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ORIGINAL RESEARCH

How realist is informational structural realism?

Billy Wheeler[1]

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Abstract

Informational structural realism (ISR) offers a new way to understand the nature of the “structure” that structural realists claim our best scientific theories get right about the world. According to Luciano Floridi, who has given the most detailed formulation of ISR so far, this structure is composed of information representing binary differences. In this paper I assess whether ISR offers a good way to resolve the tension between the no miracle argument (often taken to support scientific realism) and the pessimistic meta-induction (often taken to support antirealism). With regards to this important motivation for structural realism, I shall argue that ISR faces insurmountable difficulties. However, I agree that interpreting “structure” in terms of information can be profitable for the realist. Instead, I offer a new version of ISR that borrows from algorithmic information theory. As a result, a more realist version of ISR is provided.

Keywords Structural realism · Informational structural realism · No miracles argument · Pessimistic meta-induction · Algorithmic information theory

1 Introduction

Structural realism is a popular position in the realism-antirealism debate. One reason for its continued popularity is its apparent ability to do justice to two competing arguments: the no miracles argument (NMA) and the pessimistic meta-induction (PMI). Briefly, the NMA is said to support realism because the truth or approximate truth of our theories is the best explanation for their empirical and predictive success. Whereas the PMI, by contrast, is said to support antirealism, because if all previous scientific theories have turned out to be false, we should infer that our current

✉ Billy Wheeler
billy.w@vinuni.edu.vn

[1] College of Arts and Sciences, VinUniversity, Hanoi, Vietnam

theories will be false as well. Worrall (1989) calls structural realism the "best of both worlds". It suggests only taking a realist position towards those parts of a theory that describe the "structure" of the world. By doing so we can appeal to the NMA to support realism without needing to deny that there are significant changes in the history of science because it is usually the structural claims of theories that are preserved in scientific change.

Precisely what the structural and non-structural features of the world are, as well as how a theory represents them, have been a major point of contention for structural realists, and different interpretations of this crucial dichotomy have led to different versions of structural realism. Whilst all versions tend to agree that the laws and equations of a scientific theory are responsible for its structural claims, there is less agreement over what these claims refer to in reality. For Worrall, the laws and equations pick out relations between individuals and their physical properties. For Russell (1927) and Carnap (1928), the laws do not refer directly to physical relations, but only to their logical and mathematical properties. Maxwell (1970a, 1970b, 1972; and David Lewis, (2009) have attempted to flesh out the structural content of theories using the Ramsey sentence formula. Some advocates of structural realism have combined it with the semantic view of theories and defined structure in terms of isomorphism to partial structures (da Coast and French, 2003; Bueno 1997, 2000).[1]

More recently, Floridi (2008a, 2011) has offered a new approach to interpreting structure that draws on concepts from computer science. According to him, the structure of the world that our theories are about are comprised of *relations of binary difference*. Our theories provide data about such relations, which can be thought of as telling us whether two (or more) objects are different or the same. He calls his version "informational structural realism" (ISR) and claims that it can do justice to both the NMA and the PMI. Given the importance of this motivation for structural realism, in this paper I will evaluate whether ISR can live up to this ambition. I shall argue that it cannot. The reasons for this involve Floridi's own unique approach to the nature of theories and his account of truth. When combined, these two aspects make it impossible to achieve the best of both worlds and in fact renders ISR a rather extreme form of antirealism.

Despite these problems, I agree with Floridi that it is a good idea to interpret structure in terms of information. I will argue that a more realist version of ISR can be created if it is stated using a quantitative measure of information in the form of algorithmic information theory. According to this measure, the complexity or amount of information contained in data is equal to the shortest program that can reproduce it. I shall argue that the laws and equations in a theory are our best attempts at describing the shortest programs that can reproduce all empirical data. That such a "shortest program" exists is a well-recognized result of algorithmic information theory and because it is language independent, this represents a mind-independent feature of the world that our best theories can aim to describe.

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[1] For critical discussion of physical structure, abstract structure, and Ramsey sentences, see Frigg & Votsis (2011). For discussion of partial structures via the semantic approach to theories see Chakravartty (2001) and Landry (2007).

The rest of the paper will be as follows. In Sect. 2, I outline Floridi's ISR in more detail explaining the main differences between it and other versions of structural realism that are closely related. Section 3 introduces key concepts in Floridi's "philosophy of information" that provides the framework for ISR. Since many of these concepts are used in quite novel ways by Floridi, it is crucial to understand them before it is possible to see the implications for the NMA and PMI. In Sect.4, I explain why Floridi's theory of truth means that ISR cannot be supported by the NMA, and I also explain why his account of scientific theories in terms of levels of abstraction means that ISR cannot provide a response to the PMI. In Sect. 5, I outline an alternative version of ISR that uses the concept of algorithmic information and here I demonstrate how it can do better justice to both the NMA and PMI. As a result, a more realist version of ISR is provided.

2 Floridi's informational structural realism

Floridi understands his position as a form of realism. According to him, "ISR is a version of structural realism. As a form of realism, ISR is committed to the existence of a mind-independent reality addressed by and constraining our knowledge" (2008a, p. 240). This distinguishes ISR from the most radical forms of antirealism. ISR is not a version of idealism by the fact that he recognizes a mind-independent world that is the object of scientific study. Neither is it a form of instrumentalism as, according to Floridi, our theories are more than just tools for prediction and manipulation. They provide us with knowledge about the structure of the world. Floridi also rejects limiting our knowledge to observables and claims we can have knowledge of the structure of both observable and unobservable entities like electrons, fields and quarks. In this respect, his view is more optimistic than Bas van Fraassen's constructive empiricism.[2] He offers the following more detailed definition of his position:

> (ISR) Explanatorily, instrumentally and predictively successful models (especially, but not only, those propounded by scientific theories) at a given LoA can be, in the best circumstances, increasingly informative about the relations that obtain between the (possibly sub-observable) informational objects that constitute the system under investigation (through the observable phenomena). (2008a, p. 240)

This is a complex definition, so it is worth examining its parts in more detail. Firstly, we can see his view addresses only "*explanatorily, instrumentally and predictively successful models*". This shows that Floridi believes there is something significant about the success of a theory that supports his realist position and at other times he is explicit that it is the NMA that grounds this optimism (2008a, 223–225). His emphasis on models rather than theories reflects the fact that Floridi adopts the semantic

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[2] See Otavio Bueno (2010) for an informational version of structural realism that retains van Fraassen's agnostic stance towards unobservables.

rather than the syntactic view of theories.[3] However, from what I can tell, none of his arguments for or against ISR depends on this decision.

Next Floridi qualifies the successful models to those propounded at a given "LoA". This is in reference to Floridi's method of levels of abstraction (LoA) (2008b). It is important to understand the role this plays in Floridi's philosophy. According to Floridi levels of abstraction are an "inter-subjective, socially constructable (hence possibly conventional), dynamic and flexible way to further Kant's approach" (2008a, 226). Although Floridi accepts the existence of a mind-independent world, he does not believe we can access it directly. In fact, he takes for granted Kant's distinction between the world-in-itself (*noumena)* and the world-as-experienced (*phenomena*). The world-as-experienced or what Floridi simply calls the "system" is partially constructed by "us" and partially by the world-in-itself. However, he does not accept everything in Kant's epistemology. This is because the world is experienced not through innate conceptual schemes but through socially constructed LoAs. Each LoA provides a taxonomy for experience in terms of "observables" and their "behaviors". LoAs can be non-scientific, as in the everyday concepts we use to describe the world, or scientific, in which case they form part of a scientific theory. It is important to note that for Floridi LoAs are dynamic and change when our theories change. Despite this, Floridi does not believe LoAs are incommensurable, and he does not consider them a challenge for realism in the same way Kuhn's paradigms are thought to be (2008b, 323–325). I will come back to LoAs in more detail in the next section. For now, let us continue with his definition of ISR.

Floridi tells us that in the best circumstances (presumably when the theory is *empirically adequate*, *makes novel predictions*, *is consistent with other theories*, etc.) successive theories can be *more informative* about the relations between the informational objects that constitute the physical system and this knowledge cuts across the observable-unobservable divide. He is using "information" here in two different senses, both of which need spelling out to fully appreciate Floridi's position. In his first use of the term, when he says, "*our theories are increasingly informative*", he is using information in the sense of providing truth. According to Floridi, information is "strongly semantic" (2004) in that it contains a presumption of truth. More fully, a proposition is true if it is well-formed, meaningful, and true. There is no such thing according to Floridi as "false information". This first use, therefore, can be provisionally rendered as "truth" or "approximation to the truth" for the time being.

The second use of the term, given when he says our theories provide knowledge about the "*relations that obtain between informational objects*", is metaphysical rather than semantic. Here, he is talking about what he takes to be the ultimate nature of reality in the mind-independent world. It is here where Floridi uses informational concepts to elucidate the nature of the "structure" that can be known according to structural realism and so, in his view, provides a new ontological grounding for structural realism. Floridi defines informational objects as follows:

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[3] For a detailed explanation of the difference between syntactic and semantic approaches to the nature of scientific theories see Rasmus Grønfeldt Winther (2020).

> Informational objects [are] clusters of *data*, not in the alphanumeric sense of the word, but in an equally common sense of *differences de re*, i.e., mind-independent, concrete points of lack of uniformity...In its simplest form, a datum can be reduced to just a lack of uniformity, that is, a binary difference. (2008a, 236)

The idea that the world is—at the fundamental level—digital, is not a new position. A formulation of this idea can be found in John Wheeler's famous "it-from-bit" hypothesis according to which:

> Every particle, every field of force, even the space-time continuum itself—derives its function, its meaning, its very existence entirely—even if in some contexts indirectly—from the apparatus-elicited answers to yes-or-no questions, binary choices, bits. It from bit symbolizes the idea that every item of the physical world has at bottom—a very deep bottom, in most instances—an immaterial source and explanation; that which we call reality arises in the last analysis from the posing of yes-no questions and the registering of equipment-evoked responses. (1990, 5)

Floridi is at pains to point out, however, that his metaphysical view is different from Wheeler's. For independent reasons Floridi does not think a purely digital ontology is possible (2009). Instead, he offers an "informational ontology" that is composed, not of binary digits in the symbolic sense, but of relations of "bare differentiae". These relations (henceforth $R_{1/0}$) are informational in that they provide data about which things are different and which are the same. What the things are that are related by these relations will remain forever unknown. We do not know, for example, whether the relata are individual objects, properties of objects, other (non-binary relations), or indeed complete structures (of non-binary relations). Only the binary relations of difference are knowable, and it is ultimately this structure that can be accurately represented by our best scientific theories. In fact, Floridi takes the $R_{1/0}$ structure of the universe to be what makes knowledge of it possible:

> The relation of difference seems a precondition for any other relation and hence for any process of knowledge. *Relata* as merely *differentiated* entities are possible only because there is a relation of initial, ontological difference in the first place...Consider what a completely *undifferentiable* entity x might be. It would be one unobservable and unidentifiable at any possible LoA. (2008a, p. 234)

Floridi is giving a transcendental argument that he believes makes it rational to posit the existence of $R_{1/0}$ relations. If such relations did not exist, then we could not have any knowledge at all. Since we do have knowledge, therefore, $R_{1/0}$ structure must exist in the world. To what extent this argument is strong enough to support his structural realism I will return to in Sect. 4.

There are similarities between Floridi's view and the "real patterns" account of Dennett (1991), which has been connected to structural realism in the work of Ladyman and Ross (2007 and 2013). According to Dennett, it is not a matter of mere opinion which patterns exist in the world. Real patterns (in contrast to those that are merely projections of human minds and interests) are those that can be described using fewer bits than the bit-map transcription of the pattern, where a bit-map transcription is a list of all the points in the pattern one-by-one. The key idea here is that of a *compression*: if a rule or generalization can describe the pattern using fewer bits than the bitmap, then the pattern is compressible. Note that compression itself is not enough, however, for a pattern to be real. Many possible compressions can be found in small sets of data that fail to apply when applied to other sets of recordings of the same phenomenon. The potential rule or generalization must be projectable as well as provide an effective compression.[4] Ladyman and Ross utilize Dennett's idea in reconciling their ontological version of structural realism with a naturalistic approach to the questions of reduction and unification in science. They allow for there to be real patterns (and therefore real objects) at multiple levels of scale—a position Ross calls "rainforest realism" (2000). This is a much stronger realist position than the one that emerges out of Floridi's ISR as for him objects beyond $R_{1/0}$ relations are socially constructed and restricted to a particular LoA.

I offer the following as a simplified, more user-friendly, definition of ISR:

> (ISR) Successful scientific theories can be increasingly true about the "informational structure" of the world where informational structure is given by relations of binary difference $R_{0/1}$.

This definition does not capture everything in Floridi's account, but it is a useful tool to help us compare it with other forms of structural realism as well as evaluate how well it can reconcile the NMA with the PMI. Before a full assessment can take place, however, it will be useful to delve a little deeper into Floridi's LoAs and his "correctness theory of truth". This will show how Floridi thinks a theory captures the world's structure and what it means for a theory to be true or approximately true.

3 LoAs and the correctness theory of Truth

Floridi accepts Kant's distinction between the world-in-itself (*noumena)* and our experiences of the world (*phenomena)*, as well as conceptual schemes as a necessary precondition for any kind of experience. However, whereas for Kant these schemes are innate and fixed, for Floridi they are socially constructed and flexible (2008b). Each LoA provides a taxonomy, a classification of kinds, and scientific theories describe the world by presupposing one or more LoAs. Explaining the connection between LoAs and scientific theories requires being familiar with several key concepts that Floridi introduces.

The first concept is that of a *typed variable*, which is simply a variable that can only take values from a certain kind of data. For example, in high school algebra, the variables "x" and "y" are typed variables as the only values we assign to them are real numbers. We could not, for example, assign "elephant", "blue", or "infinity" to

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[4] I am grateful to an anonymous reviewer from *Synthese* for emphasizing this point.

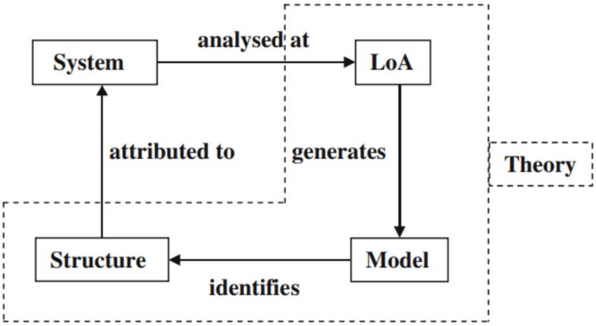

Fig. 1 The SLMS scheme

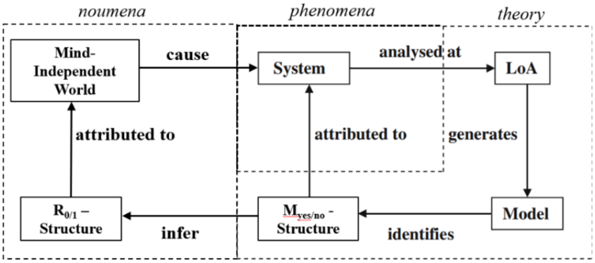

Fig. 2 Modified SLMS scheme

these variables. The type is defined simply by a set of values. Next Floridi defines an *observable* as any interpreted typed variable that stands for one or more features of a system under investigation. A note is required to clarify what Floridi means here. The term "observable" has nothing to do with what can or cannot be perceived with the unaided senses. Instead, an observable is any typed variable that is accepted to stand for or represent something else. In the sciences, that something typically involves objects and their properties in the world, but it need not be, it could represent supernatural or abstract objects as well. The term "system" is equivalent here to phenomena and does not refer directly to any object, activity, or process in the mind-independent world itself.

A LoA is a collection of observables, and a system is always analyzed or interpreted at a LoA and cannot be separated from it. LoAs by themselves do not tell us very much about systems because systems are dynamic, and their parts interact with one another in orderly ways. To capture this, Floridi introduces the concept of a *behavior*—this constrains the possible values observables can take. In scientific theories the behavior is provided by equations and laws. A *moderated LoA* is defined as a LoA with a behavior. Finally, Floridi defines a *gradient of abstraction* (GoA) as a new LoA created by combining elements of existing LoAs for certain ends and purposes. This is typically done by pairing up observables from each LoA and providing a translation of their respective behaviors.

Once scientists have determined the LoA via which they analyze a system (this is rarely made explicit), they then use this, according to Floridi, to build models of that system. These models contain individual objects, properties, and relations. From this model a *structure* can be extracted or identified for the system under investigation. Floridi calls this the system-level-model-structure (SLMS) scheme (see Fig. 1).

It should be stated that everything that goes on in the SLMS happens on the "phenomena" side of the noumena/phenomena distinction. Or perhaps better still, given the phenomena provided by the system, our LoAs allow us to construct models of it that, in turn, allow us to extract a simple structure of the system. How does the extracted structure relate to the mind-independent world? That is of course the crucial question that realists will want an answer to. I will come back to this question shortly in Sect. 4 because there is one more piece of the Floridian puzzle that needs explaining before it can be answered.

From Floridi's definition of ISR we know that scientific theories provide us with information about phenomena and potentially information about the noumena as well (restricted to the level of structure). However, Floridi adopts a "strongly semantic" theory according to which information is data that is well-formed, meaningful, and true (2004). For Floridi, information comes with a presupposition of truth. As he puts it, false information is no more real information than a decoy duck is a real duck or a false friend a real friend. Data can be noisy or clear, and although we speak of "misinformation", this is really a misnomer, just as "false evidence" is not really any kind of evidence. For this reason, Floridi prefers to speak of well-formed, meaningful, and false data as "pseudo information". This might not seem to be a problem as scientific realists typically take our best current theories to be true or approximately true and so if Floridi is saying that they are informative, and information requires truth, then there appears to be little disagreement. However, things are not this straightforward, as Floridi also commits to a particular conception of truth that places him at odds with scientific realists.

It is standard practice among realists to hold a correspondence theory of truth for theories. In the well-known definition of scientific realism outlined by Boyd (1983), a true or approximately true theory has terms that "putatively refer" to entities and properties that exist in a mind-independent world. Structural realists have typically either followed this account but restricted the reference to structural predicates or to isomorphism between the structure of models and the world. Floridi is at pains to point out that he does not advocate any of these previous conceptions of truth. Instead, he holds what he calls a "correctness theory of truth" (CTT). Like the other parts of his account, he relies heavily on technical terms from computer science, but a pre-existing knowledge of these is not necessary to appreciate its philosophical implications.

According to Floridi his "CTT seeks to reduce truth to correctness" (2011a, p. 165) where correctness is a property of answers to questions. A proposition (P) such as "the beer is in the fridge" can be reduced to a question (Q) and an answer (A) as follows:

(P) "The beer is in the fridge".
(Q) "Where is the beer?"
(A) "In the fridge".

The data contained in the proposition is equal to the question and the answer, but only a correct answer makes the proposition true and therefore information. Floridi makes correctness a Boolean function by rephrasing the question and answer for any given proposition into a yes/no question:

> (P) “The beer is in the fridge“
> ($Q_{0/1}$) “Is the beer in the fridge?“
> ($A_{0/1}$) “Yes”

This is a useful strategy given Floridi’s commitment to a reality composed of knowable binary relations $R_{0/1}$. Having the information of the theory in the same form as both data and reality makes it easier to see how the structure of a theory can relate to reality. The natural next step for a realist would be to claim that what makes a theory true (or false) is whether the yes/no theory structure is isomorphic to the binary structure of the mind-independent world. But Floridi makes no such claim. The “correctness makers” for answers to questions turn out to be decisively antirealist. Correctness is defined as a complex relational property between the model, the system, and the individual or community engaging with the world at a particular LoA. A key concept for Floridi is that of *access*. According to him a binary answer $A_{0/1}$ is *correct* for a binary question $Q_{0/1}$ (for a given context and LoA) provided it allows us to build a model for a system (at the same LoA), such that the model allows us to access the system. He envisions the model as a kind of proxy of the system by analogy to computers having indirect network connections to other network services.

Given how crucial access is for grounding the correctness of an answer (and therefore the truth of a proposition), it is surprising that this is the least developed part of Floridi’s whole account. He relies heavily on the analogy with computers telling us that “accessibility refers to the actual permission to *read* and/or *write* data as a *physical* process” (2011a, p. 163). This is not very helpful as individual scientists engaging with the world do not need permission to read or write data in the way we might need permission to access an encrypted channel. Likewise, it is hard to know what to make of describing it as a “physical process” given Floridi’s bifurcation between phenomena and noumena. Does this relate to the mind-independent world or the system at a particular LoA? When he does describe the relation in question it is clear that what he means by “access” is some level of successful human interaction for particular purposes and intentions:

> The sort of accessibility at stake here is a matter of pragmatic or factual interaction, which provides an exogenous grounding of correctness. (2011a, p. 163)
> Correctness is not an internal property of the system, but the external feature of $A_{0/1}$ that guarantees the successful, pragmatic interaction with s through m” (2011a, p. 166)

An answer counts as correct provided it allows us to build a model (m) to interact with a system (s). Floridi’s CTT is therefore a version of the pragmatic theory of truth. Although markedly different from the accounts of Peirce or James, Floridi agrees with them that truth is a function of individual interests and concerns. Whether or not a proposition is true for Floridi ultimately boils down to whether it allows us to interact with the phenomena for a particular set of goals and purposes. In the case of scientific activity, it makes sense to think of those goals and purposes being closely linked to prediction, explanation, manipulation, and the development of technologies. A proposition is true only if it can do this successfully. The relational nature of truth for Floridi means that truth is always relative to a particular LoA and the goals and purposes of the individuals interacting with the system. As I shall now argue, this brings into doubt whether ISR can really provide a version of structural realism that reconciles the NMA and PMI.

4 Can ISR reconcile the NMA and PMI?

Now that the key components in Floridi's account of the nature of theories and truth have been made explicit, it is time to assess whether ISR can in fact reconcile the two motivating arguments for structural realism: the NMA and the PMI. As seen already, Floridi identifies ISR as a brand of realism and separates it from antirealist views because he believes we can know more about the mind-independent world than the mere fact it exists. We can know its structure. This structure is given by relations of binary difference $R_{0/1}$ which are "mind-independent, concrete points of lack of uniformity" (2008a, 236). How the structure of a scientific model ($M_{yes/no}$-structure) relates to or "captures" the mind-independent structure of the world ($R_{0/1}$-structure) is not explicitly explained by Floridi. Nonetheless, if ISR is to be a genuine alternative version of realism, is needs to show how knowledge of this structure is possible.

I have added to Floridi's original SLMS scheme (see Fig. 2) showing the relationship between the parts of the theory, the system, and the mind-independent world. I have also indicated which parts belong to the *phenomena* side and which parts belong to the *noumena* side of Kant's distinction. The question now becomes: why should we believe that the $M_{yes/no}$-structure can tell us anything about the $R_{0/1}$-structure? For scientific realists as well as structural realists the main incentive has been the NMA and Floridi suggests this is also a motivating factor for his own ISR: "NMA leads to the view that the epistemic success of a theory is a function of its being correct about the structure of reality" (2008a, p. 224). A standard characterization of the NMA would go something as follows:

(1) Our best scientific theories are successful at explaining and making novel predictions about the world
(2) The best explanation of (1) is that our best scientific theories are true or approximately true
(3) Therefore, our best scientific theories are true or approximately true

In this version of the NMA, which can be thought of as an inference to the best explanation, the "truth" of a theory is being offered as the best explanation for its success. From the standpoint of correspondence and referential accounts of truth this makes sense. If our theories are true, then the entities they refer to exist and behave in ways predicted by a theory's laws and equations. Because Floridi rejects these accounts of truth in favor of the CTT, truth can play no such role. Recall that what makes an answer to a question correct is whether it allows us to build a model that provides successful access to the phenomenal world. On Floridi's CTT, success in the form of prediction, explanation, and intervention forms part of the necessary conditions for a statement to be true. As a version of the pragmatic theory of truth this is not surprising. But it does mean that Floridi can no longer appeal to the standard form of the NMA as a positive argument for realism. To do so would be tantamount to saying that our theories are successful because they are successful. As truth is defined in terms of success on the CTT, truth cannot provide any non-vacuous explanation of the success of a theory.

Floridi might respond by saying that the standard NMA presupposes a non-Kantian epistemology that fails to consider the fact that the phenomenal world is a combination of both the world-in-itself and LoAs. Just like the NMA has been claimed to be question-begging for those antirealists who reject inference to the best explanation, so Floridi might claim that the NMA is question-begging for those who hold non-correspondence theories of truth. If that is the case, then the standard NMA would be insufficient to ground belief in ISR. Russell, who like Floridi, recognized a distinction between phenomena and noumena overcame this problem by using the "different effect = different cause" principle (1927, 249). Floridi does not appeal to this principle, presumably because it makes causal claims outside a LoA. However, Floridi does believe there is a metaphysical connection between the $R_{0/1}$-structure and the system. This is his transcendental argument that if there were no $R_{0/1}$ relations then successful explanation and prediction of the phenomenal world would not be possible. Since explanation and prediction is possible, therefore there must be $R_{0/1}$ relations. Maybe this can be used to create a new version of the NMA that supports ISR? The following is one such potential argument that respects the Kantian distinction as well as Floridi's notion of truth as correctness:

> (1) Our best scientific theories are explanatory and predictively successful at the level of the phenomenal world
> (2) The phenomenal world is (ontologically) composed of both $R_{0/1}$-structure and the LoA through which it is interpreted
> (3) The best explanation of (1) is that our theories (and models) are composed of correct answers to questions about the $R_{0/1}$-structure
> (4) Therefore, our best scientific theories (and models) are correct about the $R_{0/1}$-structure of the noumenal world

Another way to put this is simply to say that, given the system studied (the phenomenal world) is composed of both $R_{0/1}$-structure and a LoA, it would be a miracle that we could successfully predict and intervene in the system, if our theories were not also sometimes correct about the $R_{0/1}$-structure. On this basis we can then proceed to say that our successful theories provide knowledge of the $R_{0/1}$-structure and therefore the structure of the mind-independent world.

The problem with this modified version is that correctness cannot transfer from successful interaction with the system to the world-in-itself because correctness is a relationship between a theory (interpreted at a LoA) and a system (also interpreted at a LoA). In other words, "correctness" cannot apply to noumena but only to phenomena interpreted at a LoA. It is only possible to have knowledge of the interpreted system—one cannot have knowledge of the world-in-itself. Floridi does suggest in places that we get *indirect* knowledge of the structure of the mind-independent world (2008, 225, 229, 249). However, he does not elaborate on the distinction between direct and indirect knowledge and how we are to understand the nature of indirect knowledge. One could attempt to infer indirect knowledge if one had logical reasons to posit a connection between the structure of the model and the $R_{0/1}$-structure. But as we have already seen, Floridi rejects any meaningful understanding of such a correspondence. The only connection we are told exists is that $R_{0/1}$-structure is a *necessary condition* for models to be successful: but this does not tell us anything much about the nature of the relations themselves. Yet this would seem to be essential if Floridi's ISR is to be distinguished from antirealism.

A consequence of Floridi's LoA and CTT is that knowledge cannot be restricted to one domain of discourse in the way selective realisms propose. Whether it is structural realism, entity realism, or even Van Fraassen's constructive empiricism, these approaches all allow that some of what our theories say are true, or approximately true, whereas for other parts we should remain agnostic. Because for Floridi there can be no theoretical discourse at the level of the $R_{0/1}$-structure, so one cannot restrict our knowledge to it in this way.

What about coming towards structural realism from the other side? Floridi suggests that ISR, like other forms of structural realism, provides a realist response to the PMI. He tells us that although "discontinuity in theory change may be radical when non-structural descriptions of the nature of entities are involved, this is counterbalanced by considerable continuity at the structural level" (2008a, 224). Since we already know that direct knowledge of the world-in-itself is not possible, this structural continuity must therefore exist at the level of our attempts to describe the phenomenal system. He also tells us that scientific theories are "increasingly informative" about the relational properties in the system under investigation (2008a, 240).

What can "increasingly informative" mean here? This sounds like a quantitative definition of information such as that given in the accounts of Shannon (1949) or Kolmogorov (1965). However, Floridi does not adopt a quantitative measure. As already seen, he adopts a qualitative view of information as well-formed, true, and meaningful content, and via the CTT this reduces to access to the system via a model at a particular LoA. Information is therefore a *relational property* of information gatherers, the model, and the system. The most likely interpretation of "increasingly informative" is therefore that a theory provides better and better access to a system. How can we measure whether one theory provides better access than another to a system? Measuring access requires a fixed point of reference, yet because the phenomenal system is a combination of both the world-in-itself and the LoA, it changes as scientific theories change. To talk of "better access" is therefore not possible if the thing being accessed is constantly changing.

Floridi could fall back on how successfully the model provides access to the phenomenal system *vis-a-vis* normal pragmatic constraints. These can be compared regardless of whether the thing being accessed has changed. For example, one key might be better than another even if they open different doors because it does not get stuck so often, weighs less, is easier to distinguish from other keys, is harder to forge, etc. A response along these lines assumes that the pragmatic criteria used to judge success between successive theories remains the same. But everything Floridi says suggests these are also likely to change. The LoAs change in response to our changing interests and needs. It is our changing pragmatic constraints that are causally responsible in part for the changing LoAs and subsequently for scientific change as a whole.

Floridi himself says that science provides increasingly informative models about the world. However, this "progressive" response to the PMI, whilst sufficient to solve it, is not actually necessary. All structural realists need is to show continuity at the structural level.[5] That it is difficult to demonstrate progress might not, therefore, be fatal to Floridi's version of ISR provided continuity can be demonstrated. Could a simpler, non-progressive, but still continuous response be open to Floridi? Unfortunately, even this weaker type of response to the PMI seems unavailable. If there is continuity of the information models provide about the world ($M_{yes/no}$-structure), then this information needs to transfer between successive periods in the history of science. Floridi sees this information flow in a non-metaphorical sense occurring between individuals or clusters of individuals engaged in scientific activity. But as Krebs (2011) has argued, Floridi's relational definition of information makes it impossible to understand it as a commodity or object that can flow. He gives as an analogy the popular piece of advice that one can get rid of fever by "sweating it out". One cannot literally sweat out fever because fever is a relational entity and cannot be explained in terms of the transfer of a substance. To do so is to commit a category mistake. He believes the same is true of Floridi's concept of information:

> A similar explanatory problem lies in the combination of transferability and relationality in the case of knowledge via semantic information: conceptualising information as a particular deprives oneself of the possibility of claiming relationality, while conceptualising informativity as a relational property prohibits its transferability. Since the relevance condition posed by Floridi clearly points towards a conception of informativity as a relational property of medial constellations, it is hard to see how the transferability condition should hold at the same time (2011, 238).

Because Floridi subscribes to a strongly semantic theory of information, information requires truth, which in his analysis means it provides correct answers to yes/no questions. The pragmatic nature of those answers raises doubts about whether this information can be transferred or transmitted. As Krebs puts it: "What sense can we make out of the idea that what gets transferred depends—among other things—on the interests of the interpreter?" (2011, 238). If information is interest-relative, then there is no literal way to track the transfer of information between individuals. The problem arises according to Krebs because Floridi has applied an aspect of *quantitative* theories of information, such as those given by Shannon and Kolmogorov, which deal with a measurable substance or commodity, with a *qualitative* analysis of information, which deals with the meanings individuals interpret or ascribe to data.[6] This

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[5] I wish to thank an anonymous reviewer at *Synthese* for pointing this out.

[6] For a fuller discussion of this issue as well as his own position, see Krebs (2019).

suggests that an informational version of structural realism, grounded in a quantitative theory of information, might provide a better response to the PMI.

5 Algorithmic structural realism

Floridi is not the first to understand the nature of science and scientific knowledge in terms of information. Many of the early developers of mathematical accounts of information did the same, although addressing slightly different concerns. Here I want to highlight the contribution of a mathematical theory of information called "algorithmic information theory" that was developed independently by Solomonoff (1964) and Kolmogorov (1965). The basic idea is that how *informative* a piece of data is is related to how *complex* that data is. Data that is highly structured, ordered, or predictable is less complex than data that is patternless and random. Like Shannon's theory of entropy, there is an inverse relationship between *informativeness* and *predictability*. However, whereas Shannon articulates that notion using probability, algorithmic information theory uses the concept of a universal computer and the resources required to reproduce data on that computer.[7]

According to Kolmogorov, the complexity (K) of a string of data (S) measured in bits is equal to the length of the *shortest program* that, when run on a universal Turing machine (U), will output S and halt. For most strings of data S the shortest program that can reproduce it is simply of the form "print S". Most strings are random and do not contain any pattern or structure. However, for some strings, called the "compressible strings", there are better ways to reproduce them. Consider the following two strings of binary digits:

(A) 0011001011110101100101011000.
(B) 0101010101010101010101010101.

The first of these shows no discernable pattern. The simplest way to reproduce this is to program the computer to "print A". By contrast, B has an obvious pattern as every "0" is followed by a "1". This allows us to program a computer to output B using fewer resources, e.g., "Print "01" 14 times". If the length of the new program is shorter than the original, it is said to be compressible. Clearly the more structured data is, the more compressible it is. Kolmogorov formally showed that for any string S there is something called its *complexity* (K) which is the length of the shortest possible program that can output S (1965, 4–5).

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[7] Majid Davoody Beni has done some work to create a version of ISR he calls "epistemic informational structural realism" (EISR). He agrees that Floridi's own ISR leans too far in the direction of antirealism (2016). He develops accounts around the idea of biosemiotics (2017) and Shannon's concept of entropy (2018). These provide interesting alternative versions to the one I give. However, both these new accounts rely on ideas that renders EISR less realist than standard forms of structural realism. For example, biosemiotics defines information in terms of "intentions" (2017, 191–195) and entropy appears to depend on numerous pragmatic constraints (2018, 639–640). For that reason, I think it is important to explore how algorithmic information theory provides a more realist measure.

Several scientists and philosophers including Solomonoff, Chaitin (1987, 2005), Gell-Mann (1987), Davies (1995), Braddon-Mitchell (2001), and Tomkow (2013, 2014) have claimed that the order and structure that we see in the world, and which science aims to describe, is best understood in terms of compressing data. They advocate what might broadly be called an "algorithmic picture of science". According to this picture, the world is understood as a source of data and one important role of science is to compress that data. This is what the laws and equations are in our best scientific theories—they are attempts to uncover the shortest algorithms (or programs) for reproducing the universe. Although Solomonoff was not interested in the realism-antirealism debate directly, he did think that algorithmic compression provided an alternative way of thinking about prediction.

> The laws of science that have been discovered can be viewed as summaries of large amounts of empirical data about the universe. In the present context, each such law can be transformed into a method of compactly coding the empirical data that gave rise to that law. Instead of including the raw data in our induction sequence, it is possible, using a suitable formalism, to write the laws based on this data into the sequence and obtain similar results. (1964, 16)

An effective algorithmic compression of a string S contains two parts: (i) an algorithm or program (P), and (ii) a list of random/unstructured data (I). If a universal Turing machine is programed using P, then I forms the list of instructions fed into U. When P is run with I the result is S. If the combined length of P+I is less than S, then S has been algorithmically compressed. If we think of scientific theories as containing the information needed to achieve such compressions, then it is natural to equate the laws and equations with these algorithms. This is how Paul Davies understands their role in scientific theories:

> The existence of regularities may be expressed by saying that the world is algorithmically compressible. Given some data set, the job of the scientist is to find a suitable compression...For example, the positions of the planets in the solar system over some interval constitute a compressible data set, because Newton's laws may be used to link these positions at all times to the positions (and velocities) at some initial time. In this case Newton's laws supply the necessary algorithm to achieve the compression. (1995, 249)

This algorithmic picture of science should be distinguished from digital physics and Wheeler's "it-from-bit" hypothesis. It is not saying that the nature of the universe is fundamentally digital or that it operates like a giant computer with the laws of nature as the programs. Whilst the algorithmic picture is certainly consistent with this metaphysical stance (and perhaps a natural companion to it), it can be held separately as an epistemological view only. On this rendition, the point being made is about the nature of knowledge, how our theories contain that knowledge, and what the limits of our knowledge are when it comes to the outcomes of scientific activity.

What are the limits of knowledge on an algorithmic picture of science? At first glance it might seem that the algorithmic view supports both instrumentalism and full-blown realism. It supports instrumentalism because it clearly refers to what might be understood as a pragmatic constraint on theory choice—namely, that our theories describe the world in the shortest and simplest way possible. Presumably, nature itself does not care about "saving resources", but for human minds that are limited, this is a crucial deciding factor in theory choice. On the other hand, it could be argued it supports a full version of realism. If the laws of nature really are the best algorithms for compressing empirical data, then these can be thought of as abstract entities that supervene on states-of-affairs. True theories are just those that correctly describe these algorithms. Or, if one subscribes to digital physics, they describe the programs immanent in the universe that produce all its output.

Here I want to argue that despite these initial appearances the algorithmic picture of science implies a version of structural realism. To see why, we need to consider a formal result of algorithmic information theory called the "invariance theorem". So far I have not said anything about the language in which the data and algorithms are composed (i.e. the operating language of U). Yet the language we choose to describe something has an impact on the length of that description. If S is written in language L_1, then we might try to rewrite S in a new language L_2 that uses fewer bits. This shows that the complexity of a string S is relative to the coding language that is used. The best compression of the universe is therefore relative to coding language and so too are a theory's laws and equations. Any decision we make about the language we use will probably involve pragmatic considerations.

However, although the choice of language we use is in some sense subjective and depends on our own choices, whether a string of data is compressible (once encoded in that language) is not. The compressibility of a string is a function of itself and how much structure it contains. Although different descriptions of it in different languages will have different lengths, these lengths only reflect our choice of language, not its inherent structure. This is the result of the invariance theorem:

$$\text{(Invariance Theorem) } (\forall S)\ |K_1(S) - K_2(S)| \leq c$$

This tells us that the difference between the Kolmogorov complexities of a string S in two languages L_1 and L_2 is bounded by a constant value c.[8] The value for c is equal to the length of a translation program that takes S in L_1 as input and returns S in L_2 as output:

$$\text{(Translation Program) } c = |P_{\text{TRANSLATE}}(L_1 \text{ to } L_2)|$$

For strings of data that are relatively short, the value of c can make a difference in the choice of language. But for strings of data that are large, c becomes increasingly less important. As the size of empirical data encompassing the universe from its beginning to its end is likely to be extremely large, this suggests that the language we choose to describe it is more-or-less irrelevant in terms of capturing its algorithmic structure. As Davies puts it: "The fact that the definition of complexity is machine-independent suggests that it captures a really existing quality of the system and is not

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[8] See Li and Vitányi (2019, 108) for the formal proof.

merely a function of the way we choose to describe it" (1995, 252). This provides optimism that science can, in principle, come to discover the world's algorithmic structure by formulating the best compression of it. On the other hand, we should be less optimistic about knowing what the fundamental kinds are. As much as our scientific taxonomy is an artefact of our language choice, we will never be able to know whether the distinctions we make really carve nature at its joints. Even though we may know the structure of the universe, we cannot know what the individuals or objects are that fundamentally make up the patterns in that structure.

This suggests an informational form of structural realism that is quite distinct from Floridi's. To distinguish the two, let us call this new one "algorithmic structural realism" (ASR):

> (Algorithmic Structural Realism) The laws and equations of successful scientific theories that compress empirical data provide true or approximately true descriptions of the algorithmic structure of the world.

The information of the universe is given by the shortest program that will reproduce it. Because the length of such a program depends on the language of the computing device, this means that all we can hope to know is its algorithmic structure. However, this is still more realist than Floridi's ISR because there is an objective (and non-pragmatic) fact about whether our current attempts at describing this structure have succeeded. Let us suppose that T_1 represents our best attempt at describing the universe and T^* is in fact the shortest program for producing it. If the difference in length between T_1 and T^* is equal to or less than the length of a program that translates T_1 and T^*, then we know that both have correctly captured the structure of the universe as any differences between T_1 and T^* merely reflect our choice of coding.

Although ASR suggests that the algorithmic structure of the universe is a mind-independent quality that can discovered, the fact that our theories provide compressions of empirical data is not sufficient yet to justify the belief that we have discovered it. The compression of empirical data can be had much too easily. To attain this additional reason we have to appeal to the standard argument in favor of scientific realism: the NMA.

Why should we believe that the laws and equations in our current theories correctly describe the algorithmic structure of the world (or are close to doing so)? It is tempting to infer simply from the fact that the laws and equations are good at compressing existing empirical data. But the amount of data collected by scientists is typically very small. Although some theory T might work quite well at compressing that data into a shorter form, this might occur because of contingent properties of that data set and do not generalize to the universe as a whole. What will support belief that the algorithms really do capture structure is the successful projection of compressibility. We want our algorithms to be good at not just compressing the data used to formulate them, but all further collected data, much of which was unknown prior to the discovery of the algorithm. A successful theory according to ASR is one which contains laws and equations that not only compress known empirical data but also novel empirical data.

Advocates of ASR can then appeal to the NMA to argue that these laws and equations would not be projectable compressions unless they had successfully described the algorithmic structure of the universe. The argument would go something as follows:

1. Our best scientific theories provide successful (projectible) compressions of empirical data.
2. The best explanation of (1) is that the laws and equations in our best scientific theories correctly describe the algorithmic structure of the world.
3. Therefore, the laws and equations in our best scientific theories correctly describe the algorithmic structure of the world.

The intuitive idea is that it would be a miracle that our theories are good at compressing empirical data if they did not provide a truthful or approximately truthful description of the structure of the world.[9] Full-blown realists will want to extend this optimism to everything that a theory says. But advocates of ASR will limit it just to the algorithms (laws and equations) and remain agnostic about the other assumptions made by a theory, such as the taxonomy of kinds and their intrinsic non-relational properties.[10]

An objection that might be raised here is that because the complexity K of any string is non-computable, so the value of K for the universe is unknowable. The reason why K is non-computable is that, on the assumption that K=n for a string of data S, if K were computable, it would be possible to write a program whose length is less than n.[11] This is a contradiction. The result is similar to other self-referential paradoxes such as Berry's paradox and the Liar paradox and has been taken by some to impose limits on what can be known (Chaitin, 2005). If this objection succeeds it would seriously undermine the support the NMA gives for ASR and render ASR weaker than traditional versions of structural realism.

Fortunately, I do not believe that the non-computability of K poses as much of a problem as it at first appears. There are two reasons for this. The first is that the non-computability of K does not rule out that we can produce a program of length K. What it means is that even if we finally arrive at the best compression, we may not know that what we have in front of us is in fact the best compression. As Grünwald and Vitányi have put the same point "eventually you know, but you do not know you know" (2008, 294). This is an important distinction to make. The non-computability of K does not imply that you cannot succeed in producing the best compression, it just means that you can never prove that you have the best compression. This is not so worrying as it is a general problem about the limits of human understanding regarding the so-called "theory of everything". If we were to discover the theory

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[9] McAllister (2003) has argued that scientific laws do not provide effective algorithmic compressions of empirical data. For a response see Twardy et al., (2005) as well as Wheeler (2019).

[10] Whilst all structural realists agree that the structure of the world can be known, and that this cuts across the observable/unobservable divide, there are differences held at the level of observables. Some structural realists allow knowledge of non-structural properties of observables whilst others do not. Here I do not take a stance on this debate and ASR could be adopted by advocates of either position.

[11] See Li and Vitányi (2019, 177) for the formal proof.

of everything, the final theory that tells us everything there is to know about the universe, how could we know that this *is* the final theory? How could we know that around the corner there is not some new empirical discovery to be had that would lead us to rethink our theories? This issue concerns all forms of realism. What the non-computability of K reveals is just this same problem, but in the language of algorithmic information theory.

The second reason is that this problem only emerges for internalist conceptions of knowledge where to know a proposition Q a person must know that they know that Q, or have good cognitive reasons to support their belief that Q. However, internalism is known to suffer from several difficult problems which is why many realists have chosen to choose an externalist approach. Here, one can know that Q without needing to know that you know that Q. Clearly taking an externalist approach would solve the problem of the non-computability of K. Provided belief in K is brought about by a reliable method, meets certain epistemic virtues, modal properties (or whatever one's preferred externalist epistemology), then it is possible to know the best compression and therefore the structure of the universe.

Traditionally, structural realists following Worrall have limited their belief to only laws and equations as a response to the PMI. This rests on a historical-empirical observation that there tends to be continuity at the level of laws and equations in theory change, but discontinuities concerning the nature of the kind of objects that populate the world. One virtue of ASR is it can explain why only the laws and equations are knowable. As discussed above, the invariance theorem only allows us to infer that the algorithmic structure of the world is mind independent. We can never know that the language we use to describe that structure successfully carves nature at its metaphysical joints because there are many alternative languages we could have used to describe the same structure. As the difference in the lengths between them will be marginal, any choices between one language or another is likely to fall to pragmatic and subjective factors.

Nonetheless, if ASR is still to provide a response to the PMI it needs to show how there is structural continuity between successive theories in science and given that these changes come with discontinuity in the language used, it is not obvious how this can be demonstrated. Suppose our first theory T_1 uses language L_1 and therefore T_1 provides an effective compression of S_1 with respect to the universal Turing machine U_1. How can we know that a new theory T_2 is an improvement over T_1 given that it is now compressing different data S_2 (because using a different language L_2)? At an intuitive level the scientist may say T_1 and T_2 are "about" the same physical system in the world and assume some level of reference or correspondence between the terms and their experiences. But this is not sufficient to prove that there is in fact continuity between T_1 and T_2 at the level of compression. To do this we need to measure the lengths of two strings of input on U that both provide the same output. Given that T_1 and T_2 are trying to provide different outputs (S_1 and S_2 respectively), this would seem to be impossible.

Fortunately, the invariance theorem provides the means to do so. The invariance theorem implies that it is possible to compare the compression achieved by algorithms in two different languages up to the value of c. Suppose T_1 and T_2 are our successive theories and that the two data sets they compress are S_1 and S_2 respectively.

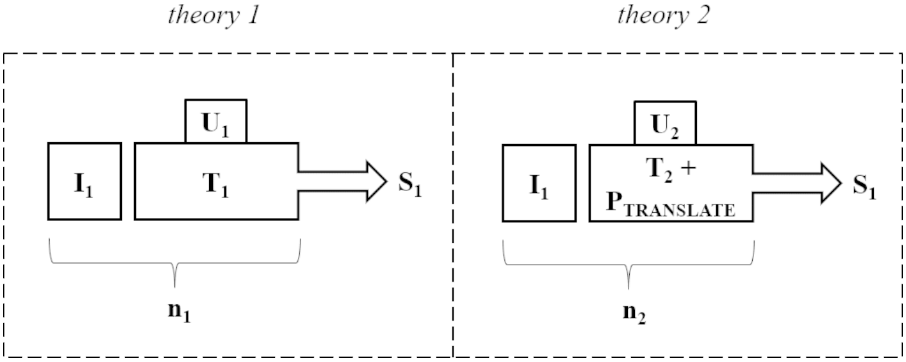

Fig. 3 Comparing successive theories

Let $P_{TRANSLATE}$ be a program that translates between the languages of S_1 and S_2. Then to show that one theory effectively compresses the data of another theory merely requires us to include the length of $P_{TRANSLATE}$ in our comparison (see Fig. 3).

If T_1 is an effective compression of S_1 then the combined length of T_1 and the initial condition data (I_1) must be shorter than S_1. Let us suppose that this is indeed the case and that the length of T_1+I_1 when input into U_1 is n_1. Suppose we now offer T_2 as a better compression than T_1. Under what circumstances would scientists accept T_2 as a better compression of S_1? Even if T_2 is written in a different coding language, provided the new combined length of T_2 and $P_{TRANSLATE}$ is shorter than T_1 alone, then the scientist must accept T_2 as a better compression of S_1.

> (Continuity and Progress) For theories T_1 and T_2 written in different coding languages, there is *continuity* of compression between T_1 and T_2 provided $n_1=n_2$, and there is *progress* in compression between T_1 and T_2 provided $n_1>n_2$.

This is not meant to be a description of how scientists compare rival theories, instead it provides the formal requirements to show that there can be continuity in theory change and at least, in principle, scientists can compare the merits of rival theories from the point of view of algorithmic compressibility even if they understand the world in different terms.

Of course, in practice, theory change is almost always accompanied by a change in language. So even if $T_2+P_{TRANSLATE}$ turned out to provide a better compression of S_1 than T_1, its unlikely scientists would continue to use the language of T_1 in encoding their empirical data. By switching to the language of T_2 scientists can make even greater gains since they now do not need to include the additional program $P_{TRANSLATE}$. However, given that the size of $P_{TRANSLATE}$ is typically very small, this is unlikely to be the main consideration for scientists. As has been discussed elsewhere, the choice of terms will reflect various other theoretical virtues such as scope, coherence with other theories, and explanatory salience. There will be pragmatic and even cultural considerations that shape our choice of theoretical language. Nonetheless, unlike Floridi’s LoAs, by adopting a concept of information as algorithmic compression, we can escape the more extreme antirealist consequences of this relativity.

6 Conclusion

Thinking of science and scientific discovery in informational terms can be useful for structural realists as it provides them with new ways to articulate how our theories relate to the structure of the world. Floridi's ISR paved the way for this new way of thinking. However, by including controversial accounts of theories and truth, his ISR pushes structural realism too far in the direction of antirealism. I have shown that it is possible to provide a more realist informational structural realism when it is grounded in algorithmic information theory. When a quantitative measure is used that provides a mind-independent quantity of information, it is again possible to appeal to the NMA and to provide a reasonable response to the PMI.

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References

Boyd, R. N. (1983). On the Current Status of the Issue of Scientific Realism. *Erkenntnis, 19*(1/3).

Bueno, O. (1997). Empirical Adequacy: A Partial Structures Approach. *Studies in History and Philosophy of Science*, *28*, 585–610.

Beni, M. D. (2016). Epistemic Informational Structural Realism. *Minds & Machines*, *26*, 323–339.

Beni, M. D. (2017). The Downward Path to Epistemic Informational Structural Realism. *Acta Analytica*, *33*, 181–197.

Beni, M. D. (2018). Syntactical Informational Structural Realism. *Minds & Machines*, *28*, 623–643.

Braddon-Mitchell, D. (2001). Lossy Laws. *Nous, 35*(2):260–277.

Bueno, O. (2000). Empiricism, Mathematical Change and Scientific Change. *Studies in History and Philosophy of Science*, *31*, 269–296.

Carnap, R. (1928). *The Logical Structure of the World*. University of California Press.

Chaitin, G. (1987). *Algorithmic Information Theory*. Cambridge University Press.

Chaitin, G. (2005). *Meta Maths - The Quest for Omega*. Atlanta Books.

Chakravartty, A. (2001). The Semantic or Model-Theoretic View of Theories and Scientific Realism. *Synthese*, *127*, 325–345.

da Costa, N. C. A., & French, S. (2003). *Science and Partial Truth: A Unitary Approach to Models and Scientific Reasoning*. Oxford University Press.

Davies, P. (1995). Algorithmic Compressibility, Fundamental and Phenomenological Laws. In F. Weinert (Ed.), *Laws of Nature: Essays on the Philosophical, Scientific and Historical Dimensions* (pp. 248–267). Walter de Gruyter & Co.

Dennett, D. (1991). Real Patterns. *Journal of Philosophy*, *88*(1), 27–51.

Floridi, L. (2004). Outline of a Theory of Strongly Semantic Information. *Minds and Machines*, *14*, 197–221.

Floridi, L. (2008a). A Defence of Informational Structural Realism. *Synthese, 161,* 219–253.

Floridi, L. (2008b). The Method of Levels of Abstraction. *Minds and Machines*, *18*, 303–329.

Floridi, L. (2009). Against Digital Ontology. *Synthese, 168*, 151–178.

Floridi, L. (2011a). Semantic Information and the Correctness Theory of Truth. *Erkenntnis, 74*, 147–175.

Floridi, L. (2011b). *The Philosophy of Information*. Oxford University Press.

Frigg, R., & Votsis, I. (2011). Everything You Always Wanted to Know About Structural Realism but Were Afraid to Ask. *European Journal for Philosophy of Science*, *1*(2), 227–276.

Gell-Mann, M. (1987). Simplicity and Complexity in the Description of Nature. Talk Delivered to The Caltech Associates, Pasadena 01/10/987.

Grünwald, D. P., & Vitányi, P. (2008). Algorithmic Information Theory. In P. Adriaans, & van J. Benthem (Eds.), *Handbook of Philosophy of Science Vol. 8: Philosophy of Information* (pp. 289–328). Elsevier.

Kolmogorov, A. (1965). Three Approaches to the Definition of the Quantity of Information. *Problems of Information Transmission*, *1*(1), 1–7.

Krebs, J. (2011). Philosophy of Information and Pragmatistic Understanding of Information. *Etica & Politica / Ethics & Politics*, XIII, 2, 235–245.

Ladyman, J., & Ross, D. (2007). *Everything Must Go: Metaphysics Naturalized.* Oxford University Press.

Ladyman, J., & Ross, D. (2013). The World in the Data. In J. Ladyman, D. Ross, & H. Kincaid (Eds.), *Scientific Metaphysics* (pp. 108–150). Oxford University Press.

Landry, E. (2007). Shared Structure Need not be Shared Set-Structure. *Synthese*, *158*, 1–17.

Lewis, D. (2009). Ramseyan Humility. In D. Braddon-Mitchell, & R. Nola (Eds.), *The Canberra Programme* (pp. 203–222). Oxford University Press.

Li, P., & Vitányi, P. (2019). *An Introduction to Kolmogorov Complexity and its Applications*. Springer.

Maxwell, G. (1970a). Structural realism and the meaning of theoretical terms. In S. Winokur, & M. Radner (Eds.), *Analyses of Theories and Methods of Physics and Psychology (Minnesota Studies in the Philosophy of Science: Volume 4)* (pp. 181–192). University of Minnesota Press.

Maxwell, G. (1970b). Theories, perception and structural realism. In R. Colodny (Ed.), *The Nature and Function of Scientific Theories* (pp. 3–34). University of Pittsburgh Press. University of Pittsburgh Series in the Philosophy of Science: Volume4.

Maxwell, G. (1972). Scientific methodology and the causal theory of perception. In H. Feigl, H. Sellars, & K. Lehrer (Eds.), *New Readings in Philosophical Analysis* (pp. 148–177). Appleton-Century Crofts.

McAllister, J. (2003). Algorithmic Randomness in Empirical Data. *Studies in the History and Philosophy of Science*, *34*(3), 633–646.

Ross, D. (2000). Rainforest Realism: A Dennettian Theory of Existence. In D. Ross, A. Brook, & D. Thompson (Eds.), *Dennett's Philosophy: A Comprehensive Assessment* (pp. 77–94). MIT Press.

Russell, B. (1927). *The Analysis of Matter*. Routledge Kegan Paul.

Shannon, C., & Weaver, W. (1949). *The Mathematical Theory of Information*. University of Illinois Press.

Solomonoff, R. (1964). A Formal Theory of Inductive Inference: Part I. *Information and Control*, *7*(1), 1–22.

Tomkow, T. (2013). The Computational Theory of the Laws of Nature. http://tomkow.typepad.com/tomkowcom/2013/09/the-computational-theory-of-natural-laws.html. Access: 08/06/2019.

Tomkow, T. (2014). Computation, Laws and Supervenience. https://tomkow.typepad.com/tomkowcom/2014/02/computation-laws-and-supervenience.html. Access: 08/06/2019.

Twardy, C., Gardner, S., & Dowe, D. (2005). Empirical Data Sets are Algorithmically Compressible: Reply to McAllister? *Studies in the History and Philosophy of Science*, *36*(2), 391–402.

Wheeler, B. (2019). Compressibility and the Algorithmic Theory of Laws. *Principia: An International Journal of Epistemology*, *23*(3), 461–485.

Wheeler, J. A. (1990). Information, physics, quantum: The search for links. In W. H. Zurek (Ed.), *Complexity, Entropy, and the Physics of Information*. Addison-Wesley.

Winther, R. S. (2020). The Structure of Scientific Theories. In Edward N. Zalta (ed.) *The Stanford Encyclopedia of Philosophy.*URL = < https://plato.stanford.edu/archives/spr2021/entries/structure-scientific-theories/

Worrall, J. (1989). Structural Realism: The Best of Both Worlds?.*Dialectica*, *43*, 99–124.