# How not to be a Realist or why we Ought to Make it Safe for Closet Structural Realists to Come out

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## 1. Introduction

When it comes to name-calling, structural realists have heard pretty much all of it. Among the many insults, they have been called 'empiricist anti-realists' but also 'traditional scientific realists'. Obviously the collapse accusations that motivate these two insults cannot both be true at the same time. The aim of this paper is to defend the epistemic variety of structural realism against the accusation of collapse to traditional scientific realism. In so doing, I turn the tables on traditional scientific realists by presenting them with a dilemma. They can either opt for a construal of their view that permits epistemic access to non-structural features of unobservables but then face the daunting task of substantiating a claim that seems to have little hope of being true or they can drop the requirement of epistemic access to non-structural features but then face a collapse to epistemic structural realism. There is thus only one well supported way to be a realist. No wonder then that many traditional scientific realists have over the years expressed views that are strikingly similar to epistemic structural realism. It is high time to let these epistemic structural realists out of the closet.

## 2. Epistemic Structural Realism

Structural realism is a factious family of related views in the scientific realism debate. There are broadly speaking three kinds of structural realism: methodological, epistemic and ontic. Let us start with the methodological kind. This focuses on the role shared structure plays in characterising scientific theories, in relating high-level theory to low-level data and in identifying links between predecessor and successor theories (see Brading and Landry 2006). Although this is certainly a structural view, it is difficult to discern how this view earns the moniker 'realism'. No realist claim on the semantic, epistemic or ontic level is made by those who endorse this view and for this reason it would be better to classify it as a structuralist view of the methodology of science.

Consider next the ontic kind of structural realism or OSR for short. Several distinct versions of it exist. What all ontic structural realists have in common is the rejection of one or more claims associated with traditional conceptions of objects. In its original formulation (e.g. Ladyman 1998), what I call the 'no objects view', the position does away with objects and attempts to make do only with structures. That is, it calls for a reconceptualisation of ontology that sees objects merely as place-holders in structures. Nobody currently advocates this view and Ladyman insists he never intended to convey such an extreme idea. Another version of OSR that is perhaps the most prominent one is what I call the 'no individuals view' (e.g. French and Krause 2006). This view maintains the existence of objects but rejects that these should be conceived as individuals. Finally, it is worth mentioning one more version that seems to be gaining prominence within the OSR camp, namely the 'no intrinsic natures view' (e.g. Esfeld 2004). According to this view intrinsic natures are eliminated in favour of individuals and structures.

Supporters of the epistemic kind of structural realism or ESR for short hold that although our knowledge of observables is unrestricted, our knowledge of unobservables is at best structural. In more formal terms, we can only know the unobservable world up-to-isomorphism. This view can be contrasted with traditional scientific realism whose advocates insist that both observable and unobservable aspects of the world are in principle fully knowable. In other words, the relevant difference between the two views is the extent to which unobservable aspects of the world can be known. There are two versions of ESR currently being sponsored. Those who endorse the Ramsey version claim that the structure of the unobservable world is best captured in the Ramsey sentence formulations of successful scientific theories (e.g. Worrall and Zahar 2001).[1] Those who endorse the Russell version claim that we can infer certain things about the structure of the unobservable world from the structure of our perceptions (e.g. Russell 1927, Votsis 2005).

For the remainder of this paper my claims are solely concerned with ESR. Unless otherwise noted, my remarks will be largely blind to the two versions of ESR, i.e. they will apply equally to both of them. Having said this, it is worth mulling over the ways in which the two versions of ESR differ. Their differences can be plotted along three axes. First, there is the direct vs. indirect realism axis. Those advocating the Ramsey-sentence approach to ESR tacitly endorse direct realism. In so doing they claim that epistemic agents perceive, cognise and are aware of the world directly. For supporters of this view some but not all physical objects are unobservable. Subatomic particles are the best candidate class of unobservables. In opposition to the direct realist view, those advocating the Russellian approach to ESR endorse an indirect form of realism. They thus presuppose that the immediate object of our perception, cognition and awareness is something internal, e.g. a mental representation or at least some kind of by-product of the human perceptual system.[2] For supporters of this view the whole external world counts as unobservable and for that reason can at most be known structurally. It is worth noting that in principle nothing stands in the way of marrying Ramsey-style ESR to indirect realism. The same cannot be said of Russell-style ESR for indirect realism is hardwired into it.

Both approaches to ESR are at variance with scientific realism on the issue of observability. Scientific realists deny that a clear line can be drawn between what is observable and what is unobservable or at least divest such a distinction of any epistemic significance. They do so because they want to undercut the empiricist anti-realist's attempts to motivate a selective agnosticism with respect to unobservables. ESR-ists also attempt to motivate a form of selective agnosticism, one that directs the agnostic attitude towards the non-structural dimension of unobservables. For this reason, ESR-ists come face to face with the same objections anti-realist empiricists find in their way. To be exact, it is only the direct realist approach to ESR that is affected by such objections. This is because the objections question whether external world objects can legitimately be divided into separate (i.e. observable and unobservable) groups, a division the indirect

[1] Many authors neglect the fact that in his original presentation of ESR Worrall (1989) does not advocate the Ramsey sentence – indeed he makes no mention of it.

[2] The identification of indirect realism with representationalism should be resisted. The latter is simply one manifestation of the former.

realist rejects. Of course indirect realists have objections of their own to worry about. Alas, this is a discussion that needs to be put on ice for another occasion.

The second axis discriminates Ramsey-style from Russell-style ESR on the basis of how each view arrives at the much vaunted structure. Advocates of the former do so by translating successful scientific theories into their Ramsified counterparts where theoretical terms become existentially quantified variables. The theoretical variables are then seen as place-holders instead of terms capable of referring to individual objects. As such the variables offer only structural clues about the individual objects that instantiate them. Psillos has called this the 'downward path to structural realism' in view of the fact that one starts with fully-fledged theories and then proceeds to peel away the non-structural elements, in this case the intensions of the theoretical terms, to get to the structure. Compare this to what Psillos calls the 'upward path to structural realism', according to which we infer various things about the structure of the unobservables from the structure of the observables on the presupposition that large parts of the two domains are isomorphic. This is the route taken by advocates of Russell-style ESR.

Finally the third axis runs along the kind of arguments that have been utilised to motivate each view. Ramsey-style ESR has been motivated by arguments from the history of science. By contrast Russell-style ESR has been motivated by arguments from perception. This being said, nothing prevents one from mounting arguments from the history of science to support Russell-style ESR. Likewise nothing prevents one from mounting arguments from perception to prop up Ramsey-style ESR. Moreover, some of these arguments can be cited to support other structuralist views. The argument from the history of science, for example, was appropriated early on by ontic structural realists.

Before we turn to the subject at hand a formal account of the notion of structure is vital. Although the following set-theoretical account is not universally accepted, it is sufficiently widespread and gives enough of an intuitive grasp of what epistemic structural realists have in mind. A structure $S$ is specified by two things: (i) a non-empty set $U$ of objects, which is also known as the domain of the structure, and (ii) a non-empty indexed set $R$ of (monadic and/or polyadic) relations defined on $U$. A structure so specified is a so-called 'concrete structure'. To understand the notion of structure that structural realists entertain we must abstract from this a notion of 'abstract structure'. This latter notion presupposes the idea of an isomorphic relation between structures. A structure $S_1=(U_1, R_1)$ is *isomorphic* to a structure $S_2=(U_2, R_2)$ just in case there exists a bijective mapping $f$: $U_1 \rightarrow U_2$ that preserves the system of relations between the two structures, i.e. for all relations $p_i \in R_1$ and $q_i \in R_2$, a set of objects $\{a_1, ..., a_n\}$ in $U_1$ satisfies the relation $p_i$ if and only if the corresponding set of objects $\{b_1=f(a_1), ..., b_n=f(a_n)\}$ in $U_2$ satisfies the corresponding relation $q_i$ – the corresponding relations have the same index. We can now define the requisite notion: An *abstract structure* $\Sigma$ is what all concrete structures that are isomorphic to one another have in common. Henceforth, and unless otherwise noted, talk of structure will denote talk of abstract structure.

**3. Accusations of Collapse**

An effective way to brush aside a viewpoint is to cast doubt on the distinctiveness of its character. Not only does this threaten to rob the given viewpoint of its originality but it also threatens to unload at its feet all the difficulties borne by the viewpoint it collapses into. In the case of ESR, two collapse accusations have come to light. The first is precipitated by the notorious Newman problem. Named after its originator, the mathematician M.H.A. Newman, the problem zeros in on the way epistemic structural realist articulate their knowledge claims. To say, like they presumably do, that for a given class there exists a system of relations with a certain logico-mathematical structure without at the same time identifying the specific relations is, according to Newman, to say nothing much of empirical importance since that same claim can be derived from theorems of set theory or second-order logic together with a presupposition about the minimum number of objects in that class. The only claim about the unobservable world, says Newman, left open for empirical determination concerns this cardinality presupposition. Those who endorse the Newman problem take ESR as collapsing into a form of empiricist anti-realism. For those harbouring hopes of a robust form of realism securing knowledge about the minimum number of unobservable objects can hardly be adequate. The Newman problem will not concern us further here – it has been widely discussed elsewhere (e.g. Ketland 2004, Worrall 2007) – though I will come back to it briefly in section four below.

The second collapse accusation has hardly received any attention in the literature. In a nutshell, it is the accusation that epistemic structural realism places no realisable restriction on what can be known and hence collapses into traditional scientific realism. I here quote from Psillos, the prime mover of this accusation:

> ... to say what an entity *is* is to show *how this entity is structured*: what are its properties, in what relations its stands to other objects, etc. An exhaustive specification of this set of properties and relations leaves nothing left out. Any talk of something else remaining uncaptured when this specification is made is, I think, obscure (1999, p. 156) [original emphasis].

In this and adjoining passages Psillos grumbles about the epistemic structural realists' adherence to the existence of something which remains structurally unspecifiable and which they call the 'nature' of an entity. This use of the term 'nature' is in his eyes anachronistic.

> I think that talk of 'nature' over and above this structural description (physical and mathematical) of a causal agent is to hark back to medieval discourse of 'forms' and 'substances'. Such talk has been overthrown by the scientific revolution of the seventeenth century (p. 155-6).[3]

Not having the same gripes with the notion of nature and the associated structure vs. nature distinction but sharing Psillos' intuition that epistemic structural realism, when properly construed, collapses to traditional realism, Papineau says:

[3] I have dealt with Psillos' objections to the structure vs. nature distinction in my (2007).

> …since our intellectual access to unobservable entities is always mediated by a structure of theoretical assumptions rather than by direct insight into their nature, Worrall's restriction of belief to structural claims is in fact no restriction at all (1996, p. 12).

All in all, Psillos and Papineau agree that ESR's collapse to traditional scientific realism is effected by the former's inability to place a realisable restriction on what can be known.

ESR cannot collapse to both realism and anti-realism unless of course they are one and the same position, a supposition we are not entertaining here.[4] Oddly this tension seems to have remained undetected by Psillos and Papineau who endorse both collapse accusations. A scrupulous reader might at this point protest that the tension is only feigned since the Newman problem does not strictly speaking threaten to expose ESR as an anti-realist view but instead as an insufficiently realist one – recall that the Newman problem diagnoses ESR with an ability to make assertions about the unobservable world's cardinality. Be that as it may, the tension does not vanish but reappears on a different level. ESR cannot collapse to both an insufficiently realist view and a sufficiently realist one.

The new tension can be dissolved by expressing the two collapse claims as distinct options in a dilemma. This approach in fact follows the tenor of Newman's original critique. Either epistemic structural realists advocate a pure version of their view which collapses to some exceedingly weak form of realism or they advocate an adulterated version which collapses to traditional scientific realism. Those wondering what a pure version of ESR looks like need not look any further than the formulations of ESR given above. As for impure versions of ESR, let's just say for now that they are versions that profess knowledge of unobservables that goes beyond their structural features.

Whether pure ESR collapses to empiricist anti-realism or at least to some exceedingly weak form of realism is not a matter to be trifled with. In my view Russell's version of ESR is immune to the Newman objection. I have argued as much elsewhere (2003; 2004, ch. 4). Let us suppose for the sake of the argument, however, that pure versions of ESR do indeed suffer this ignominious collapse. If this were true, epistemic structural realists would need to endorse an impure version of ESR. Would the mere shift to an adulterated version rob them of the originality of their view? Let us find out!

**4. Adulterated ESR**

Is the ESR dictum 'All we can know is structure' merely a catchy slogan that leaves out important qualifications? If so, do these qualifications conceal impurities that render ESR indistinguishable from traditional scientific realism? I have alluded elsewhere (2004, p. 113) that an impure form of ESR need not be a capitulation to traditional scientific realism. Here I want to take a more sustained look at this issue.

[4] It is not a-priori impossible that realism and anti-realism are ultimately identical positions. Such a line of argument has in fact been signaled by those who wish to dissolve the scientific realism debate. Although there may be something to this approach, my target audience for this paper is those for whom the legitimacy of the scientific realism debate is not at issue.

Those who fancy the Newman problem as a knockdown argument against ESR (in any of its forms) often cite Russell's letter to Newman where he seems to sheepishly admit defeat:

> You make it entirely obvious that my statements to the effect that nothing is known about the physical world except its structure are either false or trivial, and I am somewhat ashamed at not having noticed the point for myself ([1968] 1998, p. 413).

It is utterly reprehensible, however, that these same people ignore what Russell goes on to say in that letter:

> It was quite clear to me, as I read your article, that I had not really intended to say what in fact I did say, that *nothing* is known about the physical world except its structure. I had always assumed spacio-temporal continuity with the world of percepts, that is to say, I had assumed that there might be co-punctuality between percepts and non-percepts, and even that one could pass by a finite number of steps from one event to another compresent with it, from one end of the universe to the other. And co-punctuality I regarded as a relation which might exist among percepts and is itself perceptible.
>
> I have not yet had time to think out how far the admission of co-punctuality alone in addition to structure would protect me from your criticisms, nor yet how far it would weaken the plausibility of my metaphysic. What I did realise was that spacio-temporal continuity of percepts and non-percepts was so axiomatic in my thought that I failed to notice that my statements appeared to deny it. (ibid.) [original emphasis].

Russell reminds Newman that additional elements are required to make ESR stick and points out one of them – the assumption that percepts are spatiotemporally continuous with their causes.[5] This assumption is not opportunistically dreamt up by Russell but plays an integral role in his philosophy (see his 1927, ch. 21). Although an interesting matter in its own right, we will not here judge the assumption's warrantability or indeed its presumed indispensability for ESR. We simply note that Russell took it to be an integral feature of ESR that, by his own admission, seems to introduce certain impurities into the position.

Before we scrutinise this thought, I want to momentarily direct the reader's attention to another erroneous belief propagated in the ESR literature. Consider the following remark from the Routledge Encyclopedia of Philosophy's entry on Russell:

> Russell quickly abandoned [E]SR when Newman showed that any set with the right cardinality could be arranged so as to have the same structure as the world – a result analogous to that claimed in Putnam's model-theoretic argument against realist theories of reference (Demopoulos and Friedman 1989) (1998, p. 400).

Nothing could be further from the truth. Russell continued to highlight the structural nature of knowledge in much of his subsequent work. Take, for example, the following

[5] Russell in fact advocated a more general version of this principle, namely that all events are spatiotemporally continuous. The special case of the principle is established once one takes into account that percepts as well as their unobservables causes are events in his view.

passage from *Human Knowledge*, published twenty years after Russell's letter to Newman:

> Anticipating coming discussions, I shall assume that the physical world, as it is independently of perception, can be known to have a certain structural similarity to the world of our percepts, but cannot be known to have any qualitative similarity ([1948] 2009, p. 138).

The above is one of many passages that demonstrate Russell's continued loyalty to ESR. Several Russellian scholars confirm this view, documenting his reliance on structuralist ideas long after the letter was sent to Newman – one good source is Bradie (1977).

Let us now return to the question whether the spatiotemporality assumption introduces impurities into ESR, regardless of Russell's own thoughts on the matter. For something to count as an impurity it must add to the position's epistemic commitments, i.e. to the claims one is willing to endorse as knowledge. Does the spatiotemporality assumption do that? The answer to this question is rather unclear. The assumption is certainly metaphysical in character for it tells us something about the kind of world we are living in. The question then is whether our endorsement of it entails its addition to our epistemic commitments. On the one hand, it may be argued that it does not add anything to our epistemic commitments for the assumption merely helps frame the parameters of the discussion. According to this view, we *do not strictly speaking know* that the world satisfies the spatiotemporality assumption. We just make use of it to establish a correspondence between the world we perceive and the world we live in.[6] On the other hand, it may be argued that the assumption's centrality in Russell's epistemological edifice decrees its inclusion on our list of epistemic commitments. Suppose the latter is the case. Does the mere introduction of such an impurity bring about the end of ESR? This question is perhaps a bit easier to answer and the answer is 'No'. Some scientific realists openly claim to have cast their epistemic net wider than epistemic structural realists, engulfing not just structure but also various non-structural components (other than spatiotemporal continuity) that the epistemic structural realist explicitly rejects. A traditional scientific realist like Psillos insists that the history of science exhibits continuity not only at the structural but also at the non-structural level and that this lends credence to traditional scientific realism rather than ESR.[7] We return to the question of non-structural components in section five below. Here it suffices to say that if the scientific realist has indeed cast their epistemic net wider than the epistemic structural realist then it is glaringly obvious that there is no question of an impure ESR collapsing to traditional scientific realism.

Is this conclusion limited only to those advocating the Russellian version of ESR? In other words, can the qualifications made by Ramsey-style epistemic structural realists be interpreted as introducing impurities and, if so, do these impurities force a collapse to

[6] To maintain some measure of perceptual veridicality even those who reject ESR must accept some such assumption.

[7] Psillos supports this claim in spite of his pronouncements that a structural specification of the world leaves nothing out. We come back to this issue in section six below.

traditional scientific realism? In Worrall's view (forthcoming) the Ramsey-sentence of a successful scientific theory expresses much more about the unobservable world than assertions about its cardinality. Among the entailments of a Ramsey-sentence, he argues, are several theoretical assertions that no anti-realist would be willing to endorse. How is this possible one may ask, if theoretical predicates are turned into existentially quantified variables? The answer, according to Worrall, is that not all assertions made with a purely observational vocabulary are observational in character. The mark of a real theoretical assertion, he contends, is our inability to directly check its truth value by observation. Since some assertions formulated in a purely observational vocabulary cannot be checked in this way they are, for all intents and purposes, theoretical.[8] On the supposition that Worrall is right, Ramsey-style ESR takes another step into realist territory – the first step being the view's ability to make cardinality assertions about the unobservable world. Moreover, it seems to do so without shedding its pure form, for no bona fide expansion of epistemic commitments has occurred. Worrall's analysis has instead prompted us to take a closer look at what the Ramsey-sentence of a theory entailed all along.

Suppose for the sake of the argument that Worrall's elaboration of the Ramsey-sentence approach introduces impurities into ESR. Does the resulting form of realism collapse to traditional scientific realism? The answer once more seems to be 'No'. The traditional scientific realist underwrites not just the Ramsey-sentence of a successful theory, which is of course entailed by the unRamsified theory itself, but also the interpretations of the unRamsified theory's theoretical terms. The latter is something the Ramsey-style epistemic structural realist vehemently denies we have epistemic access to. For someone like Worrall interpreted theoretical terms are in effect non-structural components. Ramsey-style ESR cannot thus be accused of collapse to traditional scientific realism.

The message of this section is, I hope, plain and clear. Even versions of ESR adulterated with additional epistemic commitments do not suffer a collapse to traditional scientific realism.[9]

**5. Non-Structural Theoretical Components**

It is now time to consider in some detail the additional epistemic commitments scientific realists sanction. One piece of information that I hope surfaced in the course of the preceding section is that there are two kinds of epistemic commitments that adulterate ESR. The first kind consists of epistemic commitments that on their own do not seem to push ESR over the edge and into the territory of traditional scientific realism, e.g. the spatiotemporality assumption. The second kind consists of those epistemic commitments that are sufficient to support ESR's collapse to traditional scientific realism. We called the latter kind 'non-structural components'. This section deals with the prospects of finding non-structural components and thus substantiating the accusation that ESR collapses to traditional scientific realism.

[8] One of his examples is the assertion 'Nothing is older than 6000 years old' in the theoretical dispute between the Darwinists and the Creationists.

[9] This claim holds at least in so far as scientific realists explicitly endorse non-structural knowledge. Those scientific realists who do not endorse this claim are dealt with in section six.

We briefly indicated earlier that at least some scientific realists aver epistemic access to the non-structural components of unobservables. Psillos (1999, ch. 7), for example, asserts that theoretical components that are non-structural systematically survive theory-change. If correct, this assertion would deal a devastating blow to ESR, for it would lend credence to the view that their survival is perhaps due to the essential role they play in the predictive and explanatory success of their respective theories – success being the ultimate sign for a theory's approximate truth.[10] To properly evaluate Psillos' claim we need to comb through the history of science to ascertain: (i) whether non-structural theoretical components survive theory change and, if so, (ii) whether their survival discloses a latching onto the world or is merely an accidental, convenient or conservative feature of the process of constructing a successor theory. Needless to say that question (ii) can be posed about any type of component survival through theory change, including that of structural components.

Psillos does not corroborate his claim with a systematic analysis of the history of science – a tall order for anyone. Instead he focuses on the case that made ESR famous, i.e. the transition from Fresnel's theory of light to Maxwell's theory of electromagnetism. To be exact, he focuses on a handful of assumptions that Fresnel apparently used to derive his laws of optics:

> (a) A *minimal mechanical assumption* that the velocity of the displacement of the molecules of ether is proportional to the amplitude of the light-wave…
> (b) The *principle of conservation of energy* (‘*forces vives*’) during the propagation of light in the two media….
> (c) A *geometrical analysis* of the configuration of the light-rays in the interface of two media... (p. 158) [original emphasis].

In Psillos' view, these three assumptions are 'fundamentally correct' for they purportedly survived theory-change, finding their way into Maxwell's electromagnetic theory. Moreover, they cannot be completely accounted for in structural terms. For this reason they provide some prima facie evidence in favour of traditional scientific realism as opposed to ESR.

There seems to be no good reason to regard (a), (b), and (c) as non-structural theoretical components that have survived through theory change. The first of these, the minimal mechanical assumption, states a mathematical relation between two quantities, viz. the amplitude of the wave and the velocity of the displacement of the ether molecules. Although this mathematical relation survives into the mature version of Maxwell's electromagnetic theory, its ontological import gets reinterpreted with the displacement of the ether molecules becoming a 'displacement' of the electromagnetic field strengths.

[10] Theoretical components may of course survive theory change without playing an essential role in the predictive and explanatory success of their respective theories. Having said this, one expects to find a high degree of correlation between the survival of theoretical components and their integral role in the success of the theories they belong to for the simple reason that scientists generally aim to increase empirical success and eliminate idle wheels.

Hence no non-structural theoretical component survives in this case.[11] What is even more puzzling about Psillos' appeal to (a) is that he eventually acknowledges that it is not really performing a substantive role in the derivation of Fresnel's laws. He thus says that the only assumption required is to "take energy as a function of the square of the amplitude of the light waves" (p. 159). Indeed, Psillos reveals that Fresnel himself had recognised that "no specific assumptions about the trajectories of the ethereal molecules were necessary" (ibid.).[12]

The second assumption lends itself to a similar analysis. Jean Le Rond d'Alembert's account of the *forces vives* – or *vis viva* as it was better known – principle gives us an idea of what scientists at the time had in mind.

> Here is [the forces vives] principle which is contained in the two following laws:
>
> 1. If bodies act one against the other, either by pulling on threads or inelastic rods, by pushing or by impact, as long as in this last case it has perfect elasticity, the sum of the product of the masses multiplied by the square of the speeds will always be a constant quantity.
>
> 2. If the bodies should be animated by whatever forces, the sum of the product of the masses by the squares of the speeds at every moment is equal to the sum of the product of the masses multiplied by the square of the initial speeds. Plus the squares of the speeds that the bodies would have acquired if they had been animated by the same forces and were able to move freely on the line that it has inscribed ([1757] 2006, p. 114).

In other words, the principle asserts that the following quantity is conserved:

$$\sum_i m_i v_i^2$$

where $m_i$ indicate the masses of the bodies and $v_i$ their corresponding velocities. Since the principle states a mathematical relation between masses and velocities, two measurable and hence broadly construed observable quantities, its survival through theory change leaves the epistemic structural realist unperturbed. Today we think of the *force vives* principle as an attempt to formulate the idea that kinetic energy is conserved under elastic collisions.[13] We also have a more general principle of energy conservation, namely the conservation of total energy, which applies to both kinetic and potential energy.

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[11] In my view the wave's amplitude is not a non-structural theoretical component because it is the kind of quantity that can be measured, i.e. it is a broadly construed observable quantity. Its survival is thus no threat to ESR.

[12] Jonathan Bain also makes this point when he says that, what Psillos calls the 'minimal mechanical assumption', "was used solely to express the energy associated with a light-wave as the square of its amplitude with no essential reference to the medium of oscillation. Hence, again, one can argue that the aether was not used in the derivation" (1998, p. 163).

[13] Our understanding of this relation is adjusted by the factor ½.

The third and final assumption can also be dismissed rather easily. No realist supports the view that geometrical analysis represents any aspect of the world. Geometrical analysis is simply a tool that facilitates modelling and calculation. Its survival through scientific revolutions, therefore, has no epistemic significance for the realist, structural or other. Even if it had epistemic significance, I do not see how this would help Psillos' case since geometrical analysis involves nothing but mathematical structures and, as such, would support ESR, not traditional scientific realism.

In sum, Psillos' assumptions do not support the non-structural preservation claim.[14] What survives of the three assumptions appears to be thoroughly structural. Yet, even if we find clear cases of non-structural theoretical component preservation, we must still ask whether such components are essential in the prediction-making and explanatory aspects of theories. If they are not, their preservation will be irrelevant for realist purposes.

Before we bring this section to a close, it is worth mulling over another one of Psillos' objections to ESR that alleges epistemic access to non-structural components. In his own words:

> … it isn't clear why the first-order properties of unobservable entities are unknowable. They are, after all, part and parcel of their causal role. So, if all these entities are individuated and become known via their causal role, there is no reason to think that their first-order properties, though contributing to causal role, are unknowable (2001, p. 17); see also his (1999, p. 156).

> … these *in re* structures are individuated by their nonstructural properties since it's in virtue of these (nonstructural) properties that they have causal unity and are distinguished from other *in re* structures (2006, p. 567).

In other words, how can we claim to know the causal role of entities without knowing their non-structural properties? Following Grover Maxwell, Psillos equates non-structural properties with first-order properties. Maxwell's reason for this identification seems to be Russell's idea that the non-structural properties of phenomena need not resemble the non-structural properties of their external world causes. Yet Maxwell's identification is unwarranted. Non-structural properties need not be restricted to first-order properties in Russell's system. Moreover, Maxwell's idea is certainly not a consequence of his accepting the Ramsey-sentence approach. The Ramsey-sentence existentially quantifies over all theoretical properties without regard whether these are first- or higher-order. It thus does not force its advocates to espouse an epistemic distinction between first-order and higher-order theoretical properties.

Psillos' (and Maxwell's) misconstrual notwithstanding, the question still stands: Can we know the causal role of entities without knowing their non-structural properties? The answer to this question is 'Yes'. ESR does not deny that the non-structural properties of objects play an integral (and perhaps even necessary) causal role. Rather it holds that we

[14] Redhead makes a similar observation when he says: "Psillos presents detailed case studies for the examples of caloric and ether but what the discussion boils down to seems to be that structural aspects of the old theory are preserved in the new theory" (2001, p. 344).

have limited access to these properties, i.e. we can only know them up to isomorphism. Being necessary for a causal role does not equal being epistemically accessible. To illustrate this point consider the following analogy. Suppose you have been mugged but you don't exactly know by whom. Suppose further that unbeknownst to you the assailant mugged you because he was necessarily evil – a non-structural property he possesses. Do you need to know this property to know that you have been mugged? Of course not! Likewise in the case at hand, we need not know the non-structural properties of causes in order to know something about the causes. Indeed, if the epistemic structural realist is right, it is simply not possible to know non-structural properties.

At times Psillos' reasoning comes across as an instance of *argumentum ad consequentiam*. It starts with the premise that epistemic access to the non-structural properties of unobservables guarantees that our knowledge is realist. It then adds the premise that it is desirable for our knowledge to be realist. From this it is concluded that we have epistemic access to the non-structural properties of unobservables. It goes without saying that whether or not we have epistemic access to non-structural properties cannot be decided by what would be enough to save us from collapse to an unwanted form of realism or even anti-realism.

I would like to end this section with a challenge to traditional scientific realists. The challenge is quite simple. Specify one non-structural component that: (i) plays an essential role in the predictive and explanatory success of an abandoned theory, (ii) has survived into that theory's successor theories and (iii) cannot be replaced by a structurally identical analogue. Accomplish that and in one stroke you will render ESR lifeless.

**6. Turning the Tables Around**

Early on in our investigation I asserted that the two collapse claims are best understood in the form of a dilemma: Someone who wants to support ESR can plump for either a pure version that collapses to an exceedingly weak form of realism or an impure version that collapses to traditional realism. Over the course of this investigation, I called into question the second disjunct of this dilemma, arguing that impure versions of ESR do not automatically collapse to traditional realism. I have not called into question the first disjunct because I believe, as most epistemic structural realists do, that it contains a kernel of truth. Those who advocate ESR willingly understand it to be a weak, perhaps even a very weak, form of realism. After all, that was part of the original marketing strategy for the position, straddling the space between traditional scientific realism and empiricist anti-realism, i.e. making assertions that are weaker than those made by the former but stronger than those made by the latter. Telling epistemic structural realists that their view is a weak form of realism is therefore not an objection but an unnecessary reminder.

A more delectable upshot of this whole discussion is that we can now turn the tables on the traditional scientific realist by presenting them with an unpleasant dilemma: Either insist on non-structural knowledge of unobservables but then show up empty-handed (if the above challenge remains unmet, as I believe it will) and hence render your view false

or drop the claim to non-structural knowledge but then experience a collapse to some form of ESR. Put bluntly, submit or perish!

I spent a good deal of energy in sections four and five above trying to convey the idea that the traditional scientific realist opts for the first disjunct of the current dilemma. The truth of the matter is that this has not always been the case. Plenty of scientific realists have over the years expressed views that at the very least bear a striking similarity to ESR. In a seminal article on scientific realism, for example, Ernan McMullin emphasises the motivational importance of the convergence of structural explanations in the history of science. For example, he asserts that "[i]t is, in part at least, because the history of science testifies to a substantial continuity in theoretical structures that we are led to the doctrine of scientific realism at all" (1984, p. 22). Similarly, Howard Stein has this to say: "our science comes closest to comprehending 'the real', not in its account of 'substances' and their kinds, but in its account of the 'Forms' which phenomena 'imitate' (for 'Forms' read 'theoretical structures', for 'imitate', 'are represented by')" (1989, p. 57). Even Psillos, the arch-enemy of the structural realist, can at times be read this way. In the passage quoted earlier where the threat of ESR's collapse to traditional scientific realism looms he states: "to say what an entity *is* is to show *how this entity is structured*" (1999, 156) [original emphasis]. And he adds "[a]n exhaustive specification of this set of properties and relations leaves nothing left out" (ibid.). I am sure the reader will appreciate the irony here as this claim betrays a collapse that is the inverse of what its author originally envisaged.

Psillos will surely protest that by 'structural specification' he does not mean the same thing as the epistemic structural realists. For him this specification involves concrete structures whereas for epistemic structural realists it involves abstract structures. Yet, to demonstrate how a specific entity or system is structured requires nothing more than a specification of its abstract structure. And it is not knowledge of the elusive non-structural components that allows us to assert the claim that 'it is *this* (as opposed to *that*) entity that is so structured' but the context – causal-perceptual in mine and Russell's view – in which it is uttered. Thus even though Coulomb's law of electrostatics and Newton's law of gravity are structurally identical, the context permits a different empirical interpretation of the quantities involved, e.g. we measure mass via instruments like the triple beam balance and charge via instruments like the electrometer.

**7. Correspondence without Reference?**

I would like to end this paper by reflecting on a more radical reading of ESR that is currently in circulation. Let us first go back to the basics of scientific realism. What makes a view realist? Putnam states two conditions, which most realists endorse and which he attributes to Boyd: "(1) Terms in a mature science typically refer. (2) The laws of a theory belonging to a mature science are typically approximately true." (1975, p. 179). For many scientific realists the successful reference of a theory's (observational and theoretical) terms is in fact a necessary condition for that theory's approximate truth. This assumption has landed scientific realists into trouble. Laudan (1981) famously capitalises on this tight relationship between successful reference and approximate truth to argue against realism. To be exact, he argues that since nowadays we consider the central terms

of empirically and explanatorily successful past theories to be non-referential we can no longer claim that their respective theories are approximately true. Recall that realists want to preserve inferences from the empirical and explanatory success of theories to their approximate truth. Laudan's argument throws a spanner in the works.

One realist reaction to Laudan has been to deny the view that reference is a necessary condition for approximate truth. Hardin and Rosenberg (1982) offer a case from the history of biology. They claim that even though there is nothing in Mendel's 1866 theory that corresponds to our concept of a gene, the theory contains some important truths and can therefore be thought of as approximately true (p. 606). This reaction to Laudan is not as radical as it first sounds. Hardin and Rosenberg's defence of scientific realism does not rely solely on the severance of the necessary connection between successful reference and approximate truth. Their approach is multifaceted and includes the deployment of causally-inspired theories of reference. For instance, they offer an alternative explanation of the Mendel case, according to which Mendel's central theoretical terms do in fact refer (in the causal-historical sense) regardless of the incorrect descriptive content associated with them. More generally, Hardin and Rosenberg rule that "referential successes [must] be judged on a case by case basis" (p. 608).[15]

A more radical realist reaction to Laudan's challenge has recently been made by Cruse and Papineau (2002). According to them, the cognitively significant content of a scientific theory, i.e. what the scientific theory is really about, is captured by its Ramsey sentence. Since the Ramsey sentence of a theory turns theoretical predicates into existentially quantified variables, such variables presumably cannot be said to refer to any particular object. Cruse and Papineau take this to mean that "the referential status of theoretical terms is irrelevant" (p. 174). In their view, the question whether successful theoretical term reference and approximate truth are correlated does not even arise. To understand how this view is more radical than that of Hardin and Rosenberg we need only consider that the denial of the necessary link between referential success and approximate truth leaves open the door that the two notions are highly correlated.

In a similar vein, Worrall has in the last few years rejected referential semantics, opting for a controversial interpretation of the Ramsey version of ESR.

> If it is assumed that to be a 'real realist' one must assert that the terms in our current theories refer as part of an acceptance of a correspondence or semantic view of truth as the account of what it means for our theories to have latched on to the real structure of the world, and it is assumed that the realist must develop some sort of weakened version of correspondence as her account of 'approximate correspondence with reality' then [E]SR does not count as 'real realism'… But there is no reason why the way in which a theory mirrors reality should be the usual term-by-term mapping described by traditional semantics. Indeed, as I have remarked several times already, if we are talking about an epistemically accessible notion then it cannot be! [E]SR in fact takes it that the mathematical structure of a theory may globally reflect reality without each of its components necessarily referring to a separate item of that reality (2007, pp. 32-33).

[15] On this picture, the realist must choose on some principled basis which theory of reference to apply, otherwise the whole issue becomes trivialised.

Standard accounts of realism and the approach of Worrall (as well as that of Cruse and Papineau) are in a direct collision course. Are there any good reasons to reject this novel approach? In my view there are two very good reasons to consign this approach to the wastebasket. The first concerns the group's incoherent conception of the Ramsey sentence. Though it is true that the variables in Ramsified theories do not range over particular objects or properties, it is also true that they range over sets of such objects and properties. Thus Cruse, Papineau and Worrall might be warranted to infer that theoretical terms do not refer to singular objects/properties but they are not similarly warranted to infer that no specific reference takes place whatsoever. After all, it seems that we are fully capable of referring to sets of objects and we do so all the time regardless of whether the sets contain observables or unobservables.[16]

The second reason concerns the group's incoherent use of the notion of approximate truth. To the extent that a theory can be approximately true with respect to the unobservable world it is surely telling us something about how the unobservable world is structured. But how can we attribute structure to the unobservable world without saying something about its entities, their properties and relations? Under the traditional conception of the correspondence theory of truth, a scientific theory's truth or approximate truth implies that the theory's terms refer, among other things, to unobservables.[17] Under the new and radical conception, we are asked to imagine that the structure of our theory 'globally reflects' the structure of reality. I understand the gesturing but that is about as much as I understand of this approach. Without an unambiguous semantics that tells us under what conditions the structure of a scientific theory comes out true or false (for non-trivial reasons) I cannot begin to seriously consider this approach as an alternative conception of realism, let alone as the correct conception of realism.[18] In sum, it seems pretty nigh impossible how there can be realism without referential semantics.[19]

Those who were enthralled by Hardin and Rosenberg's more modest approach will no doubt find the second objection to Cruse, Papineau and Worrall's rebellious view unconvincing. After all, does not the denial of the necessary connection between referential success and approximate truth also not entail the possibility that we can have approximately true statements whose terms do not succeed in referring? In my view, it does not! First note that Hardin and Rosenberg target specifically the central terms of scientific theories. Otherwise put, Hardin and Rosenberg in effect deny that the reference of central theoretical terms is a necessary condition for that theory's approximate truth. Whether the theory's approximate truth can be assessed without the reference of at least

[16] Along similar lines, Grover Maxwell (1970) has argued that the theoretical variables of a Ramsey sentence refer indirectly to unobservable objects. They do so implicitly via their logical relations to unRamsified (i.e. observational) terms that refer directly to observable objects (pp. 182-3).

[17] To establish that approximate truth is a sufficient condition for referential success is of course to establish that referential success is a necessary condition for approximate truth.

[18] Even then, the advocate of this approach must still explain why it is that referential semantics is good for observational terms but bad otherwise.

[19] Unless of course some ontic structural realists are right and there are no objects to refer to. Still, one may uphold the view that theoretical terms must denote some sort of proxies for the objects, e.g. place-holders.

some of the theory's terms is left unanswered in their article. On the basis of their examples, there is in fact good reason to believe that we cannot have approximate truth without referential semantics. Take Mendel's case again. His theory may not contain anything corresponding to our concept of a gene but, in so far as it is true, it contains terms that we take to refer even today, namely hereditary factors that play the role of the unobservable causes of phenotypic traits.

**8. Conclusion**

To sum things up, you cannot claim to be a victorious traditional scientific realist if: (a) you insist on a type of knowledge that you cannot substantiate or (b) if you aspire towards a purely structural description of the world. We structural realists ought to encourage our realist brothers and sisters to come out of the closet. Wear your structural realist colours with pride!

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