Chapter 8
AI, Quantum Information, and External Semantic Realism: Searle's Observer-Relativity and Chinese Room, Revisited

Yoshihiro Maruyama

Abstract In philosophy of mind, Searle contrived two arguments on the impossibility of AI: the Chinese room argument and the one based upon the observer-relativity of computation. The aim of the present article is two-fold: on the one hand, I aim at elucidating implications of the observer-relativity argument to (ontic) pancomputationalism, in particular the quantum informational view of the universe as advocated by Deutsch and Lloyd; on the other, I aim at shedding new light on the Chinese room argument and the nature of linguistic understanding in view of the semantic realism debate in philosophy of logic and language, especially Dummett's verificationist theory of meaning. In doing so, philosophy of mind turns out to be tightly intertwined with philosophy of logic and language: intelligence is presumably the capacity to reason, and in view of a distinction between statistical and symbolic AI ("AI of sensibility" and "AI of understanding" in Kantian terms), philosophy of logic and language is arguably the part of philosophy of mind that concerns the symbolic realm of intelligence (i.e., the realm of understanding rather than sensibility). More specifically, in the first part of the article, I argue that pancomputationalism cannot be maintained under Searle's external realism; nevertheless, a radical (external) antirealist position, such as Wheeler's ("It from Bit"), may allow for a possibility of pancomputationalism. The Searle's argument and the infinite regress paradox of simulating the universe yield challenges to pancomputationalism and the quantum informational view of the universe, leading us to the concept of weak and strong information physics (just like weak and strong AI). In the second part, I argue that Dummett's principle of manifestation on linguistic understanding commits Searle to semantic realism due to the nature of his Chinese room argument. Searle's position must thus be realism in two senses, that is, it has to be external semantic realism. I finally focus upon recent developments of categorical quantum mechanics, and discuss a quantum version of the Chinese room argument. Underpinning all this is the conceptual view that the duality of meaning manifests in different philosophies of logic, language, and mind.

Y. Maruyama (✉)
Quantum Group, Department of Computer Science, University of Oxford, Wolfson Building, Parks Road, Oxford, OX1 3QD, UK
e-mail: maruyama@cs.ox.ac.uk

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8.1 Introduction: Searle's Chinese Room and Observer-Relativity Arguments

The Chinese room argument by John Searle is prominent among arguments against the concept of genuine artificial intelligence (such as strong AI or the Turing test), having been intensively discussed by both proponents and opponents (see, e.g., Cole 2009). Less known is his later argument based upon the observer-relativity of computation (Searle 2002), which shall be called the observer-relativity argument in the present article. It basically proceeds as follows.

1. Computation exists relative to observers.
2. However, human intelligence does not.
3. Therefore, the latter cannot be reduced to the former.

For the moment let us put it aside to explicate why computation is relative to observers (though Searle asserts that it is obvious in the quotation below). Interestingly, Searle (2002) concludes the article with the following retrospective remarks (p. 17):

> Computation exists only relative to some agent or observer who imposes a computational interpretation on some phenomenon. This is an obvious point. I should have seen it ten years ago, but I did not.

Although there are still quite some on-going debates on the plausibility of the observer-relativity argument, in the present article, I focus on implications rather than the pros and cons of the argument.

More specifically, the aim of the article is to show that the observer-relativity argument sheds new light upon ontic pancomputationalism, according to which the universe itself is a computing system; especially we focus upon the quantum version of ontic pancomputationalism, namely the view that the universe is a huge quantum computer (we omit "ontic" in the following; see Piccinini (2010) for varieties of pancomputationalism). This sort of quantum informational view of the universe has been advocated by Lloyd (2006), Deutsch (1997), and others including both physicists and philosophers.

The quantum informational view of the universe may appear to be an issue totally different from Searle's philosophy of mind, but it is closely related indeed. Among other things, the observer-relativity of computation seems most obvious in the case of quantum computation, which allows us to exploit microscopic quantum phenomena in order to compute faster and communicate securer than possible in the conventional classical framework. Then, it is we observers that regard the unitary time evolution of a quantum system as a computational process; the former, by itself, is merely a physical phenomenon.

In this direction, I finally argue that a quantised version of the observer-relativity argument refutes a strong form of quantum pancomputationalism as long as the universe is not observer-relative (yet a modest form of it remains maintainable even in that case). To put it the other way around, if we are happy to consider the universe to be observer-relative just as Wheeler (1990) indeed does with the famous saying “It from Bit”, then we can still keep the strong quantum informational view consistent. In order to endorse the strong pancomputationalism thesis, we must thus choose either the Searle’s realist view or an antirealist view such as Wheeler’s. In this way, pancomputationalism is tightly intertwined with the realism/antirealism debate.

How does the observer-relativity argument relate to the Chinese room argument? Just before the remarks above, Searle summarises the Chinese room argument as follows (Searle 2002, p. 17):

> The Chinese room argument showed semantics is not intrinsic to syntax.

To put it differently, syntax is not enough to confer meaning on symbols, or it is not “sufficient for semantic content” in Searle’s words. In contrast to this, the point of the observer-relativity argument is summarised as follows (*ibid.*, p. 17):

> But what this argument shows is that syntax is not intrinsic to physics.

The observer-relativity argument is more fundamental than the Chinese room argument in the sense that even if syntax is sufficient for semantics, any computer, which itself is a physical entity, cannot even represent syntax of language because physics alone is not sufficient for syntax. In other words, computation (as syntactic symbol manipulation) is more than mere physics, and thus the computer *per se* does not compute. Computation is only enabled in the presence of both a suitable physical system and an observer regarding the time evolution of the system as a computational process. From the Searle’s point of view, therefore, computation is necessarily human computation as it were; there is no computation whatsoever in the absence of observers (yet it is not clear whether non-human beings can count as observers in Searle’s view).

Now, let us turn to implications of the Chinese room argument, the second topic of the article. Searle (2002) asserts that syntax by itself is not sufficient for semantic content (p. 16):

> In all of the attacks on the Chinese room argument, I have never seen anyone come out baldly and say they think that syntax is sufficient for semantic content.

Would it really be impossible to account for semantics in terms of syntax? What is called proof-theoretic semantics (see, e.g., Kahle and Schröder-Heister 2005) may be seen as a sort of way to do it. Proof-theoretic semantics is an enterprise to account for the meaning of logical and other expressions in terms of proof theory within the tradition of Gentzen, Prawitz, and Martin-Löf. It has a philosophical origin in Dummett’s antirealist philosophy, and may be regarded as a form of inferentialism as advocated by Brandom (2000). Traditionally, the enterprise of semantics was mostly along the line of the referentialist or denotationalist account of meaning, such as the Tarski semantics, in which to understand a sentence is to know its truth-conditions through the denotations of expressions involved. It is still the dominating paradigm of semantics in many fields of pure and applied logic.

Proof-theoretic semantics objects to it, claiming that the meaning of a word can fully be given by the inferential role it plays in our linguistic practice, without any reference to objects outside language. Some proponents of proof-theoretic semantics refer to the later Wittgenstein's thesis "Meaning is use." (In light of his later philosophy, however, Wittgenstein himself would not think there is any explicit formal rule governing the use of language; this is obviously relevant to the issue of rule following and to the Kripkenstein paradox.) Especially, the meaning of a logical constant is accounted for by the inferential rules governing it (e.g., the introduction and/or elimination rules in the system of natural deduction). Thus, syntax is autonomous and meaning-conferring in proof-theoretic semantics, and we do not need truth conditions or denotations to confer meaning on logical and other symbols. There is no outside syntax in proof-theoretic semantics, and syntax is indeed sufficient for semantics.

A philosophical underpinning of proof-theoretic semantics is Dummett's arguments against semantic realism; especially, in this article, we focus on his manifestation argument, which is based on the principle of manifestation on linguistic understanding. I argue that Searle's conception of linguistic understanding violates the principle of manifestation, and thus he must be committed to semantic realism. While Searle takes the position of external realism on the nature of the universe, his position must be semantic realism as well, which is realism on the nature of meaning or linguistic understanding.

8.2 Observer-Relativity and Pancomputationalism: Keep External Realism or Allow Antirealism?

In this section, we first briefly review the Searle's idea of observer-relativity, and then address implications of the observer-relativity argument to the quantum informational view of the universe, finally leading to the conclusion that quantum pancomputationalism is not tenable as long as a form of scientific realism is maintained in the sense that the universe exists independently of observers; yet antirealism such as Wheeler's allows for a possibility of quantum pancomputationalism. Searle's external realism plays a crucial rôle in the justification of the quantum observer-relativity argument presented below.

Searle (2002) argues in favour of the observer-relativity of computation in the following way (p. 17):

1. Computation is defined in terms of symbol manipulation.
2. The notion of a symbol is not a notion of physics, but a notion of observers (who decide upon whether to regard physical tokens in Nature as symbolic entities).
3. Therefore, computation is not intrinsic to physics, and relative to observers.

There are merely some electromagnetic phenomena going on inside a computer (cf. Landauer (1991)'s dictum "Information is physical"), and the physical phenomena themselves are not computation. The computer is a system of physical devices. Any physical entity *per se* cannot be a symbol, and so cannot constitute syntax consisting of symbols, much less semantics. In a nutshell, the computer *per se* does not compute. Rather, we observers conceive of the physical phenomena as computational processes, and of the computer as computing. Whereas physical phenomena without observers are nothing more than physics, those with observers can be computation. In such a way, we may lead to the Searle's idea that computation is relative to observers. From the Searle's point of view, computation is not a matter of reality, but a matter of observation.

Searle's view may, of course, be contested from different perspectives (one could even argue that, just as computation is relative to observers, intelligence is relative to observers, and so the human does not think just as the computer does not compute); in this section, however, I aim at elucidating what insights can be derived from it, especially in relation to the quantum information view of the universe.

8.2.1 Is Ontic Pancomputationalism Tenable or Not?

Quantum computation is a relatively new, but recently rapidly growing paradigm of models of computation, facilitating much faster and securer ways of computing and communicating than classical computation. There are some other novel models of computation as well. While quantum computation builds upon microscopic physical systems, for example, DNA computation is based on biological systems, utilising their salient features as resources for computation. Searle (2002) succinctly pins down the core idea of such emergent models of computation, in saying "you can assign a computational interpretation to anything" (which is part of the quotation above), even though he does not explicitly touch upon such recent models of computation.

The basic idea of quantum computation (especially, the quantum circuit model) is that quantum states can be seen (by us observers) as information (called qubits), and the unitary time evolution (and measurements) of them as information processing. In a nutshell, we may view quantum dynamics as computational processes, and then we are able to exploit salient features of quantum physics, such as entanglement (or the Einstein-Podolsky-Rosen "paradox"), as resources for computation; it is widely believed in the quantum information community that this way of thinking played a significant role in contriving quantum protocols (e.g., quantum teleportation and superdense coding). Likewise, interpreting DNA dynamics as computational processes leads us to DNA computation. Thus, we observers are always allowed to (and not to) interpret phenomena as computation. In the light of this, I would say that Searle's observer-relativity perspective on computation is not only conceptually important, but also practically matter, indeed lying at the heart of different sorts of so-called natural computing as mentioned above.

At the same time, however, Searle's observer-relativity argument, I think, allows us to make a critical objection to the quantum informational view of the universe. I especially have in mind the claim of Lloyd (2006) that the universe is a quantum computing system. It is similar to the assertion that Nature is computational intelligence. Searle (2002) says:

> The natural sciences describe features of reality that are intrinsic to the world as it exists independently of any observers.

On the other hand, computation is observer-relative, and does not describe intrinsic features according to him. In the light of this, we may adapt the observer-relativity argument presented above to contrive the following, quantum observer-relativity argument:

1. Quantum computation exists relative to observers.
2. However, the universe exists independently of observers.
3. Therefore, the latter cannot be reduced to the former, so that the universe cannot be a quantum computer.

Actually, we do not really have to focus upon quantum computation alone, but rather we may address the possibility of pancomputationalism in general. Nevertheless, there are two reasons not to do so: firstly, non-quantum pancomputationalism is not plausible any more in the light of the quantum nature of the world; secondly, the claim of item 1 is more convincing in the case of quantum rather than classical computation as already noted above (who thought of quantum systems as computing before the discovery of quantum computation? Any quantum system would not have been computing in that classical era).

Obviously, the quantum observer-relativity argument hinges upon the claim of item 2, a form of scientific realism. Accordingly, we may seek a possibility of the quantum information view in the absence of this sort of realism. At the same time, however, Searle himself takes the position of the so-called "external realism", asserting as follows:

> There exists a real world that is totally independent of human beings and of what they think or say about it. (Searle 1998, p. 13)

> There is a way that things are independently of our representations (Searle 1998, p. 31)

We may thus conclude that the Searle's position adopting external realism together with observer-relativity is inconsistent with the quantum informational view of the universe. As already discussed, quantum computation is in good harmony with the observer-relativity thesis, and therefore the only remaining option to maintain the quantum informational view would be to revise external realism in some way or other.

Leaving this issue in the next subsection, It should be noted here that this quantum version of the observer-relativity argument never refutes the possibility of quantum computation qua technology, and does not give any objection to the so-called information (or digital) physics enterprise qua science (it seem so interesting and promising that I am indeed working on it). But rather the point is that even if it finally succeeds in accounting for the complex physics of the entire universe, it does not *ipso facto* imply that the universe *per se* is a quantum computer, or quantum computational processes.

8.2.2 Strong vs. Weak Theses of Information Physics

Information physics (aka. digital physics with a little bit different meaning) has already gained quite some successes (e.g., the well-knwon informational account of the Maxwell's demon; the operational reconstruction of quantum theory in Chiribella et al. 2011), and it would deserve more philosophical attention. Information physics ultimately aims at reconstructing and developing the whole physics in terms of information, which is taken to be a primary entity, considered to be more fundamental than physical objects. In information physics, it is not that there are computational processes because there are physical systems to implement them, but that there are computational processes in the first place, and physics is just derived from them. Philosophically, this may count as a sort of process philosophy as advocated by Whitehead and Leibniz (under a certain interpretation).

AI and information physics are quite different issues with no apparent link between them (except the concept of computation giving their underpinnings). As already seen in the previous subsection, it seems fruitful to borrow concepts in AI, or philosophy of mind, in order to shed new light on information physics. Just like the common concept of weak and strong AI, I propose to make a distinction between weak and strong IP (Information Physics), or weak pancomputationalism and strong pancomputationalism:

1. Weak IP (weak pancomputationalism) is the view that (some constituents of) the universe may be interpreted as computational processes.
2. Strong IP (strong pancomputationalism) is the view that the universe *per se* is a bunch of computational processes as a matter of fact.

The quantum observer-relativity argument presented above surely refutes the latter, but not really the former. Because interpretation is a matter of observers, and the weak IP view does not hold that the universe is computational processes independently of us observers.

We may conceive of another strong IP view that the universe can be simulated by a computer; Lloyd (2006) alleges it would, in principle, be possible. I think, however, that the notion of the computer simulating the universe would suffer from a logical paradox because it involves the following self-referential infinite regress:

1. The computer simulating the entire universe must simulate itself.
2. This implies that the computer must simulate the computer simulating the universe.
3. Likewise, it must simulate the computer simulating the computer simulating the universe.

4. This continues *ad infinitum*; hence no computer simulating the universe.

This may be called the paradox of simulating the universe (cf. the supertask paradox; the paradox of the set-theoretical universe containing itself as a set).

John Wheeler's dictum "It from Bit" is along a similar line: Wheeler (1990) endorses the following doctrine:

> All things physical are information-theoretic in origin.

However, he boldly thinks that the universe and every "it" in the universe arise from our observations (Wheeler 1990). He thus seems to reject the assertion of item 2 above, maintaining that the universe is actually relative to observers. This might make sense in quantum physics in particular. The relationships between systems and observers are quite subtle in quantum physics: there is no neutral way to see (or measure) quantum systems as they are, without disturbing them through observations, and it is impossible to assign values to all observables (physical quantities) in a coherent way (the Kochen-Specker theorem). Hence we cannot really access the "reality" of quantum systems, which, some people think, do not actually exist; at least, we cannot maintain local realism according to the Bell's theorem. Consequently, it seems plausible to some extent to think that the universe is relative to observers due to its quantum nature.

At the same time, however, Wheeler does not restrict his claim into the quantum realm, applying the antirealist view to classical macroscopic systems as well as quantum microscopic ones. Therefore, it is indeed a radical antirealist position, to which Searle's observer-relativity argument does not apply, and which may be coherent as a philosophical standpoint, at the cost of giving up the ordinary realist view of Nature.

8.3 The Chinese Room and Semantic Realism: What Does the Understanding of Language and Meaning Consist in?

In this section we first have a look at the issue of how external realism relates to semantic realism, and then elucidate Searle's position about the nature of linguistic understanding in view of the semantic realism debate concerning in particular Dummett's philosophy of language. As a case study we also discuss a quantum version of the Chinese room argument in the context of categorical quantum mechanics and quantum linguistics.

As mentioned in the last section, Searle's position on the realism debate is characterised as external realism, which is basically a position on the nature of physical reality or the universe, and as such has nothing to do with the nature of language and meaning, or the nature of linguistic understanding. Semantic realism discussed in this section is primarily about the latter, even though Dummett attempts to relate them by the so-called constitution thesis that "the literal content of realism consists in the content of semantic realism" (Miller 2010); according to Dummett, "the theory of meaning underlies metaphysics" (just as the denotationalist/verificationist conception of meaning underlies realism/antirealism). By contrast, Devitt (1991) argues (p. 39):

> Realism says nothing semantic at all beyond . . . making the negative point that our semantic capacities do not constitute the world

In such a view, semantic realism and external realism, in principle, have nothing to do with each other. Even so, however, I am going to argue in this section, however, I argue that Searle must commit himself not only to external realism but also to semantic realism, due to his view on the understanding of meaning.

8.3.1 Dummett's Manifestation Argument Leads Searle to Semantic Realism

In philosophy of logic, Dummett's view on the meaning of logical constants has led to what is now called proof-theoretic semantics, as opposed to model-theoretic semantics (in logic, semantics traditionally meant the latter only). From the perspective of proof-theoretic semantics, meaning is inherent in syntactic rules governing how to use symbols, and thus grasping meaning is nothing more than grasping those rules; there is no need of any further elements like truth conditions or denotations. Proponents of proof-theoretic semantics thus consider syntax to be sufficient to confer meaning upon symbols, and so for semantics.

This is the view of proof-theoretic semantics, obviously being in striking contrast with Searle's Chinese room view that syntax alone is not enough to account for semantic content. A philosophical underpinning of proof-theoretic semantics is Dummett's arguments against semantic realism; another is Wittgenstein's thesis "Meaning is use." Dummett (1978), *inter alia*, contrives the so-called manifestation argument, part of which we focus on here.

In this article, semantic realism is characterised as the position that admits "recognition-transcendent" (Dummett's term) contents in the understanding of language. Dummett's puts emphasis on the recognition-transcendency of truth conditions; here, not only truth conditions but also any sort of recognition-transcendent contents are allowed.

Searle (1992) explains the point of the Chinese room argument as follows (p. 45):

> I believe the best-known argument against strong AI was my Chinese room argument that showed a system could instantiate a program so as to give a perfect simulation of some human cognitive capacity, such as the capacity to understand Chinese, even though the system had no understanding of Chinese whatever.

Searle thus thinks that any syntactical or computational ability to simulate language does not, by itself, guarantee the semantic understanding of language. This is the reason why Searle says the Chinese room argument showed that semantics is not intrinsic to syntax.

What is crucial here is the following: it is not that there are some problems on the simulation of language, but that the simulation is perfect, yet it is not sufficient for the understanding of language. Searle indeed uses the term "perfect simulation" in the quotation above. According to him, understanding is more than perfect simulation.

Dummett's manifestation argument against semantic realism is based on the principle of manifestation, which Miller (2010) formulates as follows:

> If speakers possess a piece of knowledge which is constitutive of linguistic understanding, then that knowledge should be *manifested* in speakers' use of the language i.e. in their exercise of the practical abilities which constitute linguistic understanding.

That is, there is no hidden understanding beyond practical capacities to use language in various situations, namely beyond the capacity to simulate language. On the ground that anything manifested in linguistic practice can be simulated, we may conclude that Searle's idea that even perfect simulation is not sufficient for the understanding of language violates the principle of manifestation. And thus Searle is compelled to commit himself to semantic realism.

To put it differently, the principle of manifestation says that the understanding of language must be simulatable; this is Dummett's view. On the other hand, Searle is directly against such a conception of linguistic understanding as seen in his above remarks on the Chinese room argument. We may thus say that Dummett's antirealist view on linguistic understanding is in sharp conflict with Searle's realist view, especially in terms of the manifestability of understanding.

8.3.2 Categorical Quantum Mechanics and Linguistics: Can Quantum Picturalism Confer Understanding of Meaning?

Nearly a decade ago, categorical quantum mechanics (see, e.g., Abramsky and Coecke 2008) paved the way for a novel, high-level (in the technical sense), category-theoretical formalism to express quantum mechanics and quantum computation, thus allowing us to reason about quantum systems via its graphical language and thereby to verify quantum communication protocols and algorithms in a fairly intuitive fashion, with the flows of information exhibited clearly in the graphical language of quantum picturalism (Coecke 2010).

The graphical language of categorical quantum mechanics enables us to dispense with complicated algebraic calculations in the Hilbert space formalism of quantum mechanics, replacing them by simpler graphical equivalences. Still, what is provable is the same, and indeed there is a sort of completeness theorem between categorical quantum mechanics and the standard Hilbert space formalism, which ensures the equivalence between them.

The paper “Kindergarten Quantum Mechanics” (Coecke 2005) claims that even kindergarten students can understand the pictorial language of categorical quantum mechanics, and so quantum mechanics itself. It is just a simple manipulation of pictures consisting of strings, boxes, and so on; thus, children could understand it as Coecke (2005) says. The question is then the following: do those children or computers that are able to manipulate pictures in a suitable way understand quantum mechanics? For example, the quantum teleportation protocol can be verified just by “yanking” in the pictorial language, and then, do such children or computers understand the teleportation protocol? We can get even closer to the original Chinese room argument in the case of quantum linguistics.

Quantum linguistics emerged from the spirit of categorical quantum mechanics, integrating Lambek pregroup grammar, which is qualitative, and the vector space model of meaning, which is quantitative, into the one concept via the methods of category theory. It has already achieved, as well as conceptual lucidity, experimental successes in automated synonymity-related judgement tasks (such as disambiguation). It is equipped with a graphical language in the same style as categorical quantum mechanics. Then, do computers capable of manipulating pictures in quantum linguistics understand language (if quantum linguistics perfectly simulates language)? This is almost the same as the main point of the Chinese room argument. A similar question was raised by Bishop et al. (2013).

In order to address the question, I would like to make a distinction between mathematical meaning and physical meaning. Then, the question turns out to consist of two different questions: if one understands the graphical language of quantum mechanics, then does the person understand the mathematical meaning of quantum mechanics?; and how about the physical meaning?

Here let us assume that the capacity to manipulate symbols (including figures) is sufficient for mathematical understanding. Thus, for example, the mechanical theorem prover does understand mathematics. Under this assumption, the first question may be given an affirmative answer, yet the answer to the second one on physical meaning would be negative. Physical understanding must connect the mathematical formalism with elements of Nature so that the former correctly models the latter. This modelling capacity is more than the mathematical ability to manipulate symbols. Broadly speaking, physical understanding is mathematical understanding plus modelling understanding.

At the same time, however, Searle himself would probably object to the very assumption, since he puts strong emphasis on intensionality. For him, any sort of understanding, including mathematical understanding, could not be gained via the mere capacity to manipulate symbols. He would thus think that the theorem prover does not understand mathematics, even if it can prove more theorems than ordinary mathematicians; he might call it the “mathematical room” argument.

8.4 Concluding Remarks

In the present article, we have revisited the Searle's two arguments, the Chinese room and observer-relativity arguments, in relation to quantum pancomputationalism and the realism debate.

In the first paper of the article, I have argued that quantum pancomputationalism is inconsistent with external realism, yet pancomputationalism is consistent with antirealist positions, which are more or less philosophically demanding, though. To be precise, this is about pancomputationalism in the sense of strong IP; the weak IP view is consistent with pancomputationalism even in the presence of external realism. I also touched upon the paradox of simulating the universe, which is another challenge to pancomputationalism.

In the second part, I have argued that Searle must commit himself not only to external realism, but also to semantic realism, because of his position on linguistic understanding as seen in the Chinese room argument. The argument was based on Dummett's principle of manifestation on linguistic understanding. Finally, I discussed the Chinese room argument in the context of categorical quantum mechanics and its graphical language. We could separate mathematical understanding and physical understanding, and argue that the capacity to manipulate graphical rules is sufficient for mathematical understanding, but not for physical understanding. Searle would think, however, that it is insufficient for both, due to his semantic realism. No theorem prover could understand mathematics from Searle's realist point of view.

Overall, the present article may be regarded as pursuing the duality of meaning in its different guises: the dualities between the model-theoretic/referentialist/realist and proof-theoretic/inferentialist/antirealist conceptions of meaning in philosophy of logic/language/mind. These exhibit duality even in the sense that, whereas referential realism makes ontology straightforward and epistemology complicated (e.g., how to get an epistemic access to independent reality could be a critical problem as exemplified by Benacerraf's dilemma), inferential antirealism makes epistemology straightforward and ontology complicated (e.g., anything apparently existing has to be translated into something else with an equivalent function). Put in a broader context, these dualities could presumably be compared with more general dichotomies between substance-based and function/relation/process-based metaphysics.

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