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ORIGINAL RESEARCH

Experiment-driven rationalism

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Abstract
Philosophers debate about which logical system, if any, is the One True Logic. This involves a disagreement concerning the sufficient conditions that may single out the correct logic among various candidates. This paper discusses whether there are *necessary* conditions for the correct logic; that is, I discuss whether there are features such that if a logic is correct, then it has those features, although having them might not be sufficient to single out the correct logic. Traditional rationalist arguments suggest that the necessary conditions of thought are necessary and sufficient conditions singling out the correct logical and mathematical theories. In the contemporary debate, Chalmers advocates a view along this line. Jago, analogously, suggests that the necessary conditions for thought—or, as he calls them, our basic epistemic expectations—single out a family of logical and mathematical theories. Warren and Williamson, on the other hand, argue that there are no necessary conditions of thought. I argue that there are necessary conditions for thought, and these are necessary but not sufficient conditions to be the correct logic; indeed, these are features that all logics—correct or incorrect—share. No view we can understand is ruled out by the necessary conditions for thought, but we cannot understand quite any view. Human linguistic and conceptual abilities are genetically constrained, and these constraints are our best guide to the boundaries of logic. Arguing for this, I tackle two dogmas of modern rationalism: namely, the view that the biological constraints of human cognition have no bearing on the boundaries of the epistemic space, and the view that the boundaries of thought coincide with the boundaries of language.

Keywords Rationalism · Epistemic space · Boundaries of thought · Naturalistic philosophy

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1 Introduction

Philosophers often disagree about logic. Russell (2018) argues that conjunction introduction fails in some cases and Haze (2022) disagrees. Priest (1987) argues that there are true contradictions and Williamson (2017) disagrees. McGee (1985) and Mandelkern (2020) argue that modus ponens fails in some cases and Bledin (2015) disagrees. Examples can be easily multiplied.

To think about this, it is natural to invoke the notion of epistemic scenarios (Chalmers, 2011; Jago, 2009). Various views about logic partition, or divide, the space of epistemic possibilities; they separate scenarios in which the view is true from those that are not compatible with it, or neutral. The trouble is that if the epistemic space is a logical space, then in a sense disagreement about logic is impossible, because logical truths are true in every logically possible world.[1]

Chalmers argues that the epistemic space of ideal agents is a logical space; and therefore, ideal agents never disagree about logic. Considering scenarios in which certain inference rules fail might be useful "to making sense of the epistemic states of extremely non-ideal thinkers" but a more useful notion of epistemic space has to capture some sort of "rational *must*" (Chalmers, 2011, p. 7). Chalmers remains neutral as to exactly what inference rules are undeniable for ideal thinkers, but he suggests that conjunction introduction might be one of them. The trouble is that Russell (2018) offered counterexamples to conjunction introduction. Therefore, in Chalmers's view, she is likely making a mistake due to her limited cognitive capacities (Chalmers, 2004, pp. 207–210). Conversely, if Russell is not making any such mistake, then Haze (2022) is. This seems problematic, at least prima facie. Neither Russell nor Haze seem to be acting irrationally. Indeed, as Williamson (2007) emphasised, experts are unlikely to act irrationally when arguing for their views (p. 94), and in general, we might want to allow for rational disagreement about logic, at least prima facie.

Chalmers might respond that, while disagreement between Russell and Haze involves no *gross* irrationality, it involves some *subtle* confusion. Indeed, Chalmers could argue that all disagreement about logic involves some subtle confusion and that the work of philosophers debating about logic consists of eliminating some subtle—and perhaps very difficult to detect—confusion. Jago (2009) protests that this view is too restrictive, and he suggests a form of rationalism in which there can be rational disagreement about logic. In particular, he suggests amending Chalmers's view by replacing possible worlds with Priest's (2005a) open worlds. He agrees, however, that the epistemic space has to capture a rational must (Jago, 2009, p. 410). There can be disagreement about logic in Jago's epistemic space, but no scenario should fall short of our basic epistemic expectations. For instance, no rational agent should endorse an explicit contradiction or deny that 0 is 0 and not 1. The trouble is, again, that some philosophers endorse explicit contradictions and deny that 0 is 0 and not 1. Priest (1987) argues that the Russell set is and is not a member of itself, and Field (1980) argues that all mathematical sentences are false. It seems problematic, at least

[1] This picture is more complex in the case of Beall and Restall's (2005) logical pluralism: the ideal epistemic space could be the union of multiple logical spaces. I presuppose monism in what follows to avoid verbosity.

prima facie, to say that they are falling short of our basic epistemic expectations; these works display a level of sophistication that meets our highest epistemic standards.[2]

Given these difficulties, one might reject the idea that the epistemic space has boundaries. Williamson (2007) and Warren (2020), despite disagreeing on several issues, concur on this point. Williamson holds that any view about logic can, at least in principle, be rationally defended, although only one correct logic will eventually emerge thanks to general scientific enquiry. Warren holds that the scenarios accessible to speakers of a given language are constrained by meaning-determining inference rules of that language; but there is no constraint as to what sort of language a community might adopt. These positions remove the difficulties above, but they do so at a great cost. Rationalist arguments dating back to Kant and before suggest that if it were possible to determine the conditions of possibility of knowledge, this could provide a wealth of information about logic and mathematics; that is, there is some bridge principle connecting the boundaries of thought with the laws of logic and mathematic (Chalmers, 2002). If there are no conditions of possibility of knowledge—if the epistemic space has no boundaries—then these arguments are a non-starter. I argue that this is an overreaction: our conceptual toolbox has some constraints, although not the constraints that Chalmers and Jago have in mind.

Williamson and Warren are not rationalists themselves. Thus, they do not regard undermining traditional rationalist arguments as a limit of their view. To argue that our conceptual toolbox has some constraints, I need to provide evidence that non-rationalists might be willing to accept from their viewpoint. My suggestion is that to assess whether our conceptual toolbox has constraints, we should consider experimental evidence. This is why I call mine an *experiment-driven rationalism*. Human languages can develop in a myriad of different ways, but there seem to be some genetic constraints to human language development. FOXP2 is the first gene that was linked to language; it underwent a strong positive selection in the human lineage only, and people with mutations to it encounter disabling difficulties in speaking and understanding speech (Enard et al., 2002; Liégois et al., 2003). This, I argue, undermines the claim that there is no constraint to what sort of language, and logic, a human community might adopt. FOXP2 seems to have a pivotal role in shaping human linguistic behaviour and dispositions; thus, it seems, our linguistic toolbox has some constraints.

One might protest that a true rationalist should focus on the conceptual constraints of ideal agents since features of the human DNA at best are evidence for our contingent cognitive limitations. Indeed, one might insist that this matter should not or cannot be studied empirically; to study the epistemic space, one must focus on the conditions of possibility of language itself. I call these the *experimental intractability dogma* and the *language first dogma*. I argue against these and propose a rationalist view that can do without them.[3]

My position is similar to Maddy's (2007). Indeed, she might agree with me in rejecting the dogmas. However, she agrees with Chalmers and Jago that the boundaries of the human epistemic space—or "rudimentary logic"—rule out some conceivable

[2] I would like to thank Timothy Williamson for suggesting this point.

[3] More precisely, I propose a plausible view about the constraints of our conceptual toolbox that can do without the dogmas; I do not discuss rationalist exegesis here, although I do briefly point out that Kant does not seem to hold the language first dogma.

views, including, for instance, the view that there are true contradictions (Maddy, 2007, pp. 282–298). I hold that no conceivable view falls beyond the boundaries of the epistemic space, although the human epistemic space is not boundaryless, because there are limits to what humans can conceive. As a result of this, the boundaries of the epistemic space cannot be characterized in terms of logical principles falling beyond the boundaries. We cannot formulate the principles of an inconceivable logical system, because if we could formulate them, it would not be inconceivable. What lies beyond the boundaries of the epistemic space, thus falling short of the necessary conditions for the correct logic, is beyond our grasp.[4]

This paper is not concerned with discussing the metaphysical nature of the laws of logic. That is, unlike Hanna (2006) and Leech (2015), I am not arguing that the correct laws of logic are constituted, entirely or in part, by constraints upon rationality. The focus is rather epistemological. I discuss whether the boundaries of our conceptual toolbox can give us information about the necessary conditions for the correct logic, regardless of what metaphysical view about logic is being presupposed in the background. Positions in the metaphysics and epistemology of logic can, at least to some extent, be evaluated separately (Martin & Hjortland, 2022).[5] I consider a variety of metaphysical approaches, including Warren's (2020) view that the laws of logic are implicit linguistic conventions and Williamson's (2013) view that the laws of the correct logic are the most general features of the world. In each case, I argue, the dogmas of rationalism do not stand up to scrutiny.[6]

The rest of this paper has the following structure. In Sect. 2 I make some preliminary remarks concerning the nature of disagreement about inference rules and the justification of deduction. In Sect. 3, I discuss three often-invoked reasons to accept the experimental intractability dogma. In Sect. 4, I discuss the language first dogma and I point out one particularly noteworthy constraint that the human brain structure seems to impose on our conceptual toolbox; this is what Dehaene (2011) and Everett (2017) call *the number sense.* In Sect. 5, I briefly outline a rationalism without the dogmas, drawing my conclusions.

2 What Achilles said to the tortoise

Carroll (1895) suggests that a certain approach to the epistemology of logic leads to an infinite regress. In Carroll's dialogue, the tortoise asks Achilles to consider a classically valid argument in which conclusion Z follows from premises A and B.

[4] One might object that this is a rather uninformative view, I get back to this in Sect. 4.

[5] For instance, Maddy (2007) and Williamson (2007) have similar views in the metaphysics of logic, they both hold that logical facts are determined by the most general features of the world, but they hold different epistemological views.

[6] In some cases, my conclusions on the epistemology of logic have metaphysical consequences, because epistemology and metaphysics are not completely independent. For instance, when I say that there are necessary conditions that the correct logic must satisfy, this is a metaphysical consequence of the theses I am defending. The boundaries of thought track the necessary conditions that the correct logic must fulfil, we have experimental data about boundaries of thought. Therefore, we have reason to believe that there are necessary conditions that the correct logic must fulfil. Similarly, this discussion on the epistemology of logic is connected to the epistemology of the norms of reasoning, I return to this momentarily.

Then, the tortoise challenges Achilles to persuade her that one must accept Z if one accepts A and B. This, says Achilles, amounts to forcing her to accept an additional premise (C) "if A and B are true, Z must be true" (p.279). The tortoise readily accepts C but asks for a proof that one must accept Z if one accepts A, B, and C. Achilles suggests an additional premise D, which leads to an infinite regress.

This dialogue contains two crucial ambiguities.[7] First, Carroll is confusing rule circularity and premise circularity. A *premise-circular* argument is an argument whose conclusion is also a premise. A *rule-circular* argument proves that a rule is valid by employing the rule itself. In the dialogue, Achilles adds additional premises stating the validity of the argument. This is incorrect; the inference rules used in an argument are not additional premises. Therefore, an attempt to give a justification of logic need not give rise to premise circularity in the way Carroll suggests.

Arguments proving the validity of inference rules are indeed rule-circular.[8] And this raises questions about their epistemic worth. Philosophers employing rule-circular arguments tend to argue that although these arguments are not persuasive, they can be explanatory (Dummett, 1973; Warren, 2020). A *persuasive* argument could persuade a reader who is not willing to accept the conclusion from the outset. An *explanatory* argument, on the other hand, explains why the conclusion is true to a reader who is willing to accept it from the outset. Rule circular arguments can never be persuasive but—say Dummett and Warren—they can be explanatory.

I wish neither to accept nor deny this but only notice that insofar as we are interested in disagreement about logic, we should focus on persuasive arguments. Philosophers defending their views about logic attempt to persuade their readers. McGee (1985), for instance, does not take for granted that modus ponens is invalid; on the contrary, he attempts to persuade us. Carroll does confuse rule circularity and premise circularity, but in the context of his dialogue, the former is as problematic as the latter. Indeed, the tortoise expresses scepticism about classical validity, rather than asking for an explanation.

The second ambiguity in Carroll's dialogue involves pieces of reasoning and formal arguments. A *formal argument*—for the purposes of this paper—is an argument employing a proof system in which it is effectively decidable whether a given array of formulas is a well-constructed derivation according to the rules of the proof system, in a language in which syntactic properties and the interpretations of sentences are also effectively decidable.[9] A *piece of reasoning* is an argument that may not employ

[7] To be fair, the dialogue starts as Achilles overtakes the Tortoise, thus dissolving Zeno's paradox. It is entirely possible that Carroll intended his dialogue to clarify what one should not do in the epistemology of logic.

[8] One may non-circularly prove the validity of an inference rule using another inference rule. For instance, one might prove the validity of conjunction elimination using modus ponens. However, if one attempts to prove all the unproven rules, circularity eventually arises. Unless the system has infinitely many inference rules, in which case this leads to a regress. I would like to thank Florent Dumont for suggesting this point.

[9] A property is *effectively decidable* when a deterministic algorithm is given that establishes in a finite number of steps whether an object has the property. Thus, for instance, well-formedness in a language is effectively decidable when a deterministic algorithm is given establishing for every string of symbols whether it is well-formed in a finite number of steps. This is a rough-and-ready characterization of formal arguments, but it should do for the present purposes.

explicitly defined inference rules in a language whose syntactic properties and interpretations may not be explicitly defined. In this characterization, all formal arguments represent pieces of reasoning, but not all pieces of reasoning are represented by some formal argument.[10] Now, in the dialogue, the tortoise challenges Achilles to prove that an argument is valid. This could either be a challenge to provide a formal argument to the effect that the argument is valid, or a challenge to give a piece of reasoning for reaching the same conclusion.

A formal argument concluding that a rule sanctioned by its proof system is valid is clearly rule-circular. A piece of reasoning to the effect that a given formal argument is valid may not be rule-circular. Loosely speaking, rules governing our reasoning may serve as a meta-theory to discuss about logic. Lately, one type of reasoning is often invoked in connection to logical theory choice: abduction (Bueno & Colyvan, 2004; Goodman, 1955; Priest, 2005b; Russell, 2015; Williamson, 2017).

I do not discuss the merit of abduction here. It is possible that in some cases a straightforward application of abductive reasoning considering specific theoretical virtues could be problematic (Woods, 2019). Furthermore, abduction is not the only type of reasoning that philosophers use as they discuss logic. Russell (2018), for instance, uses what we may label 'reasoning by example' arguing that conjunction introduction is not valid by presenting a case in which purportedly it fails. All I am noticing here is that philosophers advocating views about logic tend to reason informally about deduction, rather than giving formal arguments. Williamson (2017), for instance, does not give formal arguments using a classical proof system to show that classical logic should be preferred. Rather, he formulates pieces of reasoning about deduction that his opponent, say a paraconsistent logician, could be willing to accept. This should be quite uncontroversial: in the philosophy of logic formal arguments are—at least indirectly—an object of inquiry, and accordingly, they are rarely used without qualifications.

The distinction between reasoning and formal arguments may seem to dissolve Carroll's challenge, but in fact, the problem arises again. This is most evident if one thinks that logic is a methodological discipline (Sagi, 2021), but it applies quite generally to anyone who thinks that there is a connection between the principles of logic and epistemic norms of reasoning. If logic has a bearing, however indirect, on how we should reason, then philosophers of logic are reasoning, at least indirectly, about

[10] One might object here that logical principles are not *about* reasoning. Williamson (2013), for instance, holds that the principles of classical logic are the most general truths about the world, not principles about how we should reason. However, Williamson too can accept what I am presupposing here because different metaphysical pictures of logic can have similar epistemological consequences (Martin and Hjortland 2022). In Williamson's view, the inference rules of classical logic are truth-preserving. Therefore, since it is in general epistemically preferable to reason from true conclusions to true consequences, he can maintain that we should reason according to the principles of classical logic (see also MacFarlane 2002). Even for those who deny that logic is *about* reasoning, there tends to be a bridge between logic and reasoning. One can in principle reject this by arguing for a complete divorce between logic and reasoning. For instance, one might in principle argue that intuitionistic logic is the One True Logic while advocating the unrestricted use of double negation elimination. This seems a difficult position to maintain and therefore, for the moment, I set it aside. On the other hand, I return in Sect. 3.3 to another, more worrying point that advocates of the view that logical truths are the most general truths about the world might make to support the experimental intractability dogma. This is the point that the world might in some cases be different from how our brains allow us to reason about it.

how we should reason. More generally, having distinguished formal arguments and reasoning, the tortoise may still ask to justify the pieces of reasoning that Achilles employs.

The default rationalist solution for this conundrum is that ultimately the justification of reasoning is non-inferential. As they reason about reasoning, Achilles and the tortoise must find some pieces of reasoning that they are both willing to accept without further discussion.[11] They may give explanations as to why they accept these arguments and argue about which explanation is correct, but they will require no further persuasive argument. At this juncture, Chalmers (2002) invokes the notion of ideal rational reflection. Jago (2009) invokes the notion of basic epistemic expectations. Warren (2020) invokes Boghossian's (2003) "meaning entitlement connection" (p. 241) to argue that we are automatically entitled to use the basic rules of our language, although there is no constraint as to the sort of language a community might adopt.

This leads us back to the idea that our conceptual toolbox may have some constraints. Logical systems formalize types of reasoning. The logic of paradox, for instance, formalizes reasoning in which a sentence A may be true while sentence A or B is false. Philosophers of logic argue, using generally accepted informal reasoning, that their favourite logical theories should be preferred. The reasoning itself can sometimes be challenged; abductive reasoning, for instance, is currently under scrutiny, but in any given discussion some patterns of reasoning must be taken for granted without requiring further persuasion. This raises the question: are there patterns of reasoning whose correctness we always take for granted? A positive answer could give us a wealth of information about the necessary condition that the correct logical system must satisfy, hence the constrained conceptual toolbox metaphor.

Both Jago and Chalmers talk about the boundaries of epistemic space, rather than reasoning. This requires one last clarification. The *epistemic space* can be used to extensionally describe the rules governing a given pattern of reasoning. Classical logic, for instance, singles out a space of scenarios in which when A is true, A or B is also true. *Reasoning,* on the other hand, is a pattern of behaviour largely governed by implicit rules. Indeed, as Warren (2017) emphasises, infants can follow a syntactic rule without being able to formulate it and without performing any semantic operation (Pinker, 1999). Because of this, it is quite unclear whether all patterns of reasoning can be described in terms of the epistemic space. Therefore, I prefer to cut the middleman and talk directly about rules of reasoning, but nothing depends on this.

Chalmers and Jago suggest that our conceptual toolbox is normatively constrained. The boundaries of the epistemic space should capture an epistemic must; they tell us how we *should* reason. In particular, Chalmers (2011) holds that while extremely non-ideal thinkers may follow just any reasoning, the reasoning of ideal thinkers—which

[11] This is not a case in support of philosophical exceptionalism: the view that philosophy has an exceptional role among sciences. An anti-exceptionalist may endorse a solution along these lines: "An indiscriminate skeptic can challenge whatever we offer as evidence, by always demanding a proof […] At some point we are entitled to hold on to what we know, and apply it" (Williamson, 2007, p. 277). The tortoise may challenge in the way she does just any of Achilles' beliefs; in this sense, the case of deduction is not exceptional. Of course, one can posit an exceptional source of justification underpinning reasoning to explain why Achilles is justified to stop the tortoise's regress, but this is a separate matter.

we *should* follow—can be formalized by a logical system. Jago (2009), on the other hand, focuses on non-ideal thinkers such as ourselves; the normative constraints he places on our reasoning are loose and fuzzy. Maddy (2007) also holds that these constraints of our conceptual toolbox rule out some conceivable views, although she agrees with me that these are biological constraints. Williamson (2007) and Warren (2020), by contrast, hold that no reasoning can be excluded in principle; our conceptual toolbox has no constraints.[12] I argue that we have strong empirical evidence to believe that human reasoning has biological constraints. These constraints fail to rule out any conceivable view in the philosophy of logic. We need to look elsewhere to find sufficient reasons to prefer a view over another, but the constraints of our conceptual toolbox can give us information about necessary conditions.

3 The experimental intractability dogma

Rationalists traditionally assume that we should focus on the metaphysical, rather than biological constraints of our reasoning. This is the idea that this matter is experimentally intractable. Here I consider three ways to back this claim. First, I consider the view that biological constraints cannot be studied because evidence is scarce. Second, I consider the view that biological constraints should not be studied, because we should rather be interested in the normative boundaries of the epistemic space. Third, I consider the view that biological constraints should not be studied because philosophers should be interested in the most general features of the world, which have nothing to do with how human reasoning happens to be constrained.

3.1 Empirical evidence of human cognitive constraints is scarce

Naturalistically minded philosophers such as Warren seem to be independently committed to the idea that we should look for the biological constraints of our reasoning. Indeed, Warren holds that our disposition to follow an inference rule depends on our communities' contingent choice of language. Thus, unlike the other authors I consider, Warren cannot claim that biological constraints are irrelevant because they are biological. In Warren's view, however a community's contingent choice of language is constrained, these constraints affect their logical and mathematical reasoning.

Warren's evidence for his view is mostly non-experimental. For instance, he argues that his view allows us to take at face value a principle that many philosophers regard as plausible: *charity* "for any language L and logical sentence ϕ: ϕ is true in L if and only if ϕ is potentially clearheadedly accepted by L speakers" (Warren, 2018, p. 11).

[12] Despite this commonality, there are important differences between their views. Williamson (2007) argues that all logical facts are philosophically contestable. This is not quite as radical as Warren's view because even if all logical facts are contestable, the broader space of reasoning may have some boundaries; indeed, this is roughly my view. Moreover, at this juncture, Williamson's view may be compatible with Chalmers's: all logical facts may be contestable for us non-ideal agents although ideal agents have conclusive evidence to choose one logic. Both Warren and Williamson give a negative answer to the question concerning our conceptual constraints. However, only Warren's view is about reasoning, not just logic, and only Warren's view entails a form of logical pluralism.

Now, I do not mean to suggest that non-experimental evidence is bad per se, but rather that given Warren's independent commitment to a naturalistic methodology, it would be natural to seek experimental support as well. At this juncture, Warren's suggestion seems to be that empirical evidence is scarce: "a full account of the inference role must await the further development of cognitive psychology" (Warren, 2020, Chap. 2 §6).[13]

It is certainly true that human cognition is still largely mysterious. This does not imply, however, that Warren's view is impossible to evaluate empirically. Indeed, some evidence can be found even without considering technical scientific literature. According to Warren's logical inferentialism, the meaning of logical expressions is fully determined by the implicit inference rules governing it. Now, in Italian, the word 'non'—ordinarily translated as 'not'—can sometimes be used in assertive sentences. For instance, the sentence 'I will stay awake until my son will return' translates as 'rimarrò sveglio finché mio figlio non tornerà,' which literally reads 'I will stay awake until my son will *not* return.' This is called pleonastic negation. Warren's (2020) criteria for an expression to be logical is that it should be "non-empirical" and "topic-neutral" (Chap. 3, §3). The Italian word 'non' seems to meet these conditions. Therefore, 'non' and 'not' are not intertranslatable after all; and most importantly, the reasoning of Italian speakers is structurally different from the reasoning of English speakers. This seems factually false. Italian logicians and mathematicians are not specially inclined to reject double negation elimination even though in Italian double negation can sometimes deny, let alone endorse a logic in which sometimes a single negation affirms. Indeed, I am aware of no Italian logician suggesting that a single negation sometimes affirms.

Warren may perhaps protest that 'non' and 'not' are stylistic variants. This does not follow under his definition of stylistic variants, since that requires that in two languages either a symbol type can systematically be replaced for another, or grammatical sentences can be turned into grammatical sentences by replacing symbols in a systematic way (Warren, 2018, p. 5). Pleonastic negation is, by Warren's account, an implicit unsystematic rule in Italian; thus, symbols cannot be replaced systematically. This said it is indeed possible that the Italian pleonastic negation is nothing more than a stylistic rule carrying no meaning. It may be difficult for Warren to develop an account of stylistic variations that can account for all potential counterexamples,[14] but I should not push this line of argument further and consider instead technical scientific literature on reasoning.

[13] I say that Warren *seems* to hold the first version of the experimental intractability dogma because as far as I can see he never explicitly addresses it. I infer that he takes the matter to be experimentally underdetermined because he remains neutral as to whether reasoning is innate, or the result of an adaptive mechanism (Ch.2 §3), and he provides mainly non-experimental evidence.

[14] For instance, in Mandarin the adverb '很'—ordinarily translated as 'very'—can serve as a copula for some complements. For instance, 'I am very good' translates as '我很 好' which literally reads 'I very good.' Thus, in Mandarin, in a sense one cannot say 'I am good' unqualifiedly; since 'good' (好) requires a copula that translates as an English adverb. The English copula seems to meet Warren's requirement for a logical expression; it is non-empirical and topic-neutral. The Mandarin copula '很' might be empirical and is not topic-neutral. Unlike pleonastic negation, it seems difficult to file this as a mere stylistic difference, but again, the reasoning of Mandarin speakers does not seem to differ from English speakers to the point of untranslatability.

Cesana-Arlotti et al. (2018) tested the reasoning of pre-verbal infants aged between 12 and 19 months. In experiments 1–4, infants were shown 24 movies in which a partially hidden object could be identified using disjunctive syllogism. Success was measured by means of oculomotor signs: pupil dilation and gazing direction. Experiments 5 and 6 compared the results from the first four experiments with situations in which the partially hidden object could be identified by direct perception rather than disjunctive syllogism. Finally, experiment 7 compared the results from experiments 1–4 with the behaviour of adults. Stable oculomotor markers could be detected in experiments 1–4 and 7 that were not detectable in experiments 5 and 6. This indicates, according to Cesana-Arlotti et al., a neurodevelopmentally stable pre-verbal precursor of logical reasoning.

This experiment repeated earlier results obtained on great apes and 2 years old infants (Call, 2004; Mody & Carey, 2016), and it was further repeated on grey parrots and monkeys, among other animals (Pepperberg et al., 2019; Ferrigno et al., 2021). The Cesana-Arlotti et al.'s experiment is especially interesting for the present purposes because by using eye-tracking techniques it could study the inferential dispositions of very young infants. The results seem to indicate that humans have an innate, or at any rate pre-linguistical, disposition to infer according to disjunctive syllogism. The results on non-human animals indicate that this disposition is cross-species. This strongly suggests that some human patterns of reasoning are not the result of implicit conventions, or at any rate, they are not *only* the result of implicit conventions; hereditary factors play a role as well.

Warren might respond to this by invoking the notion of "proto-reasoning," to which he is independently committed (2020, Chap. 2 §9). To account for the fact that non-human animals without linguistic conventions are to some extent capable of reasoning, Warren suggests that non-human animals could be capable of proto-reasoning. His treatment of this matter is very brief, but we may presume it would apply to pre-verbal infants as well. Thus, he could insist that the precursor of disjunctive syllogism detected in Cesana-Arlotti et al.'s experiment is an example of pre-verbal reasoning. Young infants are capable of proto-reasoning, but then in adulthood variations of human languages—and hence reasoning—have infinite degrees of freedom. This response is weak because the precursor of disjunctive syllogism seems neurodevelopmentally stable; it continues to affect human dispositions after we learn a language. This entails, in Warren's dispositionalist account of inference rules, that inference rules are not entirely the result of linguistic conventions, or equivalently, that human linguistic conventions are limited by the human genetic makeup.

I tend to agree with Warren that we have a great deal of freedom to choose our conceptual and linguistic tools. This said, it seems extremely unlikely that reasoning should be an entirely conventional phenomenon. Even if our reasoning depended entirely on our community's linguistic choices, this would not give it unlimited freedom. Indeed, the human disposition to develop languages is itself genetically constrained. It has long been known that the Broca region in the human frontal lobe is crucial to language processing (Schiller, 1979). Geneticists are now beginning to discover the features of our DNA underpinning this. In the introduction, I mentioned the gene FOXP2. Its mutation can cause a lack of activity in the Broca region and

its right-hemisphere counterpart, resulting in language disorder.[15] Crucially, subjects affected by this mutation show a significant under-activation of the Broca region during covert semantic search tasks, compared with unaffected family members (Liégois et al., 2003). This indicates that FOXP2 regulates not only the formation of neural pathways governing mouth and tongue motor functions but also pathways realizing the human ability to perform abstract semantic tasks. It seems hard to deny that this imposes some constraints on the semantic features of languages that humans can develop.

Warren might hold fast to his metaphysical views despite this evidence. He can concede that linguistic conventions are constrained by human biology without thereby abandoning the idea that laws of logic are nothing over and above linguistic conventions. However, Contrary to Warren's view, the epistemology of logic cannot be solely a matter of determining what collective implicit choices were made in a given linguistic community. Our common genetic makeup constrains our conventions, and it might also account—at least to some extent—for the commonalities we detect in human reasoning across linguistic communities.

Later I discuss other features of the human brain realizing an important aspect of our reasoning: the number sense. For the moment I am concerned with whether experimental data about the constraints of the human conceptual toolbox is available. The examples I have given thus far should suffice to show this. Questions on whether the human conceptual toolbox has some constraints can be studied experimentally. Specifically, there is experimental evidence indicating that not all our reasoning is linguistically constrained and that our linguistic reasoning is to some extent genetically constrained.

This leads us to a second way to support experimental intractability. One might concede that the biological constraints of our reasoning can be studied experimentally but insist that they have little philosophical interest. This is the view that human cognitive limits have no bearing on the boundaries of the epistemic space because the latter are *normative* boundaries, and one cannot derive an 'ought' from an 'is.'

3.2 Cognitive constraints have no bearing on normative epistemic constraints

Jago (2009) and Chalmers (2011) both emphasize that the constraints they are interested in should capture an epistemic must, but their views diverge on how they define these normative boundaries. Chalmers (2004) suggests that the normative boundaries of reasoning should coincide with idealized mathematical knowledge. Here *idealized* means that we disregard subjects' contingent cognitive limitations (p. 208). Jago (2009) rejects this because it purportedly entails that logical truths are uninformative, and he introduces basic epistemic expectations to take the normative role that idealization has for Chalmers. Let us consider these views in order.

[15] Damage in the Broca region may not cause language disorder if the damage is early acquired or congenital; language functions can develop in the right-hemisphere counterpart of the Broca region (Liégois et al., 2002). This does not occur in subjects with a FOXP2 mutation, indicating that this is a neurodevelopmental gene.

Chalmers (2002) says that he takes the notion of idealization to be primitive because he suspects that an attempted definition would be open-ended and incomplete (§1). Nevertheless, we can infer that ideal reasoning does not involve any capacity to prove unprovable truths. Indeed, Chalmers (2004) describes a priori knowledge as akin to mathematical knowledge (p.209). Accordingly, I assume that ideal agents cannot always prove, say, whether a Turing machine will halt with a given input because that would amount to solving the halting problem, which is provably unsolvable. If, say, the continuum hypothesis is provable, then ideal agents can prove it without breaking a sweat, but they cannot solve unsolvable problems, decide undecidable sentences, or the like.

This leads us back to the distinction between persuasive and explanatory arguments. Arguments proving that a given inference rule is valid are rule circular. They might explain why the rule is valid, but they cannot provide justification or epistemic entitlement. One needs to be entitled to use the rule prior to engaging in a rule-circular argument to reach its conclusion. Accordingly, proving formally that a given relation of logical consequence should be used is an impossible task. One may prove, say, that in a system in which disjunction introduction is valid, ex falso quodlibet is also valid, but one cannot formally justify a whole logical system without rule-circularity, just as one cannot prove a system's axioms if not in the premise-circular sense in which any axiom is also a theorem.

Here is an admittedly open-ended and incomplete definition: *ideal agents* are calculators unconstrained by the number of steps they take to solve a problem, memory, notational mistakes, and the like. Now, under this definition, ideal reasoning, far from being a too restrictive notion—as Jago has it—is too inclusive. Indeed, ideal agents are in effect Turing machines. Thus, if the Church-Turing thesis is true, ideal reasoning coincides with formal reasoning. Ideal agents can decide all sentences that are decidable under any arbitrary consequence relation. However, they cannot choose a consequence relation, since unlike us, when it comes to choosing a logical system they only accept formal proofs as evidence.

At this juncture, one might challenge the assumption that ideal agents only accept formal proofs as evidence. This response, it seems, is not available to Chalmers. Indeed, Chalmers says that when it comes to establishing the boundaries of the epistemic space, or epistemic necessity, "a priori justification must meet the sort of conclusive standard associated with proof and analysis, rather than the weaker standard associated with induction and abduction" (2004, p. 209). Ideal conceivability might be a guide to possibility, and indeed all impossibilities might be ideally inconceivable (Chalmers, 2002). However, ideal agents cannot inductively derive necessarily true claims from finitely many observations that they cannot conceive, say, a round square cupola. To get a priori justification even ideal agents need proofs. The only difference between ideal agents and us is that they never make notational mistakes and the like, hence the suggestion that they are, in effect, Turing machines, at least when it comes to evaluating necessities.[16]

[16] Because Chalmers takes the notion of idealization to be primitive, this reading is not airtight. Chalmers does tend to remark that the difference between ideal agents and non-ideal agents has to do with the cognitive limitations of non-ideal agents, and he never seems to remark that ideal agents have some special faculty that we lack, but there is a margin for error. This is partly why I consider alternative suggestions.

Even if we set aside Chalmers's particular view, it seems difficult for a defender of this ideal agents rationalism to hold that a priori justification involves something other than formal proofs. Suppose that ideal agents accept inductive or abductive arguments to gain priori justification. Then ideal agents' justification is, in a crucial sense, no better than ours. Much of the appeal of thinking in terms of idealized a priori justification is that this should conclusively single out the correct logical system. Induction and abduction are not conclusive. If a priori justification involves inconclusive means, then ideal agents are in our same predicament of uncertainty when it comes to choosing the correct logical system; thus, it becomes unclear why invoking the notion in the first place.

Suppose, then, that ideal agents have some means other than formal proofs of gaining conclusive justification. Thus, they are somehow capable of conclusively proving unprovable truths. In this view, ideal agents have, by postulation, conclusive evidence to choose their formal system, but this could not help in characterizing an epistemic must. Humans cannot prove unprovable truths; the evidence that ideal agents have access to is somewhat ineffable. Accordingly, it should not be epistemically mandatory for us to believe them; assuming that, in general, one is never obliged to believe what one is incapable of proving.[17]

If ideal agents cannot gain justification through inconclusive means available to us, nor conclusive means unavailable to us, it seems reasonable to conclude—as Chalmers does—that to establish which logical system is correct, they use conclusive means that are also available to us: formal proofs. However, because proofs that a given inference rule is valid are rule-circular, they cannot provide them with justification. Therefore, ideal agents cannot be justified in choosing any logical system. Like Turing machines, they can solve any decidable problem under any arbitrary logical system, but their standards prevent them from expressing a preference for a logical system.

Jago (2009) suggests that instead of reasoning in terms of ideal agents, we should characterize the epistemic must in terms of the notion of basic epistemic expectations. Although I have different reasons to doubt Chalmers's approach, I sympathise with Jago's idea. My problem here is with how Jago characterized our basic epistemic expectations.

Jago suggests that any competent language user would recognize as false sentences such as '$0 = 1$' and '$\phi \Lambda \neg \phi$' and we would all accept that 0 is 0 and not 1 and that wholly green objects cannot be wholly red. I mentioned two counterexamples in the introduction. Priest (1987) maintains that there are true contradictions of the form '$\phi \Lambda \neg \phi$' and Field (1980) argues that all mathematical sentences, including '0 is 0 and not 1' are false. As far as I am aware no philosopher currently maintains that 0 is 1. This, however, does not show that the claim is undefendable. Consider Field's idea that number terms fail to refer in conjunction with the view that all non-referring terms refer to the same object, a null referring element. In this account, '$0 = 1$' is true, since '0' and '1' are non-referring terms and hence they both refer to the null referring element. This view is probably false, but there seems to be nothing in it that makes it

[17] The epistemic version of Kant's principle 'ought implies can' is not fully uncontroversial (Mizrahi, 2012). Thus, one might develop a response to this based on a rejection of it. However, one would require independent reasons to abandon the epistemic 'ought implies can' principle. It would seem ad hoc to abandon it because it creates a problem with a certain definition of the epistemic must.

impossible to believe for a competent English speaker.[18] Similar considerations apply to the claim that wholly green objects cannot be wholly red. It does not seem hard to cook up a metaphysical view in which wholly green objects can be wholly red.

It seems that, under the right assumptions, virtually any claim could turn out to be true, or false. The relevant assumptions might be highly implausible, or indeed provably false, but it seems difficult to give an example of a claim that one could conclusively prove or rule out on the sole ground of one's having linguistic competence.[19] Stroud (1968) suggested that any language user might be justified to believe that there is a language, but again, this can be challenged. For instance, if 'there is' is understood as an existential quantified in a Quinean meta-ontology and we presuppose a nominalist ontology, then the sentence 'there is a language' is false.[20] Of course, a few examples are not enough to prove that any claim could be rationally defended or rejected. Indeed, it would be quite incoherent to suggest that any view could be rationally rejected and in the same breath claim that my view is undeniable. My suggestion is that the abundance of counterexamples to proposals that have been advanced so far gives us reason for a tentative scepticism.

This is not to say, however, that the notion of epistemic expectation should be discarded altogether. We do have some basic epistemic expectations. For instance, we expect that any philosophical view should be possible to formulate in a language that we can understand, otherwise it would be unclear how we could consider the view at all. This does not rule out any philosophical view. Indeed, it does not even rule out the view that humans have no linguistic competence. In a brain in a vat scenario, paired with behavioural views about linguistic competence, it might be true that we have no linguistic competence, but this scenario needs to be presented to us in a language we can understand if we are to consider it. My suggestion is that the way human reasoning happens to be constrained shapes our normative attitude toward thought. If potential understandability is an epistemic must, then the genetic constraints of our linguistic reasoning contribute to determining the conditions for a view to belong to the human epistemic space.

One might protest that, like Chalmers's, my view is too inclusive: the constraints of our reasoning are more restrictive than potential understandability. I argued that under the right assumptions, any claim could turn out to be true, or false. Accordingly, the boundaries of reasoning should not render any view true or false, but there

[18] I would like to thank Timothy Williamson for suggesting this example.

[19] Competent English speakers may appeal to their competence to justify sentences about their language such as 'the word 'apple' is an English noun.' But of course, German speakers might not know what 'apple' means. Jago suggests that there might be claims no language user should deny. This, it seems, amounts to saying that there are claims one is justified to believe on the sole ground of one's having linguistic competence, regardless of which particular language one is competent to use.

[20] Similar considerations apply to the constraints that Maddy sets on the epistemic space, which she calls "rudimentary logic." Maddy suggests that we are unable "to conceptualize what it would be for a statement to be both true and false" (2007, p. 297). This appears at odds with dialetheists, and indeed their opponents, reportedly being able to reason about true contradictions. Priest (1987) might be wrong in holding that the Russell set is and is not a member of itself—perhaps for the reasons Maddy gives, that dialetheism misrepresents the structure of the world—but it seems difficult to maintain that dialetheism, or indeed any view, can only be defended by engaging in some type of non-reasoning. Indeed, it seems that embracing the right combination of assumptions—including perhaps some very implausible assumptions—allows one to get to virtually any conclusion through perfectly rational patterns of reasoning.

might be other constraints more restrictive than mine and less restrictive than Jago's. For instance, one could argue that we have the epistemic expectation that everything presented to us should be supported with evidence. This does not rule out any view, but it imposes a more restrictive condition than potential understandability, assuming that we can understand views that are not supported by evidence.

At this juncture, my suggestion is that we should distinguish linguistic contexts: in academic journals, for instance, we expect that any view should be supported with evidence. However, this is not a general epistemic expectation. In some contexts, we have epistemic expectations stricter than potential understandability. On the other hand, if we are interested in the expectations that apply to any context, then we should consider what all humans have in common; the human genome naturally suggests itself.

Alternatively, one might protest that, like Jago's, my view is too restrictive: perhaps the genetic constraints of our reasoning determine the boundaries of the *human* epistemic space, but they fail to capture epistemic space per se. This can be supported by claiming that there might be aliens whose reasoning is not constrained in the way ours is, which is indeed a nomological possibility: humans with a FOXP2 mutation are a real-world example of semantic aliens. Perhaps in the future FOXP2 and other language-related genes will undergo a strong negative selection in the human lineage and humans will develop the ability to understand views that presently we cannot formulate.

I agree that our basic epistemic expectations are revisable. Hence, it is possible to envision creatures that lack the constraints of our reasoning. We cannot, however, envision what these creatures could tell us; since, by definition, they talk in a language we cannot understand. To characterize the epistemic must in terms of what any hypothetical creature might find intelligible amounts to denying that reasoning has any epistemically normative constraints since we (and indeed any creature) have no way of saying what hypothetical creatures could express in languages we (they) cannot understand. However, for the moment I am working under the assumption that views on the constraints of reasoning should capture some sort of epistemic must. The present version of the experimental intractability dogma presupposes exactly that. For any creature, the constraints of that creature's reasoning are the broadest epistemic must they can accept without denying this assumption. In our case, this results in a human-centric epistemic space. This does not seem to be a problem; indeed, the human epistemic standpoint, at the present stage of evolution, is our only epistemic standpoint.

Let us turn now to the view that we should not reason normatively about logic. One might defend the experimental intractability dogma without embracing Chalmers's and Jago's views on the epistemic must. In particular, one might hold that the laws of logic are maximally general descriptive laws about the world; thus, the contingent constraints of human reasoning have no bearing on descriptive general laws of logic, because the world might sometimes be different from how our brain allows us to reason about it.[21]

[21] As we saw above, in a sense, the boundaries of thought are normative even in this view, MacFarlane (2002) argues that for Frege logic is epistemically normative in the weak sense in which any scientific

3.3 Cognitive constraints have no bearing on the most general features of the world

Removing the assumption that the constraints of reasoning should capture an epistemic must, the possibility of reasoning aliens becomes more problematic. That is, those who hold—like Williamson (2013)—that logical facts are determined by general features of the world might insist that cognitive constraints are irrelevant to the epistemology of logic because the world might be different from how our brains allow us to think about it. If the reasoning of reasoning aliens can be correct, then a study of the contingent constraints of our reasoning could give us no insight into truth preservation.[22]

Haack (1982) points out that quite generally human reasoning can lead to error. Many people, Haack remarks, believe that the gambler fallacy is a correct pattern of reasoning. This is in no way an indicator that the gambler fallacy is a correct pattern of reasoning, which it is not. I should add that, indeed, the gambler fallacy might have an evolutionary basis. Lyons et al. (2013) performed two experiments to examine the relationship between betting behaviour and the inhibition of return. This is an attention-shift phenomenon whereby a stimulus draws a subject's attention to a location and shortly thereafter there is a delay in responding to stimuli coming from the same location (Klein, 2000). Lyons et al. observed that subjects with a stronger inhibition of return were also more likely to change betting behaviour after a win. This, they suggest, indicates that there is a correlation between inhibition of return and the gambler fallacy. Possibly, the human probabilistic reasoning and attention system adapted to presuppose non-random factors that make the same event unlikely to occur twice in a short time interval, which is maladaptive in genuinely stochastic scenarios.

In principle, I could set this issue aside. My main aim here is to argue that our reasoning has constraints. Perhaps we are in a sorry epistemic state and our reasoning very often leads us to error but, one might argue, this has no bearing on whether human reasoning is constrained. However, discussing this objection allows me to introduce two important distinctions to clarify exactly how our genetic makeup might affect our reasoning.

First, we should distinguish a subject's beliefs from a subject's patterns of reasoning. Haack's original point stresses that many people believe that the gambler fallacy is

Footnote 21 continued
discipline is. If it is true that, say $E = mc^2$, then the rest being equal, it is epistemically preferable to believe that $E = mc^2$. For, the rest being equal, it is epistemically preferable to believe what is true. However, logic is not strongly normative in the sense that its laws consist of prescriptions. On the contrary, they are descriptive laws of the most general kind (MacFarlane, 2002, pp. 35–38). Unless one is to argue for a complete divorce between logic and reasoning, one needs to endorse some version of this bridge principle.

[22] Chalmers (2002) considers this problem by discussing "open inconceivabilities" (§10), but Chalmers formulates this in terms of a single, ideal epistemic standpoint. I suggest that we should reason in terms of the human epistemic standpoint instead because ideal agents are in our same uncertain predicament when it comes to comparing their epistemic standpoint to others, and therefore reasoning in terms of ideal agents presents no clear advantage. Ideal agents can solve any problem that has a solution, but they cannot assess for any given problem whether it has a solution; that would amount to solving the halting problem. Consequently, ideal agents cannot prove that no other agent can solve problems that they cannot. This suggests, in Williamson's (2000) terminology, that being an ideal agent is not a luminous state: ideal agents may not be in a position to know that they are ideal agents. Thus, they are in our same position when they wonder whether other agents might be better than them.

correct. This might be a valid example to press against Dummett's (1973) view, which is the original target of Haack's criticism, but it is not a threat to my view. I argued that any claim whatsoever could not only be believed by some subject but also argued for; this includes the validity of the gambler fallacy. On the other hand, I suggested that the human patterns of reasoning—which are partially innate—affect what languages we can understand. The constraints of reasoning, in my view, cannot preclude one from believing any proposition one can understand, but they determine which propositions one can understand. While the observation that humans often believe falsehood has no bite, the observation that our innate patterns of reasoning might often be misleading threatens the foundation of this project. This is why I rephrased Haack's original point in terms of Lyons et al.'s experiments.

Second, we should distinguish escapable from inescapable patterns of reasoning. An *escapable* pattern of reasoning is one that, when given the chance, humans tend to follow, but we might not follow it in some cases. An *inescapable* pattern of reasoning is one that, when given the chance, humans could only fail to follow due to brain lesions or genetic disorders. This distinction is analogous to the familiar distinction between voluntary and involuntary motor actions. An *involuntary* motor action is an action that one may fail to perform only due to lesions or genetic disorders, unlike a *voluntary* action.[23]

Now, the gambler fallacy is clearly an escapable pattern of reasoning. Many subjects follow it when given a chance, but not everybody does. Indeed, professional poker players reason in a probabilistically sound manner even under pressure. This skill might not be common, but surely humans can acquire it. Haack's case is a counterexample to the view that all widespread patterns of reasoning are correct patterns of reasoning. I agree with Haack that this view is incorrect. Correct reasoning might not be at all widespread. However, for the moment I am concerned with *necessary* conditions for correct reasoning—in particular, the features that all pieces of reasoning, correct and incorrect, have in common—in this context, escapable patterns of reasoning are clearly out of place; since, being escapable, they do not constrain our conceptual toolbox.

I have yet to establish a crucial existence claim for inescapable patterns of reasoning, but first, let us appreciate what their existence would entail. This leads us back to reasoning aliens. A professional poker player is not a logical alien because the gambler fallacy is an escapable pattern of reasoning. A logical alien is a subject that can follow a reasoning that humans cannot follow, say by formulating it in a language that we cannot understand. Suggesting that alien reasoning, unlike ours, is correct amounts to advancing a sceptical scenario. We cannot isolate the problematic parts of our reasoning, because to do so we would need to follow alien reasoning. Therefore, everything we believe is subject to doubt on the ground that ineffable reasoning might refute it. Or, if the relevant inescapable reasoning is not topic-neutral, anything that we believe on the topic is subject to doubt on the ground that ineffable reasoning might refute it.

[23] The distinction between voluntary and involuntary actions is really a spectrum. Breathing is an involuntary cyclic motor action that unlike cardiac movement is associated with voluntary actions (Park et al., 2020), but unlike other motor actions, it cannot be fully suppressed by healthy subjects. Possibly the distinction between escapable and inescapable reasoning is also a spectrum, but I leave that discussion for another time.

This is a crucial juncture on which my views differ from Maddy's (2007). Although she might agree with my evaluation of both dogmas of rationalism, our views differ in two important regards. First, she does not distinguish escapable and inescapable patterns of reasoning. I do not exclude that the cognitive processes that Maddy discusses might be inescapable. However, Maddy focuses on the fact that these cognitive processes are detectable in young infants, and in members of other species (2007, pp. 264–270). The inhibition of return—which is maladaptive in genuinely stochastic scenarios—can also be consistently detected in young infants (Butcher et al., 1999), and in members of non-human species (Gabay et al., 2013).

Second, Maddy holds that human cognitive constraints track logical facts in a way that is not modally robust. In Maddy's view, our cognitive functions have adapted—or perhaps we acquire them "via more general learning mechanisms" (2007, p. 270)—to track features of the actual world. Thus, if the actual world were different, so would our cognitive functions. By contrast, in my view, our epistemic access to the necessary conditions for the correct logical system need not be tied to features of the actual world. I suggest that the only possible worlds in which humanly inescapable patterns of reasoning fail to track logical facts are worlds in which a radical sceptical scenario is actual. In this scenario, some rules in all graspable logical systems are incorrect. The correct rules are ungraspable; thus, we cannot identify the problematic cases. Therefore, the entire human epistemic standpoint should be impeached.[24]

At this point, one might attempt a refutation of this sceptical scenario. Perhaps an argument against this case can be developed along the lines of other recent anti-sceptical arguments (Chalmers, 2018; Rinard, 2018; Wright, 1991), but again, it is unclear that this is required. It seems quite generally possible to conceive scenarios in which, say, the laws of physics, or the laws of mathematics are humanly impossible to know, and as a result, most or all human beliefs fall short of knowledge. One should be wary of letting this sort of doubt be a reason to impeach our epistemic standpoint. If the actuality of a radical sceptical scenario is the only case in which the boundaries of thought fail to track logical facts, then our trust in basic human cognitive functions is as modally robust as our beliefs that we are not brains in a vat. Brain in a vat scenarios can pose a challenge to any sort of scientific knowledge, it is unclear that our epistemology of logic should require any more modal robustness.[25]

Here the notion of inescapable patterns of reasoning is doing much of the philosophical heavy lifting. Accordingly, I should provide evidence that there are some.

[24] Not every case in which logical aliens are correct leads to a sceptical scenario. Logical aliens might reason in a way we cannot, but which is functionally equivalent to some pattern of reasoning we can grasp. This case is unproblematic. The case in which aliens can express ineffable truths that contradict none of our beliefs also does not lead to scepticism. In this case, alien reasoning is an extension of our reasoning; both can be correct. A sceptical scenario arises considering the case in which some of our reasoning is incorrect, but only aliens could realize that it is; that is, some humanly inescapable reasoning is incorrect. This, it seems, is what one would need to maintain to push the objection that I am defusing, namely that the constraints of our conceptual toolbox have no hold on reality.

[25] Here I am only concerned with *epistemic* modal robustness: which sets of worlds does a study of the actual boundaries of thought give us access to? The point that a study of the boundaries of thought affords us modally robust conclusions does not depend on the metaphysics of logic. Radical sceptical scenarios should be disregarded, or at any rate, they should not impeach our epistemic standpoint—I suggest—because that would be an epistemic dead end, whatever type of possibility these scenarios constitute.

There is one simple reasoning that I left somewhat implicit so far. This starts with the assumption that humans cannot understand every possible language, which entails that the patterns of reasoning that can be phrased in the languages we can understand are humanly inescapable. Our linguistic reasoning must follow one of those patterns, and we can envision aliens understanding a language that we cannot.

This rests on the assumption that there are languages we cannot understand. One way to support this assumption is to consider extremely complex languages. Plausibly, humans cannot understand, say, a language structurally identical to English with words so complicated to pronounce that it takes a century to utter a sentence. This is not the right sort of impossibility. The right sort of impossibility involves a hypothetical language that is not structurally identical to any language humans can understand. To support this, one can observe that human linguistic abilities are realized by features of the human brain, which are encoded in the human genome. Plausibly, no human trait has infinite degrees of freedom. For instance, not only our muscles cannot lift a weight arbitrarily heavy, but they also cannot bend backwards. It is unclear why human linguistic abilities should be an exception to this regularity. If they are not an exception, then there are some linguistic tasks that humans cannot perform, although in principle they can be performed by creatures with a different brain structure realizing different abilities. Of course, one can deny all this. To do so, however, entails that human linguistic abilities are an unpassable evolutionary peak. Many animals have limited linguistic abilities. Bottlenose dolphins, for instance, have communication skills but they cannot understand all nuances of human language (Janik, 2013). To deny that there are languages that humans cannot understand amounts to claiming that we could not possibly be in the same predicament, hence the metaphor of an evolutionary peak. This notion is quite problematic since it seems to presuppose a unilinear pattern of evolution that modern biology resolutely rejects.

The main limit of this argument is that it can only establish that human linguistic reasoning has *some* constraints. It cannot point out any specific condition of possibility for human knowledge. To do that I need to consider concrete aspects of human reasoning that might plausibly be inescapable. This finally leads me to the second dogma of rationalism: reasoning is a linguistic phenomenon, or at any rate, it can be described in linguistic terms.

4 The language first dogma

Traditional forms of rationalism tend to be susceptible to what we may call the *non-informativeness objection*. They contend that some conceivable views are inherently irrational, but when they mention specific views, examples of seemingly rational agents defending them swiftly emerge. For instance, Chalmers names a purportedly undeniable inference rule—conjunction introduction—when he says that only "non-ideal reasoners [could] accept s and t while denying $s\&t$" (2011, p. 6), and shortly thereafter, Russell (2018) argues against conjunction introduction on seemingly rational ground. Chalmers can respond to this that all sorts of views might *seem* rational from our limited viewpoint, but ideal agents can see through even the most subtle of confusion. I argued above that this response is unsatisfactory; ideal agents could only conclusively

justify their inference rules if they had some ineffable proof method unavailable to us because the ones available to us—rule-circular formal proofs—cannot provide justification. Even if we set this aside, Chalmers's view remains uninformative. In his traditional form of rationalism, *some* conceivable inference rules can be ruled out a priori, but due to our limited cognitive capacities, we are unlikely to ever know which ones these are.[26]

The form of rationalism I am proposing is immune to this objection. Indeed, I have argued that any conceivable view can be rationally defended. The neurodevelopmentally stable precursor of disjunctive syllogism detected in young infants by Cesana-Arlotti et al. (2018)—if it is unescapable—might affect the reasoning of all logicians as they develop their logical systems, but surely it does not do this to the point of making paraconsistent logics irrational. Paraconsistent logics are conceivable, and indeed it is perfectly possible to follow the patterns of reasoning they prescribe. Therefore, they fall within the boundaries of the epistemic space. Indeed, even the view that all instances of disjunctive syllogism fail is conceivable and therefore it could be rationally defended.[27] Traditional forms of rationalism tend to be uninformative because they hold that some conceivable views are inherently irrational, but they struggle to specify which ones. My proposed view is immune to this because I hold that no conceivable view is inherently irrational.

This being said, two variants of the non-informativeness objection can be leveraged against my proposal. First, one might argue that my view is uninformative because it does not rule out any conceivable position. Second, one could argue that even if a view that does not rule out any conceivable position can in principle be informative, mine is not because I have not given enough details about how exactly the epistemic space is constrained. I consider these two variants in order.

Let us suppose, for the sake of argument, that only views ruling out some possibility can be informative, or else this objection would have no leverage. Now, even with this assumption in place, there seems to be space to argue that my view rules out some possibilities. Indeed, the observation that there can be creatures reasoning in a way that we cannot strongly suggests that there is *something* being ruled out. We cannot express *what* is being ruled out in terms of a humanly intelligible proof system, but we can describe the reasoning of logical aliens in other terms. Crucially, we can describe the cognitive processes, and biological machinery, from which our own linguistic behaviour arises, and conversely, we can describe what a creature with a different conceptual toolbox would be like. This is indeed what Liégois et al. (2002) do in their study of humans with a FOXP2 mutation.

I label *language first dogma* the view that the philosophical study of logic should consist of an analysis of language. With this assumption in place, it might seem that

[26] Notice that the non-informativeness objection has a stronger leverage against Jago's (2009) view because he abandons the notion of ideal agents. Therefore, unlike Chalmers, he cannot say that views falling short of our basic epistemic expectations involve subtle confusion that non-ideal agents could fail to detect.

[27] As far as I am aware, nobody has defended this view in print. Paraconsistent logicians dispute that disjunctive syllogism is universally valid, they do not hold that it always fails. However, it seems entirely possible to develop a logical system in which one can always derive the negation of A or B having assumed A. This inference rule is very likely incorrect; but plausibly, with the correct combination of assumptions, it is possible to develop rational arguments to support it.

patterns of reasoning that humans cannot grasp are impossible to describe. In fact, although we cannot phrase the beliefs of logical aliens, we can describe, among other things, their behaviour, linguistic and non-linguistic, and their brain structure. Therefore, if the language first dogma is abandoned, the suggestion that the view I am proposing does not rule out anything—or, at any rate, that it does not rule out anything *that we can describe*—loses its apparent plausibility.

One way to challenge the language first dogma is to argue that our own reasoning—not only the reasoning of logical aliens—is not best understood in purely linguistic terms. Above, I have mainly taken for granted the language first dogma. Indeed, I focused on human *linguistic* reasoning, but none of the constraints of reasoning I considered is best understood in linguistic terms. The precursor of disjunctive syllogism seems non-linguistic since pre-verbal infants have behaviour consistent with it. The gambler fallacy seems related to the inhibition of return, which is an attention-shift phenomenon. Even FOXP2 might primarily regulate non-linguistic behaviour. Schreiweis et al. (2014) genetically engineered mice to carry the human FOXP2. These, compared to non-engineered mice, were quicker to transition from procedurally learning a task to performing it automatically. Schreiweis et al. conjecture that the human FOXP2 improved our ancestor's ability to use procedural forms of learning to automatize tasks. However this might have affected the emergence of human language, it is unclear that it is best described in terms of what sort of beliefs humans can have, or what sort of sentences we can assent to.

It is certainly true that the study of language can help us understand thought. However, we should be wary of generalizing this to the claim that the study of language is our only means to understand thought. Not only can we reason informally without employing a decidable proof system, but much of our reasoning is also not linguistic at all. Moreover, even when we do reason using a language, we exercise abilities that cannot obviously be described in linguistic terms. One might protest that linguistic reasoning and specifically formal reasoning is somewhat better than non-linguistic reasoning. Warren (2020), for instance, suggests that we can engage in *complex* rule-following because we are linguistic creatures, or at any rate, "it is hard to imagine non-linguistic creatures doing it" (Chap. 2 §9). The problem with this is that even if linguistic reasoning were in general better than non-linguistic reasoning,[28] this would only matter to single out the sufficient conditions for correct reasoning. As far as we are interested in the necessary conditions for correct reasoning, a study of language cannot bring us very far. Because we can reason without employing any language; infants can learn a language without knowing any, and even if infants could 'speak' the language of thought (Fodor, 1975), it seems hard to maintain that adults with a lesioned Broca region can.

[28] This is quite dubious. Infants perform no better than primates in mathematical and logical tasks, they excel only in social tasks (Herrmann et al., 2007). Admittedly, through social skills, humans learn new skills including abstract logical reasoning. It is far from obvious that acquired formal skills are in some sense better or more truth-conductive than the innate social skills we acquired them with. One could protest that the best reasoning in itself is linguistic, regardless of the contingent development of human evolution, but this brings us back to considerations about reasoning aliens. It does not seem inconceivable that there could be creatures that reason better than us but possess no language because they evolved under no pressure to develop the innate social skills that we developed.

This addresses the first variant of the non-informativeness objection. It is not possible to say what logical aliens believe or to state the inference rules that they follow. Nevertheless, we can describe their patterns of reasoning, and indeed the boundaries of our own conceptual toolbox, in other terms. This response is not ad hoc because we have independent reasons to think that our most basic patterns of reasoning—from which we build first linguistic competence and later logical competence—are non-linguistic. Indeed, non-linguistic cognitive processes are the most plausible candidates for cognitive constraints affecting the entirety of our reasoning, including formal reasoning.

The second variant of the non-informativeness objection, on the other hand, still lingers. One could argue that although the non-linguistic boundaries of human reasoning can in principle be described, I have not adequately described them. It is unclear, for instance, whether the aforementioned precursor of disjunctive syllogism is inescapable; that is, we do not know if humans are able to voluntarily suspend its activity. We can be reasonably certain that however FOXP2 constraints our linguistic reasoning, it does this inescapably; one cannot voluntarily and reversibly experience aphasia. However, it is still very unclear how FOXP2, among other genes, constrains our linguistic reasoning. Schreiweis et al. (2014) suggest that it improved our ancestor's ability to automatize tasks. It is unclear that this can be anyhow related to questions that rationalists have been traditionally interested in concerning the justification of mathematical or logical knowledge.[29]

There is a grain of truth to this last objection. As I pointed out above, the functioning of the human brain is still largely mysterious. Consequently, there is indeed much to be discovered about our basic cognitive functions. This is not to say, however, that presently there is no hope to relate studies about biological constraints of human reasoning with traditional rationalist questions. Studies on the number sense, for instance, give us reason to be hopeful.

The *number sense* is an inescapable, inherited cognitive function that allows humans and other animals to make approximate calculations. It has been argued that there is a mapping between the number sense and the reasoning prescribed by elementary arithmetic (Dehaene, 2011). Some disagree on this (Everett, 2017), but there is consensus that the number sense corresponds to at least *some* of the reasoning prescribed by elementary arithmetic. One can rationally reject all arithmetical sentences—as Field (1980) does—but one cannot cease to reason in a way that maps to at least some basic arithmetic, and as we saw above, unless we inhabit a sceptical scenario these patterns of reasoning are truth-tracking.

Dehaene (2011) describes the number sense as an inherited capacity that we share with other animals to rapidly perceive, compare, and calculate the approximate magnitude of collections of objects (Chap. 10). This consists of at least two abilities to represent numbers without counting: the *small-number system* represents exactly sets of 1, 2, or 3 objects, and the *large-number system* represents greater quantities with increasing approximation (Hyde & Spelke, 2009; Revkin et al., 2008). Subjects with brain damage undermining their number sense might be able to speak, perform

[29] Since FOXP2 constrains our linguistic reasoning, there must be *some* relation between it, language, and logic. The point here is that, presently, the nature of this relation is unclear, hence the non-informativeness objection.

symbolic calculations, and memorize a multiplication table but they might fail simple subtractions and number comparisons calling to point out the largest of two one-figure Arabic numerals (Dehaene & Cohen, 1997). This indicates a dissociation between linguistic knowledge and arithmetical knowledge.[30] Brain activity consistent with the adult number sense was detected in pre-verbal infants (Berger et al., 2006; Izard et al., 2008). This indicates that the number sense is an inherited capacity. Moreover, subjects whose number sense is undamaged seem unable to suspend its activity. For instance, the sense-perception component of the number sense cannot be switched off: humans without acalculia when presented with a collection of two objects and a collection of ten cannot suppress the perception of a difference in magnitude (Burr and Ross, 2008). This suggests that the number sense is inescapable.

Humans can deny all arithmetical propositions, as Field (1980) does. It seems, however, that the number sense amounts to a constraint of our conceptual toolbox, at the present stage of evolution. We may deny that 50 minus 2 is 48, but we cannot suppress the perception that a collection of 50 objects minus 2 is only slightly less than 50. Now, according to Dehaene, the number sense informs much of our arithmetical thinking and even formal theories of arithmetic. If this is true, it would effectively vindicate Kant's idea that the foundation of our arithmetical knowledge lies in the constraints of our perception or imagination. Kant argues that no collection of objects we might perceive or abstractly think about can violate the principles of arithmetic, and this—assuming that we do not live in a sceptical scenario—justifies us to believe the principles of arithmetic. If Dehaene is right, then we might finally have the empirical evidence to back Kant's claim. Kant did not foresee the possibility that someone could perceive differences in magnitudes and yet deny arithmetical claims, as Field does. Nevertheless, we might be able to use Kant's reasoning to back our entitlement to follow arithmetical reasoning.

As it happens, though, the claim that the number sense informs much human arithmetical thinking and formal theories of arithmetic is controversial. Everett (2017) argues that our arithmetical reasoning is only mildly constrained by the number sense, and most of it is a linguistic convention. Everett's case study focuses on *anumeric* populations, these are populations that speak languages without number words or theories of arithmetic. The subjects in Everett's studies tend to solve correctly tasks involving groups of 1, 2, or 3 objects. This indicates that the small-number system strongly informs their reasoning. However, anumeric people regularly fail tasks involving collections of 4 or more objects, contrary to Dehaene's prediction that the level of approximation of the large-number system should very gradually increase as the size of the collection of objects increases.

Everett does not deny the existence of the number sense. Indeed, his findings confirm that the small-number system informs the reasoning of anumeric populations.

[30] Because of this dissociation, it is not obvious that the number sense constraints logical as well as arithmetical reasoning. It seems very plausible that the reasoning of logicians developing new logical systems is informed by the number sense, but we cannot be certain at this stage. If there is a complete separation between logical and arithmetical thinking, then the number sense does not constitute a boundary of logic, although it constitutes a non-topic neutral boundary of reasoning. This hypothesis is unlikely, but I need not argue against it here. The discussion about FOXP2 independently establishes the existence of boundaries of logic, although presently we do not know *how* FOXP2 constrains logical reasoning.

He suggests, however, that the constraints of human reasoning leave a great deal of freedom to our arithmetical thinking, to the point that an anumeric person may fail to see a difference between a collection of four objects and a collection of five objects. I do not wish to take a position on this debate here but only emphasize that this matter is experimentally tractable. If Dehaene is right, then much of our arithmetical reasoning—our reasoning about positive integers—is informed by the number sense. If Everett is right, only our reasoning about the numbers 1, 2, and 3 is genetically constrained. Either way, the scientific consensus seems to be that arithmetical reasoning has *some* constraints that are not linguistic, inescapable, and inform our linguistic reasoning, they inform at least our linguistic reasoning about the numbers 1, 2, and 3. This not only constitutes evidence against the language first dogma, but it also gives us a more qualified description of the condition of possibility of human knowledge.

5 Rationalism without the dogmas

Frege and Russell argued, contra Kant, that the justification of arithmetic lies in the principles of logic, which govern all correct reasoning. This paradigmatic shift led generations of analytic philosophers to focus on language to understand thought. This matter should be studied abstractly, it is often assumed, because we are interested in thought in general, not in the contingent features of human thought. I called these the language first dogma and the experimental intractability dogma.

There is a sense in which the dogmas seem quite correct. If we are to specify the features of a correct logical system it is very unclear that the way humans happen to reason should inform our inquiry, and linguistic reasoning, thanks to its topic-neutrality, seems an excellent tool to express our views. I called this the project of providing sufficient conditions for correct reasoning. Plausibly, in the pursuit of this project, we should aim at scientific consilience rather than trying to model widespread patterns of reasoning.

In another sense, however, these dogmas seem quite problematic. If we are to specify the minimum features that all reasoning must have, then it is dubious that we should focus only on linguistic reasoning, or that the contingent constraints of human reasoning should make no difference. I called this the project of providing necessary conditions for correct reasoning.

Kant, Frege, and Russell thought that the necessary conditions for correct reasoning are also sufficient to single out a logical theory and a theory of mathematics. Kant thought that principles constraining our logical reasoning single out syllogistic logic, and the pure intuitions of space and time which constrain how objects can be given to us, single out mathematics. Frege thought that the principles constraining our logical reasoning single out classical logic and arithmetic, and pure intuitions single out geometry. Russell thought that the constraints of logical reasoning single out both classical logic and mathematics.

These views are false. Humans can rationally deny the principles of classical logic and the principles of mathematics. That is, the constraints of our reasoning leave us much more freedom than Kant, Frege, and Russell thought. We should not hastily conclude, however, that reasoning has no constraints at all. Empirical evidence strongly

suggests that basic human arithmetical reasoning is non-linguistically constrained by inherited traits. This partly vindicates Kant's view on this matter, although not without much rephrasing.

One could invoke the notion of reasoning aliens to argue that we might lack entitlement to reason in the way we do. If there are other sorts of reasoning, those might be correct rather than ours. This amounts to a form of scepticism. The number sense uncontroversially constrains human reasoning about collections of 1, 2, or 3 objects. Conjecturing that we might sometimes lack entitlement here—given that we cannot possibly identify the problematic cases—amounts to conjecturing that we always lack entitlement when we reason about small groups of objects. Kant attempted to rule out sceptical scenarios, but he was never quite satisfied with his arguments against scepticism (Guyer, 1983). We might be now in a better position to reject scepticism (Chalmers, 2018; Rinard, 2018; Wright, 1991), or we might embrace Frege's attitude on this matter and simply remark that denying our epistemic standpoint is "an attempt to jump out of one's own skin against which I can only urgently warn" (Frege, 2016, p. xvii). Either way, there seems to be a philosophical value in assessing the necessary conditions for correct reasoning, although they have turned out to be much less restrictive than Kant and Frege thought.

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