of inference (Kapsner 2014 73).

conventionally for each logical system, the outcome remains unchanged: if the acceptability of logic, or of a particular logic, is to be judged, this can only be done *a posteriori*. As Quine himself pointed out in 1969 in relation to epistemology, it is imperative to 'naturalize' logic as well (1969).

What would Kant have thought about the possibility of synthetic *a priori* judgments if he had had access to alternative logical systems competing for academic hegemony? Perhaps he would have reconsidered the possibility of such judgments a couple of times.

The challenge we encounter is the justification of logic, a task made more complex by the diverse range of logical systems that have emerged over the past four decades. Confronted with this array of alternatives, the pressing question becomes: why should one adopt any particular logic?

A panorama unfolds before us. One that ranges from classical deductive logic and its old contender, intuitionist logic, through free logics and conservative extensions of logic (within which one must choose, for example, between the modal extensions T, S4, and S5), to non-monotonic, paraconsistent, and fuzzy logics, to mention the most well-known. Attempts at mutual reduction and criteria for identifying intersystem equivalences point, perhaps, to the recovery of a unique system. But, with the general challenge of justifying logic already on the horizon, why trust that even if there were a single system, it would be the correct one? Did the mere fact of having known only one system in the past guarantee its accuracy due to its uniqueness?

In the ensuing discussion, I pose the general problem of the justification of our criteria of rationality, understanding by 'rationality' the capacity to infer (which I will define more precisely later). Once the issue has been raised, I propose an *a posteriori* strategy to identify the reasonableness of logical systems. This proposal aligns with antiexceptionalism,¹² the position according to which logic, since it

¹² "Logic isn't special. Its theories are continuous with science; its method continuous with scientific method. Logic isn't *a priori*, nor are its truths analytic truths. Logical theories are revisable, and if they are revised, they are revised on the same grounds as scientific theories" (Hjortland 2017 2).

is a posteriori, that is, it is empirical, requires the same methods of validation as the empirical sciences. I believe that an antiexceptionalist stance is inevitable given the impossibility of justifying anything a priori. Within this general conception of the methodology of science, I suggest a specific strategy for the case of logics. This strategy does not necessarily presuppose an essential difference between them and other scientific disciplines. As a result, it leads to a pluralist approach, acknowledging multiple correct inferential systems. Moreover, it is normative, as it asserts that some systems are preferable for conducting inferences. We do not deal with human inferences in contexts of uncertainty or limitations, nor with inferential complexity. We also do not concern ourselves with the rationality or normativity of a theory of reasoning, nor with the rationality of a logic as conditioned by its link with a theory of reasoning. A logic, considering the multiplicity of existing systems, does not always aim to model ordinary inference, although it always aims to model inferences (otherwise, I would not consider it logic). Logical systems no longer have that single objective, that is, to represent the inferences of ordinary language or to ensure the transmission of truth. Consequently, what follows from what will depend on what is intended to be conveyed through the inferential link, and for what purpose. Once a logic has been evaluated based on whether it captures a certain inferential notion for which it was designed, it is not necessary to further justify it through bridge principles.

We do not conclude which systems would be correct, but rather we provide a criterion for the justification of logical systems and, therefore, for the recognition of correct inferences.

2. A FORM OF THE NATURALISTIC FALLACY

Considering how various scientific disciplines have successfully justified various disciplines, let's assume that to justify our logical systems we may turn to experience. What experiences should we consider? If we consider the argumentative utterances of human beings in their concrete contexts, the evidence thus obtained would not be

normative. Suppose we derive a set R of inference rules and a set T of theorems that, in the best of cases, everyone accepts and applies consistently. Does this imply that they should accept them? Does it mean that using those rules in everyday life guarantees “good” reasoning? Yes, if we define “reasoning well” as reasoning in the way that people do in their daily lives. However, this does not guarantee that “reasoning well” has normative force. There seems to be no reason to continue doing something just because it is a common practice. Moreover, if we interpret “correctly” in a normative sense, the fact that people act in a certain way routinely does not imply that it is the correct way. This is, in summary, the naturalistic fallacy.

Next, I will argue that some attempts to overcome the fallacy I describe are ineffective or only partially effective. In the following section, I will present my proposal.

Evolutionary reasons: We could provide reasons, especially in the case of the justification of inference, that support a certain normativity in its use. For instance, evolutionary reasons: our intellectual capacities, such as inference, memory, idea association, and numerical ability, are the product of our evolution as a species. We no longer confront a transcendental reason or the *logos* structuring the cosmos, guaranteeing its knowability. We are dealing with human reason that has been essential for our survival as a species. So, should we not value and preserve it? It's a possibility, but it doesn't guarantee that it's the best option. Evolutionary justification may offer a degree of normativity, but not one that evaluates other forms of reasoning that we indeed employ.

In this argument, we have assumed two premises: 1) that we never make mistakes, which may be false, and 2) that we all reason in the same way, which is debatable. If these premises were true, an empirical study focused on our inferential behavior would give us the desired criteria. However, this is not the case for two reasons:

Firstly, the occurrence of reasoning errors must be acknowledged. Without such errors, logic as a normative system would be redundant. We do not treat the laws of physics as norms; it would be nonsensical to mandate that objects must continue in their state of motion or rest unless acted upon by an external force, simply because this is not a rule that can be violated. Similarly, if flawless reasoning accord-

ing to certain patterns were universal, there would be no need to enforce these patterns as a standard for proper reasoning. However, if incorrect reasoning is possible, meaning if we deviate from established inferential patterns or lack them altogether, then an empirical study of our reasoning would fail to provide relevant data for establishing norms. This would be true unless we had a way to identify these errors, which would assume the very point at issue. For instance, if people commonly commit the fallacy of affirming the consequent, a researcher documenting patterns of thought might erroneously validate this fallacy. In essence, if we accept all inferences made by individuals as valid, we would be left with few, if any, to categorize as incorrect—only those that nobody actually makes. But proposing a normative system to exclude patterns that are never used would be pointless.

Statistical analysis based on usage: One might consider an approach where, despite acknowledging that people sometimes err, we could assume that statistical analysis would allow us to validate the most frequently used rules and dismiss the less commonly used ones as inadequate. Nevertheless, this approach is flawed for several reasons: Firstly, there is no substantial reason to believe that the frequency of a rule's use ensures its correctness. This might hold for conventional rules, such as those governing grammar, but when we seek rules that better transmit truth or information, popularity doesn't necessarily equate to reliability. Secondly, as demonstrated by a famous experiment by Wason (1966) presupposing the use of *modus tollens*, the error rate can be overwhelming. Wason (1968) notes a 90% error rate. How, then, can we make judgments about correct inferences when errors are almost systematic? Moreover, what acceptance percentage should be the threshold for validating or rejecting a rule? Could not a rule that is less widely used still be a good one? For instance, a rule that is a composite of others, like dilemmas, should it not be acceptable even if only a few individuals use it, considering it derives from others and thus ensures the same outcomes? Following this argument, might there not be a few individuals, more intelligent in some relevant aspect, who employ excellent rules for truth transmission that the majority have not yet grasped, even if these rules are not derived from more well-known ones?

Statistical analysis regarding intuitions: An alternative proposal for experimental study might not only focus on inferential uses but also, or primarily, on speakers' inferential intuitions. This approach has the advantage that we have intuitions about what is correct as well as what is incorrect. Unlike usage, which only allows us to distinguish rules that are used from conceivable but unrealized uses, intuitions enable us to differentiate between acceptable and unacceptable inferences. For example, if we take the rule of *modus tollens* and find that 8 people use it and 2 do not, the mere fact of non-use doesn't indicate its invalidity. However, if intuitions are considered and it turns out that 20% reject its use, we have a criterion for rejection that isn't dependent on the percentage of individuals who use it. Moreover, if some people practice an inference but intuit that they shouldn't, this gives us an indicator of error. Thus, faced with a sample that presents inconsistencies (some people accept the fallacy of affirming the consequent as an argument, others claim that this should not be done), the experimenter could use inconsistency as an additional decision-making criterion. They might exclude from their sample those individuals who are inconsistent, who sometimes use or accept from their intuitions and sometimes reject the same argument form. They might also exclude rules considered inappropriate by some, even if others use them, if the users do not express having intuitions about them. The inconsistency criterion might resolve some issues, but it still leaves many options open. Is a rule acceptable if used by a small subset of individuals, say, by 1% of the population, if no one explicitly rejects it? Is a rule acceptable if, though not actually rejected by anyone, it would be if someone were to reflect upon it? In other words, should only previous facts be considered, or should ideal speakers be considered? As we can see, the empirical acceptability of uses and intuitions requires additional criteria. It is unclear how to justify since we lack experience as a guide (it's about deciding which experience to accept) and we also lack reason as a guide, since that is precisely what we are trying to justify.

Coherence: The coherence of rules is a promising criterion for making decisions when a rule is less frequently used than others. A rule that is derived from widely accepted rules, or interdefinable with known rules, should be accepted. Con-

versely, rules that lead to results incompatible with non-problematic rules should, it seems, be rejected. The internal consistency between syntax, semantics, and prior objectives, as well as the philosophical intuitions of each system, also contribute to its rationality.¹³

Internal coherence, however, does not constitute a decision-making criterion between alternative logical systems. Although it could allow us to discard some systems for being inconsistent, it does not provide us with a criterion to distinguish among the rest.

When we consider not only classical logic but also the empirical assessment of other contemporary logical systems, an additional problem arises: assuming that specific instances of argumentation represent one system over another presupposes the adoption of a formalization of those cases. This formalization invariably necessitates reinterpreting the argument under precise schemes, which people generally do not have when they argue. Almost any inference can be reinterpreted in most logical systems; any inferential deviation from the norm can be reinterpreted as a new pattern within some system, as ordinary inferences are too imprecise to allow for selection among formal systems that are precise and, though often incompatible, only minimally divergent in what they represent. In other words, the vagueness of an ordinary inference permits a variety of representations that can easily fit into inconsistently related systems, just as a child's blurred mental image of a large bird with short legs could be interpreted in our more precise and adult system as either a duck or a goose, indistinctly. The empirical identification of arguments with certain forms over others is, in itself, an anticipatory decision about which system to accept. This identification tends to be based primarily on the argumentative intuitions of the proposing logician. Since historically proposed logical systems by both philosophers and mathematicians have not typically relied on empirical studies, only their

¹³ We analyze this link in Pazos and Gaytán (2023). The intuitions of researchers, although not decisive in themselves, constitute an important part of the reasons to evaluate, as they represent prior philosophical motivations.

intuitions remained. These are not naive intuitions, of course, but rather ones that are considered, systematized, and developed, yet intuitions, nonetheless.

This criterion, the logician's intuitions, is not arbitrary: it involves a self-reflection on one's own inferential patterns, patterns that are expected to share a significant degree of homogeneity with those of the analyzed community, especially if the evaluated community is the same one the logician is part of. However, given the multiplicity of systems developed over half a century of thought, where each system appears to be backed by its own equally strong and reasonable intuitions, intuition alone does not provide the primary path forward. Although it is an important criterion of adequacy since systems have been developed from it and it would be internally inconsistent if they did not align with their original intuitions, intuitions do not serve as definitive criteria for evaluating different logics.

Non-Human Intelligence: Next, I propose an initial solution to the paradox of the multiplicity of logics. This solution does not circumvent the multiplicity, but rather constrains it to what is reasonable, with a sufficiently precise criterion of reasonableness. From this point forward, I will opt to use the term 'reasonableness' instead of 'rationality', since the proposed criteria yield fallible results. I will use both terms, rationality, and reasonableness, in this more flexible sense.

We propose that the solution can be achieved through specific criteria based on concrete, successful, and formally advanced empirical research. Research in artificial intelligence, not to model what we, human beings, do (since that would presuppose knowing what we do), but to model specific tasks that require inferences leading to defined results.

3. A CASE FOR ILLUSTRATION: AN EMPIRICALLY ADEQUATE COMPUTATIONAL SYSTEM

The Brazilian João Inácio da Silva took on the task of designing a robot, with the sole capability of moving in an unstructured environment,¹⁴ by implementing the computational logic of Newton da Costa's paraconsistent logic, without colliding with surrounding objects.¹⁵ With this goal in mind, he reinterpreted the Annotated Paraconsistent Logic (LPAv2)¹⁶ to fit the needs of his small mobile device. This device, which he named Emmy, and of which he successively developed three versions (Emmy I –in 1999–, Emmy II –in 2002–, and Emmy III –in 2009–),¹⁷ measuring 60 cm in its first version,¹⁸ was conceived with the purpose of evaluating the computational performance of a paraconsistent logic.¹⁹ The implementation of the program is complemented by two ultrasonic sensors. Through these, Emmy

¹⁴ The notion of an unstructured environment refers to a setting that is irregular and not necessarily geometric or controlled. Moving on a flat surface is, of course, simpler. However, it is crucial to design robots that can navigate uneven terrain. For instance, a mechanism intended for exploring the surface of an unknown planet would require this capability.

¹⁵ In addition, the third version aims to find a predetermined destination in the environment (Martins et al. 2009 12).

¹⁶ As Gómez (2017) indicates, the annotated paraconsistent logics were first developed by Subrahmanian. Later, Blair and Subrahmanian (1989) applied them to databases. Da Silva revisited them from the Brazilian Newton da Costa, who in 1991 co-wrote with Subrahmanian (da Costa et al. 1991). See the works of da Silva from 1999 and 2010.

¹⁷ See Martins (2009).

¹⁸ Cfr. (Gómez 2017). The subsequent prototypes, Emmy II and III, were smaller.

¹⁹ A paraconsistent logic is, by definition, one that does not allow the inference of any statement β from inconsistent premises, one of which is the negation of the other. It is a logic in which the rule 'Ex contradictione quodlibet' is not available. From a semantic perspective, paraconsistent logics are interpreted as those that do not allow inferring everything from an 'inconsistent' base. This presupposes conceiving the base of the inferential rule as consisting of statements or propositions, bearers of truth, since it is the statements that can be inconsistent with one another. A computatio-

receives two signals. According to da Silva's semantic interpretation, Emmy assigns to a 'proposition' P , which we can understand as 'There is an object ahead', a degree of favorable evidence $\mu(P)$, which is the result of applying to P the function μ , and a degree of unfavorable evidence $\lambda(P)$, whose values can be 0 or 1. We interpret ' $\mu(P)=1$ ' as 'There is evidence in favor of there being an object' and ' $\mu(P)=0$ ' as 'There is no evidence in favor of there being an object.' Whereas ' $\lambda(P)=1$ ' is understood as 'there is evidence against there being an object,' and ' $\lambda(P)=0$ ' as 'there is no evidence against there not being an object.' The combination of signals from both sensors, $P(\mu,\lambda)$, assesses the evidence for and against the presence of an object in front of the robot. Da Silva (2010, p.12) indicates four possible states of the robot:²⁰

- 1) $P(1, 0)$, which symbolizes V and is termed true,
- 2) $P(0, 1)$, which symbolizes F and is termed false,
- 3) $P(1, 1)$, which symbolizes T and is termed inconsistent and
- 4) $P(0, 0)$, which symbolizes \perp and is termed indeterminate.

nal implementation of a logic is always an implementation of its syntax, not its semantics. What the computer (in this case, the robot) follows are the syntactic rules; it 'knows' nothing about semantics and cannot interpret its inputs as true or false statements, nor, therefore, its input data as inconsistent in a semantic sense. However, its logic is paraconsistent by definition if it violates the principle of *Ex contradictione*. This is independent of how the programmer interprets, in turn, the semantics they assign to their robot, a robot that does not interpret anything by itself. Of course, the states are not semantic for the robot. For the robot, it can be considered that they do not mean propositions, nor therefore inconsistent propositions. The logic used in Emmy's operation is only inconsistent in the sense that it reproduces a system that, with its original semantics (that of the logic's creator, Newton da Costa), is so.

²⁰ Emmy I also has four intermediate values, which in Emmy 1 are reduced to two and in Emmy III disappear (Martins 2009).

From these results, a movement for the robot is inferred in each case.²¹

- 1) In state V, the robot moves forward.
- 2) In state F, it stops.
- 3) In state T, it turns left (there would be an object on the right side of its visual field).
- 4) In state \perp , it turns right (there would be an object on the left side).

What can a logic like the one described above, implemented in a small robot with limited functions, reveal to us about our criteria for rationality in comparison with actions that human beings carry out based on arguments? I will maintain, in what follows, that it can give us the key to what we need to evaluate alternative criteria of inferential rationality.

Why should one consider paraconsistent logic? Is there a genuine intuitive basis for the idea that we can derive valid conclusions from contradictions? Classical logic is known for deducing any and all propositions from a set of contradictions, a counterintuitive aspect that critics often highlight. Despite this, classical logic's widespread acceptance is due to its compelling advantages. Some of these advantages include the categorical intuitiveness of many of its rules, the applicability of modus ponens, the ability to represent arguments by *reductio ad absurdum*, semantic-syntactic completeness, and the ability to justify mathematics, among other notable qualities.

²¹ This presentation is a simplification, omitting differences between the various versions of the robot. An algorithm is developed between the results (V,F, T and \perp) of $P(\mu,\lambda)$ and the movements, based on the Degree of Certainty DC and Degree of Uncertainty Dct functions. A paraconsistent logical state is defined as: $\varepsilon\tau(\mu, \lambda)=(DC, Dct)=(\mu - \lambda, \mu + \lambda - 1)$ and it is from the result of this algorithm applied to V, F, T, and \perp , not directly from the results V, F, T, and \perp , that the robot's movement follows. Thus, for example, for $P(1,0)$ the paraconsistent logical state resulting from the algorithm is $\varepsilon\tau(1,0)$ and by the rule 'If $\varepsilon\tau(1,0)$ then Emmy moves forward', it is inferred that the robot advances. In versions I and II, the intermediate cases also yield, through this algorithm, a result among the same four alternatives (moving forward, left, right, or stopping) (Martins 2009).

Although classical logic dictates that anything can be inferred from a contradiction, we don't follow this principle in everyday life. It's not just that it feels counterintuitive; in practice, people don't make arbitrary inferences from a contradiction. Consider Einstein as an example: he didn't conclude that the moon is made of cheese because of the dilemma that light was seen as both a wave and a particle.²² Nevertheless, he didn't dismiss all inferential possibilities upon recognizing the contradiction. Instead, he understood the implications of light acting both as a wave and as a particle.

To prevent a theory from becoming trivial when using classical logic, one approach is to halt inferences upon encountering a contradiction. It can be argued that it's crucial to restore consistency before proceeding with further inferences. Theories of reasoning, as Harman suggests for modeling belief revision, describe non-arbitrary shifts in response to new evidence that contradicts existing information. These theories might augment classical logic in cases of inconsistencies due to new information. While they address inference amid inconsistency, they presuppose the removal of certain information to achieve consistency. They assert that information contraction should be minimal, yet they don't specify the retraction process. Logic is applied only after this retraction. Therefore, they are not entirely suitable for modeling inferences from contradictions, as they neither elucidate the mechanism of retraction nor model the state of inconsistent belief.

²² Instead, after initially interpreting evidence that provided alternating reasons supporting the truth of each inconsistent claim (that light is a particle, that is, a piece of matter, and that it is a wave, that is, a movement in the medium), he preferred to conclude, and thereafter maintained, that light 'behaves' (meaning, it isn't but behaves) sometimes as a wave, sometimes as a particle. In other words, the inference seemed to consist more of a belief change that, rather than inferring everything, contracted the original set of information through a reasonable, minimal procedure, retaining almost everything while forming a new, now consistent set of information. This type of inference cannot be represented by traditional deductive logic at all.

²³ I am grateful to an anonymous reviewer for their suggestion regarding modeling using modal logic.

Modal logic offers another way to deal with inconsistency: by framing it not as outright contradiction but as a reflection of conflicting belief states. This approach presents an epistemic conundrum without necessitating a contradictory formulation, thus preventing any and all propositions from logically following. The expressions ' $C(\alpha)x$ ' meaning 'x believes α ' and ' $C(\neg\alpha)x$ ' meaning 'x believes not α ' are not mutually inconsistent statements. The statement 'x believes α and not α ' is an attribution of inconsistency but it is not in itself a contradiction. Attributing contradictory beliefs does not seem irrational in principle, since there may be irrational people who believe contradictory statements. Therefore, modal logic does offer a sophisticated means to represent situations fraught with inconsistencies, marking a significant step forward in such modeling.

Belief logics typically uphold modus ponens within the level of ascribed beliefs: from ' $C(\alpha)x$ ' and ' $C(\alpha\rightarrow\beta)x$ ', we derive ' $C(\beta)x$ '. This suggests that if we were to assume subject x employs classical logic, we'd have to concede that ' $C((\alpha\&\neg\alpha)\rightarrow\beta)x$ ' for any β , which leads to ' $C(\beta)x$ '. Naturally, rejecting ' $C((\alpha\&\neg\alpha)\rightarrow\beta)x$ ' would mean rejecting the premise that the speaker reasons with classical logic. Thus, the issue with classical logic enabling inferences that humans neither make nor deem legitimate resurfaces unless, in developing a logic for attributing beliefs, we also step away from classical logic as the model not just for belief attribution but for the inferences that speakers are rightfully making. If we uphold classical logic as the benchmark for correct inference, the dilemma remains. On the other hand, while epistemic logic isn't plagued by the contradictions of classical logic, if it extends classical logic, non-modal inferences remain valid within the expanded system.

In other words, an appropriate modeling of belief attribution sidesteps an inconsistent assertion but doesn't address the original problem of modeling rational inference among beliefs (not between their attributions)

A logic that addresses belief change, by focusing directly on beliefs rather than their attribution, might prove more suitable. Within this framework, a correct model of how humans ought to reason could be based on this logic, rather than classical logic. This would support Harman's view that a proper model of ordinary reasoning is not the theory of inference but the theory of reasoning. In this context, an epis-

temic logic might be more effectively constructed as an extension of the theory of rational belief change rather than an extension of classical logic.

Likewise, all paraconsistent logics also avoid this consequence of the classical system.

The previous example of Emmy, with the semantics that da Silva assigns to his robot, hints at the existence of inconsistencies concerning the truth of a consistent proposition P ('There is an object ahead'), which will be true or false in relation to the world. That is, the world itself is not considered inconsistent; it is the robot that may be in an inconsistent state regarding the proposition P. Furthermore, there are other types of discourse where we reason from contradictions without needing to attribute the terms of a contradiction to states of the world, such as the already mentioned case of choosing between incompatible alternatives, a common mode of inference. If we were to use classical logic in these situations, making a choice would simply be impossible.

The challenge of justifying logic need not be confined to classical deductive logic. Within the landscape of new logics, there are no arguments that categorically define classical logic as 'logic' and a system of rules for belief change as a 'theory' (non-logical) of reasoning. The categories proposed by Harman are not helpful for evaluating whether other formal systems, beyond classical logic and the theory of reasoning, qualify as logical.

In this context, the issue of the rationality of classical logic, the logic of belief change, the paraconsistent logic LPAv2, and other emerging inferential systems is on an equal footing. Each logic has its strengths in modeling certain intuitions and practices, as well as drawbacks when compared to others.

4. EMMY AND HUMAN INFERENCE

Moreover, applying a paraconsistent logic to a robot's inferential system is not something that can be deemed rational from a human-centric theoretical perspective. Its rationality cannot be assessed by the same standards.

In the case of Emmy, paraconsistency doesn't mean that the whole language is derived from inconsistent information. Instead, very little is derived: only a clearly defined result from an algorithm, which can be one of four actions: moving right, moving left, moving forward, or stopping. Similarly, in the theory of belief change, the outcomes are limited: only one of the initial options. If deciding between going to the cinema or the theater, there are only two possible inferences. Yet, despite these similarities, the inferences made by the robot Emmy seem quite removed from representing the most of our typical inferences, whether in everyday life or in scientific reasoning:

What connection could such primitive states have with our complex inferential abilities, one might ask? One might argue that apparently, we don't need logic to walk; we don't perceive affirmative evidence with one eye and negative evidence with the other. Generally, we don't receive contradictory evidence from both eyes; that is, typically objects are either in front of both eyes or not at all. And if they are only in front of one (for instance, positioned right at one eye's blind spot), we simply gather affirmative evidence with that eye and disregard the other's input. Occasionally, we see double: the same object appears in two different places. In such cases, what we infer is that something is likely wrong with our eyes. We don't reason, nor do we 'see', one might argue, in the same way or through the same underlying mechanism as Emmy. Since when does seeing imply reasoning? It involves, the argument goes, a complex mechanism, indeed, but not an inferential relationship.

However, this conclusion may be premature, as it presupposes something we've taken for granted: that there's no chance our complex sensory processes also have an inferential aspect. We're not asserting this happens, but it's worth keeping the possibility open. Should this be the case, logics like Emmy's could prove useful in shedding light on our own biological mechanisms of perception.

It can be said that Emmy exhibits a 'logic' of perception, a logic by which it infers an interpretation of sensory data from the data itself. While that may be true, can we rule out that we ourselves don't have a logic of perception? What's to stop us from suggesting that between the automatic receipt of photosensitive data by the rods in our retina and the conceptualization of a visual field, there is an intermediate

process that could, in some sense, be called inferential? Our lack of awareness of such a mechanism doesn't negate its potential existence. On the contrary, the relative immediacy with which our visual imagery translates mechanical data into images suggests that if there were an inferential procedure, it would unfold too quickly for us to register phenomenally. Just as people who solve mathematical problems swiftly sometimes can't articulate the process they used, if there were a quasi-instantaneous, yet complex, inferential process bridging perception and concept formation, we would likely be unable to recognize it. Inference, it should be clear, isn't necessarily a conscious act. In fact, it's rare to be aware of the rules we're applying while reasoning. From a phenomenological standpoint, an inferential process usually manifests as a sensation of vague mental effort without further features.

We would not be aware of an inferential mechanism if one existed. It's also unlikely for it to be identical to the one Emmy is executing. Yet, it's not the comparison with our perceptual processes that would validate Emmy's logic. Rather, I will argue, it's the success in the task for which it was designed that would determine its correctness.

It could be argued that our human inferences in situations of inconsistency are not mirrored in Emmy's logic. Perhaps, even if it could be, in some way, appropriate for representing our visual or, more broadly, sensory inferences, it doesn't capture what we ideally want to epitomize as the ideal of reason. What we truly aim to grasp is the nature of our complex inferences that lead to the development of profound thoughts and successful scientific theories.

5. LOGIC AND LOGICS

Building on the previous reasoning, we might indeed be curious to uncover a logic of perception, yet that's not our benchmark for rationality. We acknowledge that there are numerous other inferences that this model does not address. But that's not our primary concern. What Emmy's programming illustrates is not a logic for common reasoning but an empirical adequacy criterion that supports the acceptabil-

ity of a logic. This same criterion could be applied to other logics, regardless of their kind, including, for instance, a logic of belief change, which Harman categorizes not as logic, but as a theory of reasoning.

Of course, moving beyond the exclusivity of classical logic requires us to clarify what we mean by 'logic.' Broadly speaking, as Harman discusses in relation to what he calls the 'theory of inference,' logic indicates 'what follows from what' (see footnote 5 above); according to Beall and Restall, it's 'what is derived from what' (see footnote 10 above). Both definitions hint at a theory of logical consequence. Since traditional philosophy of logic confines logical consequence to the preservation of truth among formulas, logic now calls for a broader definition. Syntactically, we could view it as a theory about how to obtain one piece of data from another, without the necessity of assigning a truth value to that data. Semantically, as a theory about the preservation of a value, which will be determined for each system. Formally, we might define logic as a system $\langle \text{For}, \vdash, \vdash \rangle$ consisting of a set of well-formed formulas and their semantic and syntactic inferential relationships, as defined by their respective rules. This allows for the inclusion of classical logic, intuitionist logic, theories of belief change, Emmy's logic, and other new 'logics' (extensions and variations of classical logic). There's no guarantee that the definition will fit perfectly for all instances termed as logic. What's crucial is that it's suitable for encompassing a set of systems for which we can propose criteria to assess their rationality.

6. WHY ACCEPT A LOGIC? EMPIRICAL ADEQUACY AS A CRITERION

Let's consider, for a moment, a second example: recently, a chess-playing program, *AlphaZero*,²⁴ has proven to be definitively superior to any living player, winning every match without fail. Unlike previous programs, AlphaZero wasn't designed

²⁴ Developed by *DeepMind* in 2017.

based on recognized chess strategies. Instead, it was equipped only with the rules of chess, from which it programmed itself by playing against itself for hours.²⁵ The first and unexpected outcome was that the program proved to be superior in gameplay to any other player, whether real or virtual. The second consequence is that since the program 'self-programmed,' we don't know the specifics of that programming. It learned, we might say, through 'experience.' It's likely that the implemented program doesn't resemble how other players operate. Yet, given its remarkable effectiveness, no one would dispute that it's a 'good' program. AlphaZero, regardless of the procedure it uses, 'thinks' exceptionally well. In other words, its inferential process, whatever it is, can be considered highly reliable. No one would argue that it's irrational or 'reasons incorrectly.' True, we don't know how this process we deem reliable actually works. The point is that the reliability of this process, like our own reasoning, can be judged by its outcomes. Perhaps we also don't know exactly how we, humans, think, and what we have are approximate models of unknown processes. But the success of the inferences ensures the reliability of the underlying system. The pertinent conclusion is that the process doesn't need to be intuitive or conform to certain formal standards.

Reasonable inference, according to this argument, is not about elucidating or exactly imitating our own patterns of inference. It doesn't necessarily replicate our correct inferential patterns, nor even any prior inferential pattern. To reason adequately simply means to reason in such a way that the inferential outcomes are successful. In the extreme case, where new patterns are completely successful—that is, they always produce correct results—the rationality is beyond dispute.

²⁵ The program differs from other chess-playing software in its foundational algorithm: it employs a Monte Carlo search tree rather than the more commonly used Minimax algorithm. However, the specific procedures it has developed from this algorithm are unknown, as they have been the result of its repeated self-play. As O Cinneide points out: 'It is assumed that the first game would have consisted of entirely random moves. By the end of this game, *AlphaZero* had learned that the losing side had made less intelligent moves and the winning side had played better' (2018). But this 'assumed' suggests that we don't actually know what the program did.

The empirical adequacy of an inferential system, conceived as a system for deriving information from premises (in this case, inputs), doesn't hinge on mirroring human inferential patterns but on implementing patterns that are useful. By 'useful,' we mean highly successful in achieving a specific goal through a process that extracts information from input data. The fact that human inferential patterns have been useful, aiding our survival as a species, is secondary to the criterion I am proposing.

Useful inferential criteria, being formal processes, do not need to be tied to the semantics of the system, it's crucial to note. In the case of the paraconsistent logic LPAv2, da Silva proposes a semantics where the two original functions are considered as evidential criteria: the first as evidence for, and the second as evidence against. This semantics undoubtedly influenced the intuitive perception the author had of what his logic represents. However, Emmy has no 'notion' of evidence when, upon sensing both sensors simultaneously, it executes a series of algorithms resulting in movement. The robot has no semantics. Like the Chinese Room, Emmy does not need to 'understand' anything to act. The idea that the μ and λ functions apply to a proposition P 'there is an object ahead' is practically meaningless. Strictly speaking, the robot doesn't apply functions to anything. It simply runs a sequence of bits that triggers a movement. The semantics with which da Silva conceptualizes are not 'inside Emmy'—not in its 'mind,' nor anywhere else. Moreover, it's worth noting that this isn't even an intuitively correct semantics of how we reason in the face of evidence. While evidential semantics allow for a third value, namely the absence of evidence, Emmy acts as if the absence of evidence is evidence against; that is, if it doesn't detect an object, it assumes there isn't one.²⁶ There's no violation of the law of the excluded middle in the system, as is common in epistemic logic systems. In

²⁶ It is interesting to note that there is a certain inadequacy between his interpretative epistemic assumptions and the formal semantics he proposes. His interpretative judgment of his semantics is that it functions as an epistemic semantics. Accordingly, he calls the inputs on which the robot's logic operates 'evidence' for or against. However, this semantics does not align with the usual intuitions of evidential semantics; it proceeds as if there were evidence against something based on data

short, Emmy's semantics is a representation for da Silva, not for Emmy. The robot operates solely on syntax.

Of course, this doesn't mean that semantics is irrelevant to the inferential process in humans. In fact, as I have just indicated, da Silva likely needed it to comprehend and design the program. The fact that humans have 'qualitative' states, which at least partially encompass semantic notions, might be a crucial, even essential, component in our inferential processes. These human inferential processes, just like informational ones, should be evaluated based on their outcomes.

Regarding Emmy, how do we determine if its logic is appropriate? It avoids obstacles, one might say. Its movements, becoming increasingly precise in later models, reduce the error rate. In the case of Emmy II, 'collisions are mainly due to sensor failures,' as Gómez (2016 35) points out. This suggests that the logic itself is sound. If this is the case, and the robot avoids obstacles, then the logic is, if not entirely rational, at least reasonable. It doesn't matter if no one else uses it or if it was designed specifically for a machine; it forms a solid criterion for logicity.

about what he calls a lack of evidence. If there is evidence that there is no object and no evidence that there is not (Indeterminate state), Emmy turns right. This would be odd unless the absence of evidence that there is not an object ahead is taken to mean that there is an object ahead. What happens is that the author arbitrarily names the input from the left sensor as 'evidence for' and from the right sensor as 'evidence against.' This represents no intuition at all; the same thing happens in each sensor; an object is detected or not. In one sensor, detection is interpreted as evidence for; in the other, as a lack of evidence against, but since both sensors do the same thing, one on the right and one on the left, the type of information obtained is also of the same kind. There is no intuitive reason why the detection of one sensor should function as evidence for and the other as evidence against, as both operate identically. The evidential interpretation is just an assumption made to make sense of what is said, but it does not fit the intuitions of evidence logic; instead, it meets the specific requirements needed for the robot to function well. All of this implies that there is a mismatch between the prior philosophical semantics and the formal semantics. This highlights that while intuitions are important (da Silva probably could not have conceptualized the problem without a semantics at hand), they need not be adhered to if there are additional reasons to deviate from them.

This kind of analysis of logical systems will yield, as is already evident, more than one system of rationality. Some may indeed be reducible to others. However, there's no reason to presuppose that, just like Kant's *a priori* categories, there is only one adequate form of inference.

Logics of vagueness, for instance, have been successfully utilized in the development of robots with efficient behaviors and have also been effectively implemented in household appliances. While these appliances may not be as intelligent as us, they certainly perform tasks with precision and suitability.

7. THE PROBLEM OF CIRCULARITY

The empirical testing of systems, whose acceptability is judged by the aforementioned success criterion, naturally requires its own inferential criteria. One might ask, what is the connection between theory and evidence, between a logical proposal and its applications, such that a given logical system can be considered corroborated? How can we argue for the rationality of a specific inferential system without presupposing the prior acceptability of an inferential system? This critique is valid. Assuming a logic is necessary to accept or reject systems, since the link of empirical testing is an argumentative one. Does this fact invalidate all attempts to justify sys-

²⁶ Es interesante señalar que existe cierta inadecuación entre sus presupuestos epistémicos interpretativos y la semántica formal que propone. Su juicio interpretativo sobre su semántica es que funciona como una semántica epistémica. Conforme a ello, denomina "evidencia" a favor o en contra a los inputs sobre los que la lógica del robot trabaja. Sin embargo, esa semántica no responde a las intuiciones habituales de las semánticas de la evidencia; a partir de datos sobre lo que denomina falta de evidencia, procede como si hubiese evidencia en contra. Si hay evidencia de que no hay un objeto y no hay evidencia de que no lo hay (estado Indeterminado), Emmy gira a la derecha. Eso sería extraño a menos que se asumiera que el que no hay evidencia de que no hay un objeto delante del robot significa que hay un objeto delante del robot. Lo que ocurre es que, arbitrariamente, el autor denomina evidencia "a favor" la del sensor izquierdo y evidencia en contra a la del derecho. Eso no representa ninguna intuición en absoluto; en cada sensor ocurre lo mismo, se detecta un objeto

tems of rationality? It weakens them, certainly, but I do not believe it nullifies them. The reason becomes clear if we briefly examine the nature of the link between theory and evidence: it's a non-deductive relationship, as Hempel, Popper, and others promptly pointed out. A variety of non-deductive logics can be proposed for this, but not every logic is suited for this role. Thus, validating a logic does not depend on repeating it at the metatheoretical level, as might be initially assumed. It's not about defending the validity of *modus ponens* by demonstrating it metatheoretically through the application of another isomorphic *modus ponens*. The logics suitable for system acceptance based on data all fall within a specific area with common characteristics, such as allowing inference from the particular to the general and admitting, at least, some degree of failure, given the recognized possibility that failure could stem from the physical implementation of the program, rather than the program itself. All of these are non-monotonic logics (new information can overturn previous conclusions) and they all share the same goal: to support a system in its applications. Although different logical systems for testing may lead to different conclusions, their use in selecting logics for purposes other than testing is not strictly circular.

o no se lo detecta. En un sensor, el detectarlo es interpretado como evidencia a favor; en el otro, como falta de evidencia en contra, pero puesto que los dos sensores hacen lo mismo, uno del lado derecho y otro del lado izquierdo, el tipo de información obtenida es también del mismo tipo. No hay razón alguna por la cual sería intuitiva una interpretación por la que la detección de un sensor funciona como evidencia en favor y la del otro en contra, puesto que ambos funcionan igual. La interpretación evidencial es sólo una interpretación que se asume para dar sentido a lo que se dice, pero no se ajusta a las intuiciones de la lógica de la evidencia, sino a los requerimientos específicos que se requieren para que el robot funcione bien. Todo esto implica que hay una inadecuación entre la semántica filosófica previa y la semántica formal. Ello pone de manifiesto que, aunque las intuiciones son importantes (probablemente da Silva no podría haber pensado el problema a menos que hubiese tenido a su disposición una semántica), no se requiere respetarlas si hay razones adicionales para desviarse de ellas.

8. CONCLUSIONS

Philosophy was born with a firm belief in the apodictic nature of reason. This confidence was grounded in *a priori* principles, contrasting with the uncertainty of knowledge based on experience. Despite the rise of the sciences at the dawn of modernity being tied to the naturalization of thought (that is, the birth of 'natural philosophy'), philosophy long sustained its faith in *a priori* principles as the cornerstone of reason.

Just as non-Euclidean geometries once challenged the boundaries of analyticity, necessitating an *a posteriori* decision between a Euclidean universe and alternative non-Euclidean, curved universes (a detail I won't delve into here), logic has once again contested the limits of analyticity. This has transformed the choice among its alternatives into an empirical decision, one that demands the involvement of experience.

Given that the faculty of reason, like other natural abilities, is an evolutionary adaptation to the environment, it needs to be examined from its earthly nature. Furthermore, just as evolution permits beneficial mutations that have yet to emerge, inference could harbor undiscovered mechanisms that are more adaptive or reliable than current ones. Experience, particularly when applied to computing, gives us the chance to explore these alternatives. It's crucial to note that since artificial intelligence has different capabilities from humans regarding inferential systems, it's possible that certain systems that are not suitable for us may be effective for AI.

As for us humans, if our specific inferential capacity turned out to be biologically fixed and unchangeable, it would limit us irreparably. However, perhaps the specific structures are not biological.²⁷ Nothing prevents reason, understood as the general ability to extract information from an initial set, from manifesting in different ways in human beings. Thus, humans could also adopt new forms of rationality, just like robots.

²⁷ Of course, every capability has a biological basis; a reptile surely lacks the biological foundation that allows humans to think, and perhaps even a chimpanzee doesn't possess it. But from that foundation, there may still be a wide range of variability.

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