Newman's Objection is Dead; Long Live Newman's Objection!

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Abstract

There are two ways of reading Newman's objection to Russell's structuralism. One assumes that according to Russell, our knowledge of a theory about the external world is captured by an existential generalization on all non-logical symbols of the theory. Under this reading, our knowledge amounts to a cardinality claim. Another reading assumes that our knowledge singles out a structure in Russell's (and Newman's) sense: a model theoretic structure that is determined up to isomorphism. Under this reading, our knowledge is far from trivial, for it amounts to knowledge of the structure of the relations between objects, but not their identity. Newman's objection is then but an expression of structural realism. Since therefore the content of theories is described by classes of structures closed under isomorphism, the most natural description of a theory in structural realism is syntactic.

Keywords: structural realism, ontic structural realism, epistemic structural realism, Ramsey sentence, Newman objection, abstraction, isomorphism, adverbial theory of perception, model theoretic argument

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1 Introduction

Structural realism (SR) is often considered tantalizingly close to being a perfect example of philosophical synthesis: As Putnam (1975b, 73) demands, it doesn't render the success of the sciences a miracle. At the same time, it heeds the result of the pessimistic meta-induction developed by Laudan (1981) and does not commit to the existence of the objects named in successful theories. SR is importantly related or even central to the philosophies of, among others, Kant (Ladyman 2014, §3.1), Duhem, Poincaré, Carnap, and Russell (Gower 2000) and it has been suggested as the true ontology of modern physics (Ladyman 2014, §4.1). Its beauty and clearness is at present mainly obscured by two clouds. First, it is not quite clear what is meant by 'structure', and thus not quite clear what SR is being realist about. Second, to the extent that the meaning of 'structure' *is* clear, it seems that claims about structure can only entail trivial claims about the world. The latter cloud has cast a shadow over SR at least since Newman (1928) argued that Russell's causal theory of perception (Russell 1927) is trivial.

In the following, I want to disperse both clouds at once by identifying two ways of reading Newman's objection. The first makes the popular assumption that a theory's structure is given by an existential generalization on non-logical symbols of the theory. I will argue that existential generalizations cannot possibly describe the structure of a theory, however, and that in that sense, Newman's objection is dead (§3). The second reading is based on the notion of isomorphism. It fits better with Russell's and Newman's notion of structure and entails that Newman's objection is no trivialization of SR, but a compact description of its very point (§4). Thus Newman's objection is very much alive as the cornerstone of a precise, non-trivial account of SR.

The second reading of Newman's objection leads to a description of the structures of SR by classes of model theoretic structures, and these classes have compact syntactic descriptions. Then, surprisingly, one disambiguation of Russell's theory of perception leads to a SR that is identical to the semantics of scientific theories according to the logical empiricists (§5).

While I provide a provably non-trivial formulation of SR and thus a defense of the position, I will provide no further positive justification. I will but muse a little upon the implications of the results of this paper for such a justification and also upon the relation of SR to the inscrutability of reference and the adverbial theory of perception (§6).

2 Prologue: How We Got Here

SR can be seen as one of the two straightforward intermediate positions between realism and antirealism about scientific theories.[1] The realist position may have its strongest intuitive support in the no-miracles argument, described by Putnam (1975a, 73) as follows:

> The positive argument for realism is that it is the only philosophy that doesn't make the success of science a miracle. That terms in mature scientific theories typically refer [. . .], that the theories accepted in a mature science are typically approximately true [. . .]—these statements are viewed by the scientific realist not as necessary truths but as part of the only scientific explanation of the success of science, and hence as part of any adequate scientific description of science and its relations to its objects.

Putnam's argument relies on an inference to the best explanation, specifically an inference to the only explanation. Whether this is a valid inference scheme is controversial, but, as Laudan (1981, 24) points out, this is not the only problem with Putnam's argument:

> Are genuinely referential theories (i. e., theories whose central terms genuinely refer) invariably or even generally successful at the empirical level [. . .]? There is ample evidence that they are not. The chemical atomic theory in the 18th century was so remarkably unsuccessful that most chemists abandoned it[.]

So it seems that the central premise of Putnam's inference to the best explanation is false, as there is no explanation to be had from the reference of scientific terms. For if many theories with referring terms are unsuccessful, there is no reason to expect yet another theory with referring terms to be successful, and hence this assumption cannot provide an explanation of the success of such a theory. But

1. The complementary intermediate position would be entity realism (Hacking 1983, 29).

even leaving the question of the explanatory power of genuine reference and the validity of inferences to the best explanation aside, the conclusion of Putnam's argument, that the terms of successful theories are likely to refer, is false (Laudan 1981, 27):

> What we are confronted by in 19th-century aether theories, then, is a wide variety of once successful theories, whose central explanatory concept Putnam singles out as a prime example of a non-referring one[.]

One of these aether theories, Fresnel's theory of light, is so successful that its equations for the relative intensity of reflected and refracted light beams are still being used. But as Worrall (1989, 117) argues, following Poincaré, not everything about Fresnel's theory should be considered false:

> There *was* an important element of continuity in the shift from Fresnel to Maxwell—and this was much more than a simple question of carrying over the successful *empirical* content into the new theory. At the same time it was rather less than a carrying over of the full theoretical content or full theoretical mechanisms (even in "approximate" form). [...] There was continuity or accumulation in the shift, but the continuity is one of *form* or *structure*, not of content.

This observation leads Worrall to what has been called *epistemic structural realism* (ESR). "This holds that it is reasonable to believe that our successful theories are (approximately) *structurally correct* (and also that this is the strongest epistemic claim about them that it is reasonable to make)" (Worrall 2007, 125).

Worrall assumes that the success of theories is their empirical success (cf. Worrall 2007, 126), and that as far as the empirical implications are concerned, we can know that successful theories are literally true, that is, both regarding their structure and the referents of their terms. Of the non-empirical, theoretical implications, however, we can only ever know that they are structurally correct, whence this position may be called *theoretical* ESR. *Complete* ESR is accordingly the claim that of a theory as a whole, both with respect to their empirical and theoretical implications, we can only know that it is structurally correct.

A natural question to ask about ESR is *why* we can only know the structure of (the theoretical part of) the world. One possible answer is given by ontic structural realism (OSR): We cannot know the objects that instantiate the structure of the world because there are no such objects. This position is suggested by Ladyman (1998). Since there are two versions of ESR, there are also two different versions of OSR, each providing an explanation for one of the two version of ESR.

Given these two distinctions between theoretical and complete SR and between ontic and epistemic SR, there are four kinds of SR:

Definition 1. *Complete OSR* (*complete ESR*) is the claim that all there is to (all we can know about) the world is its structure*.

Definition 2. *Theoretical* OSR (*theoretical* ESR) is the claim that all there is to (all we can know about) the world is its structure* and observable objects with their observational properties.

However, for each of these four kinds of SR, these are definitions *obscurum per obscurius* unless the notion of 'structure*' is given—hence the asterisk, which I will drop until §4. Demopoulos and Friedman (1985, 624) provide such a notion after identifying an early account of theoretical ESR, Russell's *Analysis of Matter* (1927):

> [O]n Russell's "structuralism" or "structural realism", of "percepts" we know both their quality and structure [. . .], while of external events we know only their structure.

Percepts are observations, and thus are described by the empirical implications of theories. The external events, or "stimuli", in Russell's terminology, are what I have been calling theoretical. Demopoulos and Friedman (1985, 622) then argue for a specific formal account of Russell's theoretical ESR: "Russell in 1927 is prepared to accept the Ramsey-sentence [. . .] as the proper statement of our scientific knowledge."

If our scientific knowledge described in a scientific theory is given by a single sentence ϑ of predicate logic, the theory's Ramsey sentence $\mathsf{R}_{\mathscr{O}}(\vartheta)$ is obtained by generalizing on all theoretical terms that occur in ϑ. More precisely, assume that the vocabulary $\mathscr{V}$ of the language in which ϑ is formulated is bipartitioned into an observational vocabulary $\mathscr{O}$ and a theoretical vocabulary $\mathscr{T}$. Since ϑ is a single sentence, it contains at most finitely many observation terms $O_1,\dots,O_m \in \mathscr{O}$ and finitely many theoretical terms $T_1,T_2,\dots,T_n \in \mathscr{T}$. In a slight abuse of notation, ϑ can then be written as $\vartheta(O_1,\dots,O_m,T_1,\dots,T_n)$.[2] The existential generalization on all theoretical terms then leads to the *Ramsey sentence* of ϑ,

$$\mathsf{R}_{\mathscr{O}}(\vartheta) = \exists X_1 \dots X_n \vartheta(O_1,\dots,O_m,X_1,\dots,X_n)\,, \tag{1}$$

which contains only observational terms (whence the subscript '$\mathscr{O}$'). For the Ramsey sentence to be an explication of theoretical SR, one has to assume that the extensions of all terms in ϑ are fixed in this world by what one could call an 'intended structure'. The existential generalization then replaces the theoretical terms by variables, which have no fixed interpretation.

With theoretical ESR explicated by the Ramsey sentence, Demopoulos and Friedman (1985) further assume that the world is given by some model theoretic structure and that ϑ is formulated in first order logic. Then, they point out, theoretical SR is trivial in that the most it can state about the theoretical world is the cardinality of its domain, nothing more. For if all observational implications

2. More precisely: One can introduce a higher order $m+n$-place formula ϑ^* such that $\vartheta^*(O_1,\dots,O_m,T_1,\dots,T_m) \mathrel{=\!\!|\!\!\models} \vartheta$. The identification of ϑ and ϑ^* will not lead to any confusion in the following.

of ϑ are true in a structure, then $\mathsf{R}_{\mathcal{O}}(\vartheta)$ is true in an elementary extension of that structure as well (Demopoulos 2011, 186).[3] Demopoulos and Friedman (1985, 635) conclude:

> Newman's problem can be put this way. [The Ramsey sentence procedure] threatens to turn the *empirical* claims of science into mere *mathematical* truths. More precisely, if our theory is consistent, and if all its purely observational consequences are true, then the truth of the Ramsey-sentence *follows* as a theorem of set theory or second-order logic, provided our initial domain has the right cardinality[.]

In short, theoretical ESR does not describe the theoretical world at all.

There have been a number of suggested responses to this trivialization result, none of which save the Ramsey sentence approach (Ainsworth 2009). They either accept the trivialization result, abandon the Ramsey sentence approach, or modify the semantics of the existential generalization in higher order logic. Since changes to the semantics also change the logic, the latter kind of responses implicitly also abandon the Ramsey sentence approach: They describe theoretical ESR with the help of something that looks like the Ramsey sentence of higher order logic but which is in fact some formula in a different (and typically woefully under-specified) logic, and thus has different content.

3 Newman's Objection is Dead

Newman's objection applies both to theoretical ESR and theoretical OSR: In the case of ESR, its conclusion states that all we can know about the theoretical world is the number of not further distinguishable objects it contains. Its conclusion is even more dire for OSR, because it states that all there is in the (theoretical) world is a specific number of not further distinguished objects. Since this conclusion entails that there is specifically no structure to the set of objects, it is the exact opposite of OSR, which is intended to express that there is structure but there are no objects. If sound, Newman's objection is thus devastating for SR. I will argue that Newman's objection as developed by Demopoulos and Friedman (1985) is not sound. Specifically, I want to show that the explication of 'structure' by existential generalization is inadequate.

3.1 Ramsey Sentences

For Worrall, maybe the main proponent of this approach, the Ramsey sentence expresses the claim that there are properties that stand in a specific logical relation to each other, and he takes this claim to have a non-trivial ontological import. For "if we follow Quine's dictum that 'to be is to be quantified over' [. . .] then the Ramsey sentence [. . .] clearly asserts that the 'natural kinds'

3. See Shoenfield (1967, §5, ex. 9.a). Tuomela (1973, theorem III.3) gives a proof.

$[X_1, \ldots, X_n]$ exist in reality just as realists want to say" (Worrall 2007, 152). And this "is just a second-order mirroring of Quine 1961 on ontological commitment" (Worrall 2011, 170). But the Ramsey sentence can assert no such thing if Demopoulos and Friedman (1985) are correct in their criticism of the Ramsey sentence. That they are correct becomes clear when considering deductions that are sanctioned in higher order logic (independently of any semantic assumptions). Here is an example of a Ramsey sentence whose existence claim for alleged natural kinds disappears:

$$\mathsf{R}_{\mathcal{O}}\big(\forall x\big[(O_1x \rightarrow T_1x) \wedge (T_1x \rightarrow O_2x)\big]\big) \tag{2}$$

$$\dashv\vdash \exists X_1 \forall x[(O_1x \rightarrow X_1x) \wedge (X_1x \rightarrow O_2x) \tag{3}$$

$$\dashv\vdash \forall x[O_1x \rightarrow O_2x] \tag{4}$$

$$\dashv\vdash \mathsf{R}_{\mathcal{O}}\big(\forall x[O_1x \rightarrow O_2x]\big)\,. \tag{5}$$

Stated informally: The Ramsey sentence of a theory that states that T_1 mediates between O_1 and O_2 is equivalent to the statement that everything that is O_1 is also O_2. For instance, the claim that everyone who is hugged becomes happy and everyone who becomes happy starts smiling turns into the simple statement that everyone who is hugged starts smiling (assuming that 'becoming happy' is the sole theoretical term). Thus the Ramsey sentence does not describe the structural relation of the theoretical term to the observation terms; the Ramsey sentence simply eliminates the theoretical term. Conversely, a simple cardinality condition suffices for introducing non-trivially related variables for theoretical terms into the Ramsey sentence of a theory that itself contains no theoretical terms at all:

$$\mathsf{R}_{\mathcal{O}}\big(\forall x\big[(O_1x \rightarrow O_2x)\big] \wedge \exists^{\geq 6}x(\neg O_1x \wedge O_2x)\big) \tag{6}$$

$$\vdash \exists X_1 \ldots X_7 \forall x\big[(O_1x \rightarrow X_1x) \wedge (X_1x \rightarrow X_2x) \wedge \cdots \wedge (X_7x \rightarrow O_2x) \wedge \bigwedge_{i<j} X_i \neq X_j\big] \tag{7}$$

$$\vdash \mathsf{R}_{\mathcal{O}}\big(\forall x\big[(O_1x \rightarrow T_1x) \wedge (T_1x \rightarrow T_2x) \wedge \cdots \wedge (T_7x \rightarrow O_2x) \wedge \bigwedge_{i<j} T_i \neq T_j\big]\big)\,. \tag{8}$$

Thus Newman's objection (in Demopoulos and Friedman's guise) can just be rephrased: If the Ramsey sentence were to express that the natural kinds exist in reality, then the existence of the natural kinds would follow from the truth of the theory's empirical claims and a cardinality constraint.

So much for the syntactic argument. What exactly is going wrong with the Ramsey sentence approach to theoretical SR becomes obvious when considering the semantics of the Ramsey sentence. It is a basic theorem of model theory that the truth value of a sentence depends only on the domain and the interpretation of the terms that appear in the sentence. If this theorem did not hold, an interpretation of a sentence would require an explicit assignment of extensions to all terms in the vocabulary of the language. Instead, for a sentence ϑ containing the terms $O_1, \ldots, O_m, T_1, \ldots, T_n$, the structure

$$\mathfrak{A} = \langle \mathrm{dom}(\mathfrak{A}), O_1^{\mathfrak{A}}, \ldots, O_m^{\mathfrak{A}}, T_1^{\mathfrak{A}}, \ldots, T_n^{\mathfrak{A}} \rangle \tag{9}$$

already determines ϑ's truth value, even if $\mathcal{O}$ and $\mathcal{T}$ contain more terms than $O_1, \ldots, O_m$ and $T_1, \ldots, T_n$, respectively. Call a structure that interprets all and only the terms that occur in a sentence a *minimal structure* of that sentence, and a minimal structure in which the sentence is true a *minimal model* of that sentence. It is clear that a sentence ϑ only restricts the interpretation of the terms in its minimal models, for expanding a minimal model of ϑ so that it interprets terms not in ϑ will result again in a model of ϑ. Now consider ϑ's Ramsey sentence $\mathsf{R}_{\mathcal{O}}(\vartheta)$. Its minimal structures and models have the form

$$\mathfrak{A} = \langle \mathrm{dom}(\mathfrak{A}), O_1^{\mathfrak{A}}, \ldots, O_m^{\mathfrak{A}} \rangle \ , \tag{10}$$

which makes it obvious that $\mathsf{R}_{\mathcal{O}}(\vartheta)$ restricts only the interpretation of observation terms. This is more precisely expressed by

Claim 1. *For every $\mathcal{V}$-structure $\mathfrak{A}$, $\mathfrak{A} \vDash \mathsf{R}_{\mathcal{O}}(\vartheta)$ if and only if $\mathfrak{A}|_{\mathcal{O}} \vDash \mathsf{R}_{\mathcal{O}}(\vartheta)$.*

Proof. Since $\mathsf{R}_{\mathcal{O}}(\vartheta)$ contains only $\mathcal{O}$-terms, its truth-value in $\mathfrak{A}$ is only determined by the domain and the interpretation of the $\mathcal{O}$-terms, that is, $\mathfrak{A}|_{\mathcal{O}}$. □

$\mathfrak{A}|_{\mathcal{O}}$ here is the reduct of $\mathfrak{A}$: The structure that results from $\mathfrak{A}$ by restricting its interpretation to the terms in $\mathcal{O}$. Thus the Ramsey sentence cannot possibly determine the structure of the referents of theoretical terms, because it determines nothing about them. This follows directly from claim 1:

Corollary 2. *For any two $\mathcal{V}$-structures $\mathfrak{A}$ and $\mathfrak{B}$ with $\mathfrak{A}|_{\mathcal{O}} = \mathfrak{B}|_{\mathcal{O}}$, $\mathfrak{A} \vDash \mathsf{R}_{\mathcal{O}}(\vartheta)$ if and only if $\mathfrak{B} \vDash \mathsf{R}_{\mathcal{O}}(\vartheta)$*

Proof. $\mathfrak{A} \vDash \mathsf{R}_{\mathcal{O}}(\vartheta)$ if and only if $\mathfrak{A}|_{\mathcal{O}} \vDash \mathsf{R}_{\mathcal{O}}(\vartheta)$ if and only if $\mathfrak{B}|_{\mathcal{O}} \vDash \mathsf{R}_{\mathcal{O}}(\vartheta)$ if and only if $\mathfrak{B} \vDash \mathsf{R}_{\mathcal{O}}(\vartheta)$. □

It is for this reason that the use of the Ramsey sentence for the description of theoretical SR is misguided in its very core assumptions, and that Newman's objection as reported by Demopoulos and Friedman (1985) is no threat to ESR. Or, for that matter, to OSR.

3.2 Newman Sentences

Besides not being a threat to theoretical SR, Newman's objection as reported by Demopoulos and Friedman (1985) is also not the objection that Newman (1928) actually levels against Russell's theory of perception. Newman (1928, 144) proceeds from two passages of Russell's. In the first, Russell (1927, 254) concludes what we can infer from perceptions:

> Thus it would seem that wherever we infer from perceptions it is only structure that we can validly infer; and structure is what can be expressed by mathematical logic.

In the second passage, Russell (1927, 270–71) applies this conclusion to our knowledge of the stimuli—the external, physical world—as inferred from our perceptions:

> The only legitimate attitude about the physical world seems to be one of complete agnosticism as regards all but its mathematical properties.

Newman (1928, 142) summarizes Russell's position as follows:

> Briefly: of the external world we know its structure and nothing more.

In this version of SR, there is then no mention of any relation between the observational objects (the percepts) and the theoretical objects (the stimuli). Rather, of the theoretical objects only their structure is known. Thus this position of Russell's amounts to *complete* ESR. Note, however, that we do know observable objects directly. It is just that they do not play a role in our knowledge of the unobservable objects beyond determining the structure of the unobservable objects.

At the core of Newman's objection to Russell's ESR (140) is his observation that

> no important information about the aggregate A, except its cardinal number, is contained in the statement that *there exists* a system of relations, with A as field, whose structure is an assigned one.

Thus Newman is considering a description of the stimuli given by a sentence $\tau(T_1,\dots,T_n)$ containing only theoretical terms and treats as its structure the sentence $\exists X_1 \dots X_n \tau(X_1,\dots,X_n)$, which contains no terms at all. In the contemporary discussion, it is usually assumed that one is dealing with a theory $\vartheta(O_1,\dots,O_m,T_1,\dots,T_n)$ that contains both theoretical and observation terms (see Worrall 2007, 3(c)), but one nonetheless existentially generalizes on all terms in ϑ. This leads to what could be called ϑ's *Newman sentence*[4]

$$\mathsf{R}_{\varnothing}(\vartheta) = \exists X_1 \dots X_{m+n} \vartheta(X_1,\dots,X_{m+n}) \tag{11}$$

Newman's objection applies independently from any assumptions about which terms occur in the theory, as long as one generalizes on all of them. In model theoretic terminology, Newman assumes that there is some domain A, and points out that the truth of the Newman sentence at best determines its cardinality. This near-triviality of the Newman sentence follows immediately from claim 1:

4. I thank F. A. Muller for this moniker.

Corollary 3. *For any two $\mathscr{V}$-structures* $\mathfrak{A}$ *and* $\mathfrak{B}$ *with* $\mathrm{dom}(\mathfrak{A}) = \mathrm{dom}(\mathfrak{B})$, $\mathfrak{A} \vDash \mathsf{R}_{\varnothing}(\vartheta)$ *if and only if* $\mathfrak{B} \vDash \mathsf{R}_{\varnothing}(\vartheta)$

Proof. In claim 1, choose $\mathscr{O} = \varnothing$. The corollary follows because $\mathfrak{A}|_{\varnothing} = \mathrm{dom}(\mathfrak{A}) = \mathrm{dom}(\mathfrak{B}) = \mathfrak{B}|_{\varnothing}$. □

Thus the Newman sentence is true if and only if the domain of the theory has the right cardinality. But this result is as unsurprising as the analogous result about the Ramsey sentence: Since the minimal model of a Newman sentence is a structure with a domain but no interpretation of any terms, the Newman sentence does not determine anything but the cardinality of its domain. Together with the domain of the theory, the theory's Newman sentence thus expresses not SR, but rather its complement entity realism: The entities described in the theory are real, but their properties are unknown or do not exist. On its own, the Newman sentence cannot even determine the objects in the domain, since any structure with a domain of the right cardinality is a model of the Newman sentence:

Corollary 4. *For any two $\mathscr{V}$-structures* $\mathfrak{A}$ *and* $\mathfrak{B}$ *with* $|\mathrm{dom}(\mathfrak{A})| = |\mathrm{dom}(\mathfrak{B})|$, $\mathfrak{A} \vDash \mathsf{R}_{\varnothing}(\vartheta)$ *if and only if* $\mathfrak{B} \vDash \mathsf{R}_{\varnothing}(\vartheta)$.

Proof. If $|\mathrm{dom}(\mathfrak{A})| = |\mathrm{dom}(\mathfrak{B})|$, there is a bijection from $\mathrm{dom}(\mathfrak{A})$ to $\mathrm{dom}(\mathfrak{B})$. By the bijection lemma 7 below, there is then a structure $\mathfrak{C}$ with $\mathrm{dom}(\mathfrak{C}) = \mathrm{dom}(\mathfrak{B})$ that is isomorphic to $\mathfrak{A}$. Therefore $\mathfrak{A} \vDash \mathsf{R}_{\varnothing}(\vartheta)$ if and only if $\mathfrak{C} \vDash \mathsf{R}_{\varnothing}(\vartheta)$ according to the isomorphism theorem. Since $\mathrm{dom}(\mathfrak{C}) = \mathrm{dom}(\mathfrak{B})$, $\mathfrak{C} \vDash \mathsf{R}_{\varnothing}(\vartheta)$ if and only if $\mathfrak{B} \vDash \mathsf{R}_{\varnothing}(\vartheta)$ by corollary 3. □

The conclusion of Newman's original objection is that the Newman sentence of a theory is true if the domain of the theory has the right cardinality. But as corollary 3 shows, the Newman sentence does not contain any structural information. Therefore the only moral that one can draw from Newman's objection is the following: If one does not have any structural information, then one has no information. This is obviously compatible with the view that structural information is the only information that counts. The conclusion of the contemporary version of Newman's objection is that the Ramsey sentence of a theory is true if the domain of the theory has the right cardinality and the theory's observable implications are true. But as corollary 1 shows, the Newman sentence does not contain any theoretical structural information. Therefore the only moral that one can draw from this version of Newman's objection is the following: If one does not have any theoretical structural information, then one has no theoretical information. This is obviously compatible with the view that theoretical structural information is the only theoretical information that counts.

4 Long Live Newman's Objection!

When based on existential generalization, Newman's objection applies to a position that is not SR (neither theoretical nor complete). Thus Newman's objection to SR fails. Put in a slightly different way, Newman's objection is a symptom of the incorrect explication of SR by existential generalization. The challenge is then to find a different explication of SR that does not fall prey to an analogous objection. As already intimated, Russell and Newman's original exchange already contains a different, much more plausible explication, and I will show in the following that this explication is not trivial and thus cannot fall prey to an analogue of Newman's objection. The explication of SR is based on model theoretic notions, but does not identify the notion of structure* needed for SR with the model theoretic notion of structure. Hence in the following I will use the term 'abstract structure' and suggest that it should play the role of structure* in SR.

4.1 Isomorphic Structures

Newman's objection is based on passages in which Russell claims that, as Newman (1928, 142) puts it, "of the external world we know its structure and nothing more". But even Newman's own paraphrase of Russell's position does not ascribe to Russell solely the claim that *there exists* a system of relations on the external stimuli. Rather, it ascribes to Russell the claim that the stimuli have some specific structure*. In the early days of logic, the two descriptions may have seemed synonymous (cf. Hodges 2001, 2), but in current model theory, their distinction makes all the difference. That the structure* claim leads to something very different from existential generalizations is clear when considering Newman's exposition of Russell's concept of structure* (Newman 1928, 139):

> For our purpose it is not necessary to define the single *word* "structure" but only what is meant by the *statement* that "two systems of relations have the same structure". Let a set, A, of objects be given, and a relation R which holds between certain subsets of A. Let B be a second set of objects, also provided with a relation S which holds between certain subsets of its members. The two systems are said to have the *same structure* if a (1, 1) correlation can be set up between the members of A and those of B such that if two members of A have the relation R their correlates have the relation S, and *vice versa*.

Newman here describes two structures (in the modern sense of the term) that are isomorphic (cf. Russell 1927, 249–50; 1919, 60–61). I will say that each structure is a representative of an equivalence class of structures that have the same *abstract structure*.

Definition 3 (Russell, Newman)**.** Two structures have the same *abstract structure* if and only if they are isomorphic. An abstract structure is described by an equivalence class of isomorphic structures.[5]

And since the notion of structure* that Russell and Newman assume is abstract structure, their accounts of theoretical and complete structural realism should rely on abstract structures as well. Indeed, I suggest to consider the structures* in all kinds of SR abstract structures:

Definition 4. A structure* is an abstract structure.

The following then holds:

Claim 5. *According to theoretical ESR, our knowledge of the world given by structure* $\mathfrak{A}$ *and our knowledge of the world given by structure* $\mathfrak{B}$ *is the same if and only if* $\mathfrak{A}$ *and* $\mathfrak{B}$ *are isomorphic.*

Proof. From definitions 1, 3, and 4. □

Isomorphism is a clearly semantic notion, and has nothing to do with an existential generalization on non-logical symbols. This already indicates that the trivialization argument that works against the Ramsey and the Newman sentences will not work against SR when 'structure*' is explicated by abstract structure. The explication of complete ESR by way of the Newman sentence is trivial in that it can at the most distinguish between structures with domains of different cardinalities. The explication of complete ESR by way of isomorphism is not trivial in this sense, simply because two structures being isomorphic is a much stronger condition than their domains having the same cardinality. Specifically, the following holds:

Claim 6. *There are structures* $\mathfrak{A}$*,* $\mathfrak{B}$ *with* $\mathrm{dom}(\mathfrak{A}) = \mathrm{dom}(\mathfrak{B})$ *(and hence* $|\mathrm{dom}(\mathfrak{A})| = |\mathrm{dom}(\mathfrak{B})|$*) that are not isomorphic.*

Proof. $\langle\{1,2\},\{1\}\rangle$ and $\langle\{1,2\},\{1\},\{2\}\rangle$ are not isomorphic. □

What, then, does Newman's objection amount to? He phrases his criticism as follows (Newman 1928, 144):

> Any collection of things can be organised so as to have the structure W, provided there are the right number of them. Hence the doctrine that only structure is known involves the doctrine that nothing can be known that is not logically deducible from the mere fact of existence, except ("theoretically") the number of constituting objects.

5. The (proper) class of isomorphic structures is at the most as problematic as the class of models of a set of sentences. Linnebo and Pettigrew (2014, 274) discuss the subtleties involved. I thank Sten Lindström for inquiring about this.

The second sentence applies to complete SR explicated by the Newman sentence, but it does not follow from the first, which applies to complete SR explicated by isomorphism. This first sentences follows from

Claim 7 (Bijection lemma)**.** *For any structure $\mathfrak{A}$ and any set B with a bijection $b : \mathrm{dom}(\mathfrak{A}) \longrightarrow B$, there is a structure $\mathfrak{B}$ with $\mathrm{dom}(\mathfrak{B}) = B$ such that b is an isomorphism from $\mathfrak{A}$ to $\mathfrak{B}$.*

Proof. Let $\mathfrak{A} = \langle A, R_1, \ldots, R_r, f_1, \ldots f_s, c_1, \ldots, c_t \rangle$. For each function f_i define $b(f_i) = b \circ f_i \circ b^{-1}$. For each k-ary relation R_i and any k-tuple $\langle x_1, \ldots x_k \rangle$ of objects of the appropriate types on A, define $b(R_i)\big(b(x_1), \ldots, b(x_k)\big) \Leftrightarrow R_i(x_1, \ldots, x_k)$. It follows by induction on the order of types that $b : A \longrightarrow B$ is an isomorphism from $\mathfrak{A}$ to $\mathfrak{B} = \langle B, b(R_1), \ldots, b(R_r), b(f_1), \ldots, b(f_s), b(c_1), \ldots, b(c_t) \rangle$. □

Newman's objection follows as

Corollary 8. *For any structure $\mathfrak{A}$ and any set B with the same cardinality as* $\mathrm{dom}(\mathfrak{A})$*, there is a structure $\mathfrak{B}$ with $\mathrm{dom}(\mathfrak{B}) = B$ that has the same abstract structure as $\mathfrak{A}$.*

Proof. If $\mathrm{dom}(\mathfrak{A})$ and B have the same cardinality, there is a bijection from $\mathrm{dom}(\mathfrak{A})$ to B. The corollary follows from the bijection lemma and definition 3. □

Since abstract structures are not trivial, Newman's objection does not trivialize complete SR. It rather expresses that the identity of an abstract structure is independent of the objects occurring in any of its representatives. This is expressed by another, trivial corollary of the bijection lemma:

Corollary 9. *Any object of a structure's domain* $\mathrm{dom}(\mathfrak{A})$ *can be switched with any other object (not necessarily in* $\mathrm{dom}(\mathfrak{A})$*) without changing the abstract structure that $\mathfrak{A}$ represents.*

In other words, if only the abstract structure is known, then no specific object is known. Thus if, as complete ESR claims, we can only know the abstract structure of the world, then we can know something non-trivial about the world but not what objects reside in it. Thus Newman's observation is no objection to complete ESR, but rather a paraphrase of its very point.

It might seem that while abstract structures can express complete ESR, they are unable to express complete OSR. For even thought an abstract structure does not determine a specific set of objects, it still seems to express that there *is* some set of objects. But this impression stems from an interpretation of equivalence classes that is not necessary and not even in line with how equivalence classes are often interpreted in the sciences. There can be different reasons why the objects in abstract structures are not relevant: because we do not have access to them or because they do not exist. In the sciences, an equivalence class is very often interpreted in the second sense. Temperature measurements are identified if they only differ in their scale, because the numerical value does not correspond to anything in the world. In Newtonian mechanics, descriptions that differ only in their origin, orientation, or constant relative motion are taken to describe the same system because there are neither an absolute origin nor absolute orientations nor absolute velocities. Thus in the sciences equivalence classes are often used to avoid commitment to those referents that do not occur in all representatives of the equivalence class. In this sense, one can coherently state that some system is completely described by an equivalence class, for the assumption is that the system only contains whatever is shared by all representatives of the equivalence class. This is, for instance, how manifolds are described in differential geometry (and thus in general relativity): A manifold is a specific topology together with a specific equivalence class of atlases (sets of local coordinate systems on the topology); new concepts can only be defined relative to the whole equivalence class of atlases, not relative to a specific representative of the equivalence class (a specific atlas). The reason is that the features that are not shared between all atlases are not considered real, but only artifacts of the specific choice of atlas.

Thus the difference between ESR and OSR lies in the different interpretation of abstract structures, but not in a different formalization. Therefore the following holds:

Claim 10. *According to complete OSR, two structures $\mathfrak{A}$ and $\mathfrak{B}$ represent the same description of the world if and only $\mathfrak{A}$ and $\mathfrak{B}$ are isomorphic.*

Proof. From definitions 1, 3, and 4. □

'To represent' here has its technical meaning 'being a representative of', since two structures represent the same equivalence class if and only if they are isomorphic.

4.2 Isomorphic Structures with Identical Observable Objects

Expressing theoretical SR in terms of abstract structures requires a decision on how observable objects are to be delineated. In one major approach that fits with the model theoretic notion of 'structure', to know the observational objects $\mathbf{O}$ in a structure $\mathfrak{A}$ is to know the substructure $\mathfrak{A}|\mathbf{O}$ of $\mathfrak{A}$ that has the domain $\mathbf{O}$ (e. g., van Fraassen 1980, 64). Understood literally, this approach has the awkward implication that knowing an observational object entails knowing all its properties, including highly theoretical ones like its chemical and subatomic composition (Lutz 2014a, 3206). It also does not express theoretical SR as given by definition 2, which only demands that the *observational* properties of observable objects are known. An appropriate generalization of the substructure approach is given by

Definition 5. The observable objects $\mathbf{O}$ and their observable properties (named by $\mathscr{O}$) in a structure $\mathfrak{A}$ are described by the structure's relativized reduct $\mathfrak{A}|\mathbf{O}_{\mathscr{O}}$.

$\mathfrak{A}|\mathbf{O}_{\mathscr{O}}$ is the substructure (with domain $\mathbf{O}$) of the reduct of $\mathfrak{A}$ to the observation terms $\mathscr{O}$: $\mathfrak{A}|\mathbf{O}_{\mathscr{O}} = \mathfrak{A}|_{\mathscr{O}}|\mathbf{O}$.[6] This definition leads to

Claim 11. *According to theoretical* ESR, *for observable objects* $\mathbf{O}$ *and observational terms* $\mathscr{O}$, *our knowledge of the world given by structure* $\mathfrak{A}$ *and our knowledge of the world given by structure* $\mathfrak{B}$ *is the same if and only if* $\mathfrak{A}$ *and* $\mathfrak{B}$ *are isomorphic and* $\mathfrak{A}|\mathbf{O}_{\mathscr{O}} = \mathfrak{B}|\mathbf{O}_{\mathscr{O}}$.

Proof. From definitions 1, 3, 4, and 5. □

For theoretical OSR, the definition leads to

Claim 12. *According to theoretical* OSR, *for observable objects* $\mathbf{O}$ *and observational terms* $\mathscr{O}$, *two structures* $\mathfrak{A}$ *and* $\mathfrak{B}$ *represent the same description of the world if and only* $\mathfrak{A}$ *and* $\mathfrak{B}$ *are isomorphic and* $\mathfrak{A}|\mathbf{O}_{\mathscr{O}} = \mathfrak{B}|\mathbf{O}_{\mathscr{O}}$.

Proof. From definitions 1, 3, 4, and 5. □

According to claims 11 and 12, theoretical OSR and theoretical ESR are not trivial, that is, do not include all structures. The reason is that abstract structures already allow for the exclusion of some structures and the demand for the identity of the relativized reducts allows for the exclusion of even more. Claims 11 and 12 therefore show that theoretical SR (definition 2) is non-trivially explicated by the definitions of abstract structures (definition 3) and observable objects (definition 5).

5 The Content of Scientific Theories

With a non-trivial concept of 'abstract structure' at hand, it is now possible to provide an account of the content of scientific theories such that structural correctness of theories "is the strongest epistemic claim about them that it is reasonable to make" (Worrall 2007, 125).

5.1 A Semantic Approach

In the semantic view, "[t]o present a theory is to specify a family of structures, its *models*" (van Fraassen 1980, 64). The models of a theory are for example specified using what is often called a 'Suppes predicate', a set theoretic description of the conditions that the models of the theory satisfy. With the full content of a theory presented by specifying its class of models,[7] the structural content of that theory is then presented by specifying the class of abstract structures (the theory's *abstract models*) that its models represent. In other words, to discard the non-structural content of a theory, it suffices to close the class of its models under

6. A substructure is a special case of a relativized reduct with $\mathscr{T} = \varnothing$.
7. The distinction between family and class is irrelevant for my, and van Fraassen's, discussion.

isomorphism. Thus if $\mathbf{T}$ is the class of the theory's models, then its structural content is given by the class

$$\left\{\mathfrak{A}: \text{ For some } \mathfrak{B} \in \mathbf{T}, \mathfrak{A} \text{ is isomorphic to } \mathfrak{B}\right\}. \tag{12}$$

As a shorthand, one can say that the content of a theory according to complete SR is given as the class of its abstract models.

In theoretical SR it is assumed that theories have not *only* structural content, since observable objects and their observational properties can also be known. To arrive at the content of a scientific theory according to theoretical SR, then, the class $\mathbf{T}$ of models of the theory only has to be expanded to include those structures that are isomorphic to models of the theory while retaining their observable objects and observational properties. More precisely, if $\mathbf{T}$ is the class of the theory's models, then its content according to theoretical SR is given by the class

$$\left\{\mathfrak{A}: \text{ For some } \mathfrak{B} \in \mathbf{T}, \mathfrak{A} \text{ is isomorphic to } \mathfrak{B} \text{ and } \mathfrak{A}|\mathbf{O}_{\mathscr{O}} = \mathfrak{B}|\mathbf{O}_{\mathscr{O}}\right\}. \tag{13}$$

5.2 A Syntactic Approach

Ladyman (1998, §3.1) lays the failure of the Ramsey sentence as an explication of 'structure*' to the feet of syntactic approaches, which describe scientific theories by sets of interpreted sentences in predicate logic. French and Saatsi (2006, 552) even imply that structuralism is incompatible with any syntactic approach when they reject the use of predicate logic in semantic approaches because "the deployment of linguistic formulations [would] strike to the structuralist heart of the semantic approach". Thus it may look like a fool's errand to try expressing the structural content of theories within a syntactic approach. However, it has been shown in some detail that structures (and hence abstract structures) require a language of predicate logic to be expressive enough for the formalization of scientific theories (Halvorson 2012, 2013, 2016; Glymour 2013; Lutz 2014b, forthcoming; Krause and Arenhart 2017).[8] Thus if the use of the language of predicate logic were to preclude syntactic approaches from expressing abstract structures, it would just as much preclude semantic approaches. But, in the contrapositive, since semantic approaches can express abstract structures, so can syntactic ones.

Indeed, the content of a theory according to complete SR can be expressed particularly straightforwardly in a syntactic approach due to a feature of standard predicate logic described briefly above and more eloquently by Beth (1963, 479–80, footnote removed):

> [N]atural language can be used in two different ways, which I should like to denote as *strict usage* and *amplified usage*, respectively. In strict usage of natural language, we refer to a definite model of the theory

8. Incidentally, the higher order formula ϑ^* described in footnote 2 is the syntactic analogue of the Suppes predicate for ϑ.

> to which our statements belong; it is this model which has been called the *intuitive model*. In amplified usage of natural language—and in all usage of formalised languages—on the other hand, we refer to any model of this theory.

What Beth calls the 'intuitive model' I have called the 'intended structure' above. So Beth's point is that formal languages, and thus specifically any language of predicate logic, are usually assumed to be used amplified, that is, without an intended structure. Without an intended structure, a set of sentences of predicate logic can determine its models at the most up to isomorphism, that is, at the most up to abstract structures; thus without an intended structure, predicate logic can express only the structural content of a theory. Assuming now that the set Θ of sentences can express the class $\mathbf{T}$ of models of a theory up to isomorphism, the theory's structural content is given by the class

$$\left\{\mathfrak{A} : \mathfrak{A} \models \Theta\right\}. \tag{14}$$

The following holds trivially:

Claim 13. *If the set Θ of sentences expresses the class $\mathbf{T}$ of models of a theory up to isomorphism, then the content of the theory according to complete* SR *in semantic approaches* (12) *is identical to that in syntactic approaches* (14).

Thus the content of Θ consists of abstract structures and corollary 9 applies. Incidentally, Putnam (1989, 353) relies on corollary 9 as well (albeit restricted to exchanges of objects in the same domain) when discussing his famous model theoretic argument against realism (Putnam 1977) and concluding:[9]

> [I]f there is such a thing as 'an ideal theory' [I], then that theory can never implicitly define its own intended reference relation. In fact, there are always many different reference relations that make I true, if I is a consistent theory which postulates the existence of more than one object.

The preceding discussion has thus established that SR embraces Putnam's argument and provides a means of retaining some realistic interpretation of theories in spite of it.

One may object to all of this with van Fraassen (1989, 211, n. 31), who notes that first order predicate logic cannot describe all classes of structures up to isomorphism, so that the syntactic description of abstract structures would reduce the expressiveness of SR. This objection fails, however, because nothing in my defense of the explication of 'structure*' by 'abstract structure' assumes a restriction to first order logic.[10] Indeed, it is very plausible that if a scientific theory can

9. It should be noted that Winnie (1967) and Przełęcki (1969, 24–31; 1974, 405) already made the very same point.

10. Demopoulos and Friedman's criticism of the Ramsey sentence approach assumes that the theory is given in first order logic, but my criticism does not.

be described by a class of structures, that class of structures can also be described by sets of sentences of higher order predicate logic (Lutz 2014b, §2).

The content of a theory according to theoretical SR is fixed beyond isomorphism, which requires, in Beth's terminology, a strict language for predicate logic. And as Beth (1963, 481) puts it: "It would be quite possible to introduce a special formalised language for strict usage in addition to the various formalised languages already in existence." He adds in a footnote: "It is, of course, possible to resort to other devices to obtain the same practical effect". A specialized formal language could, for instance, identify strictly interpreted terms with a dot. This allows expressing the content of a theory Θ according to structural SR as $\Theta(\dot{O}_1,\dots,\dot{O}_m,T_1,\dots,T_n)$, where the terms $O_1,\dots,O_m$ have a strict interpretation and the terms $T_1,\dots,T_n$ have an amplified one. This approach achieves what the use of the Ramsey sentence was meant to achieve: The interpretation of the observational terms is fixed while for the theoretical terms only the structural relations are retained. But this approach fixes the interpretation of observation terms even for unobservable objects, and this is incompatible with epistemic SR, which restricts the fixed interpretation to observable objects. To achieve this restriction, one needs to resort to other devices, namely intended structures and relativized reducts.

The domains of intended structures $\mathbf{I}$ according to ESR contain only observable objects, and they interpret only observational terms $\mathscr{O}$. Assuming again that the set Θ of sentences expresses the class $\mathbf{T}$ of models of a theory up to isomorphism, the theory's content is then given by those models of Θ that respect the intended structures. More precisely, the theory's content according to ESR is given by the class

$$\left\{\mathfrak{A} : \mathfrak{A} \vDash \Theta \text{ and } \mathfrak{A}|\mathbf{O}_{\mathscr{O}} \in \mathbf{I}\right\} . \tag{15}$$

In a semantic approach, the class $\mathbf{I}$ of intended structures is uniquely determined by the class of models of the theory: $\mathbf{I} = \left\{\mathfrak{J} : \mathfrak{J} = \mathfrak{A}|\mathbf{O}_{\mathscr{O}} \text{ for some } \mathfrak{A} \in \mathbf{T}\right\}$. The following holds:

Claim 14. *If the set Θ of sentences expresses the class $\mathbf{T}$ of models of a theory up to isomorphism and $\mathbf{I} = \left\{\mathfrak{J} : \mathfrak{J} = \mathfrak{A}|\mathbf{O}_{\mathscr{O}} \text{ for some } \mathfrak{A} \in \mathbf{T}\right\}$, then the content of the theory according to theoretical SR in semantic approaches* (13) *is identical to that in syntactic approaches* (15).

Proof. Assume that $\mathfrak{C} \in \left\{\mathfrak{A} : \text{ For some } \mathfrak{B} \in \mathbf{T}, \mathfrak{A} \text{ is isomorphic to } \mathfrak{B} \text{ and } \mathfrak{A}|\mathbf{O}_{\mathscr{O}} = \mathfrak{B}|\mathbf{O}_{\mathscr{O}}\right\}$. This holds iff $\mathfrak{C} \vDash \Theta$ and $\mathfrak{A}|\mathbf{O}_{\mathscr{O}} = \mathfrak{C}|\mathbf{O}_{\mathscr{O}}$ for some $\mathfrak{A} \in \mathbf{T}$, which holds iff $\mathfrak{C} \vDash \Theta$ and $\mathfrak{C}|\mathbf{O}_{\mathscr{O}} \in \mathbf{I}$ and thus iff $\mathfrak{C} \in \left\{\mathfrak{A} : \mathfrak{A} \vDash \Theta \text{ and } \mathfrak{A}|\mathbf{O}_{\mathscr{O}} \in \mathbf{I}\right\}$. □

Incidentally, the content (15) of the theory according to theoretical SR is the same as one developed by Marian Przełęcki (1969, ch. 6; 1973, 287) for the semantics of theories according to the received view on scientific theories of the logical empiricists.

6 Ruminations on Structural Realism

The bijection lemma at the core of Newman's objection and SR is so general that the connection between SR and the semantics of logical empiricism is far from the only one. For instance, the bijection lemma is also at the core of one of Quine's arguments for the inscrutability of reference (Quine 1981, 19). Davidson (1979, 9), like Putnam, restricts his discussion of the inscrutability of reference to permutations rather than bijections. Winnie (1967), relying on unrestricted bijections, anticipates Putnam's model theoretic argument against realism. Since these arguments rely on the bijection lemma, however, they can only be used to criticize realism, not SR. Rather, like Newman's objection, they express the irrelevance of objects in scientific theories.

Importantly, the central role of the bijection lemma in Quine's and Davidson's arguments implies that Quine's and Davidson's accounts of language can also be used for SR, and specifically for complete SR, since they do not allow for any fixed reference whatsoever. So there is no particular need to worry, for instance, about complete SR being unrelated to the world, seeing that Quine's and Davidson's accounts of language seem to allow for substantial statements about the world. Russell (1919, 61), after presenting what is essentially corollary 9, puts the matter as follows when discussing the relation between worlds with identical abstract structure:

> In short, every proposition having a communicable significance must be true of both worlds or of neither: the only difference must lie in just that essence of individuality which always eludes words and baffles description, but which, for that very reason, is irrelevant to science.

However, complete SR makes no distinction between the observable and the unobservable world, which may worry empiricists. In theoretical SR, there is no such worry: The extensions of observational terms are fixed for observable objects, and the relations between the extensions of the theoretical terms are only determined up to isomorphism (unless the extensions contain observable objects). In complete SR, on the other hand, the relations between the extensions of all terms are determined only up to isomorphism. To retain the assumption of complete SR, any distinction between observational and theoretical terms therefore must not lead to a distinction between isomorphic structures and thus must not distinguish specific extensions.

Since observational and theoretical terms cannot be distinguished by way of extensions, it may be that the distinction can only be made on the level of the properties that the terms name. This would mean that there are some properties to which we have direct access through our perception, and some properties to which we have access only through their relations to each other and to the properties to which we have perceptual access. This requires an account of perception that does not rely on the existence of objects, an account like the adverbial theory of perception.[11]

In the adverbial theory of perception, "whenever a sensory quality appears to be instantiated then it is instantiated [and] we should think of these qualities as modifications of the experience itself" (Crane and French 2017, §3.2.1). A standard example is that rather than thinking of perceiving a red and square object, one should think of perceiving redly and squarely. (If one is less purist about the proper phrasing, one may also think of perceiving in a red and square manner (cf. Tye 1975, 138). I will often be less purist in the following.) The experience being modified is, of course, that of some observer, but as is typical in the discussion in the philosophy of science, I will abstract from any specific observer. I will also ignore many subtleties of (the different versions of) the adverbial theory; what is important here is only that there are adverbial theories that are compatible with the description of the world in abstract structures. Indeed, the approach of the adverbial theory can for my purposes also be applied to, for instance, measurement results: Just as one can perceive brownly, one can measure "3°C-ly" or, somewhat more gracefully, in a 3°C manner: Just as the sensory quality modifies the experience, so the measured value modifies the measurement. An empiricist complete SR thus can rely on the adverbial theory of perception (possibly extended to an adverbial theory of measurement or the like) for observational terms while continuing to rely on Davidson's semantics for theoretical terms.

But it is not only that the adverbial theory of perception provides a coherent way for complete SR being empiricist. Complete SR also provides a coherent way of responding to some of the criticisms of the adverbial theory of perception. For many of the criticisms allege that some description of perceptions or another cannot be expressed within the conceptual apparatus of the adverbial theory. But, as Russell pointed out, "every proposition having a communicable significance" can be expressed in abstract structures alone. This is exemplified very clearly in the discussion of the many-properties problem (Jackson 1975, 129). According to this criticism of the adverbial theory, "we must be able to distinguish the statements: 'I have a red and a square after-image', and 'I have a red, square after-image'", where the adverbial theory "does not appear to be able to do this" (130). Jackson comes to this conclusion by in effect assuming that the adverbial theory simply assigns a class of perceived properties to each moment of perception. But if the adverbial theory allows assigning an abstract structure to each moment of perception, the many-properties problem disappears: When I have a red and a square after-image, this can be described by the abstract structure represented by '$\langle\{1,2\},\{1\},\{2\}\rangle$' (assuming the second element of the tuple stands for 'red' and the third stands for 'square'), and when I have a red, square after-image, this can be described by the abstract structure represented by '$\langle\{1\},\{1\},\{1\}\rangle$'.

11. The most prominent competitors of the adverbial theory of perception assume direct perceptual access to objects: Both the naive realist theory and the intentionalist theory assume direct access to physical phenomena, and the sense datum theory assumes direct access to sense data (see Crane and French 2017, §3).

Sellars (1975, 151) makes this very point when he suggests that one can phrase the distinction as one between 'sensing in an of-a-red-object manner and in an of-a-square-object manner' and 'sensing in an of-a-red-and-square-object manner'. This description is actually very close to the way abstract structures are described by way of equivalence classes: Objects are used as dummy variables to relate the different properties in complex ways, but commitment to the objects' existence is denied—in Sellars' case by the adverbial construction, in the case of abstract structures by using equivalence classes of isomorphic structures.

With theoretical SR being empiricist by design and complete SR allowing for an empiricist version, the realism debate comes again into view: Abstract structures provide a means of describing a non-trivial SR, but being non-trivial is not the same as being true. Indeed, with a precise account of SR at hand, it is clear that the SR debate might have the same structure as the realism debate: While realists must defend the existence of theoretical entities and their theoretical properties, structural realists must defend the existence of theoretical properties. They could, for instance, try to establish that without the existence of the theoretical properties postulated in our best theories, the theories' success would be a miracle. Conversely, structural anti-realists could find examples of empirically unsuccessful theories that postulate properties which we now consider to exist, and examples of empirically successful theories that postulate properties which we now do not consider to exist.

7 Conclusion

Even though the debate about SR may become as protracted as the debate about realism, the definition of the different versions of SR in terms of abstract structures can be progress: The resulting SR is not trivial, and Newman's objection provides a pithy reformulation of its central idea. And in spite of the failure of the definition of SR in terms of Ramsey sentences, SR can be expressed very naturally and compactly in a syntactic way. Indeed, ESR finds its natural expression in the semantics of theories given by the logical empiricists. Furthermore, the central role of the bijection lemma in SR and a number of other philosophical positions highlights the possibilities for combining SR with, for instance, Davidson's semantics. And combining SR with the adverbial theory of perception not only provides responses to some popular criticisms of the adverbial theory, but also allows for a completely structural but still empiricist description of the world. This still does not make SR a perfect example of a philosophical synthesis, but it's not too bad either.

A Epilogue: Where Things Went Awry

The Ramsey sentence explication of SR is implausible, as I hope to have made clear. Newman may be considered one source of this unfortunate explication.

But Demopoulos and Friedman (1985, 622) provide another source:

> As Grover Maxwell emphasized, it is possible to extract from [Russell's *Analysis of Matter*] a theory of theories that anticipates in several respects the Ramsey-sentence reconstruction of physical theories articulated by Carnap and others many decades later.

In one of the two papers they refer to, Maxwell (1970, 185) discusses model theory as follows:

> Consider for example the function
>
> $$\forall x \forall y[(Sx \wedge Sy) \rightarrow (Rxy \rightarrow \neg Ryx)] \tag{f}$$
>
> where 'S' and 'R' are free predicate variables. If 'S' is replaced by a predicate ['M' and] 'R' by ['O' such that] a true proposition is obtained[, then] the ordered set (M, O), satisfies (f) and, consequently, is a model of (f).

Note that Maxwell assumes that variables are interpreted by the structure (cf. Mates 1972, 59–60), not some variable assignment or similar.[12] Thus a minimal model for (f) has the form $\langle \mathrm{dom}(\mathfrak{A}), S^{\mathfrak{A}}, R^{\mathfrak{A}} \rangle$. Maxwell (1970, 185) then defines a "mixed function" as containing both free (higher order) variables ψ, φ and non-logical constants C, D ("descriptive terms") and defines a "common model" as "a model of a mixed function in which the descriptive terms retain their original meaning". With this terminology, Maxwell (1970, 186–187, my notation) states:

> To assert that
>
> $$\forall x\big(\psi x \wedge \varphi x \rightarrow \exists y C y\big) \tag{i}$$
>
> has at least one common model is equivalent to asserting the proposition
>
> $$\exists \psi \exists \varphi \forall x\big(\psi x \wedge \varphi x \rightarrow \exists y C y\big)\,. \tag{j}$$
>
> As is well known, (j) is the Ramsey sentence of the little 'theory'
>
> $$\forall x\big(Ax \wedge Dx \rightarrow \exists y C y\big)\,. \tag{k}$$

Maxwell (1970, 188) then suggests that the Ramsey sentence "may be taken as an explication of the claim of Russell and others that our knowledge of the theoretical is limited to its purely structural characteristics".

For Maxwell, the step from (k) to (i) corresponds almost exactly to the move from a single intended model of a structure in which all terms are uniquely interpreted to set of structures according to (15) if one assumes that an object is

12. He also does not distinguish between constants in the object language and their extensions, which will become important in a bit.

observable if and only if it is in the extension of an observational term. For C retains its intended interpretation, whereas the intended interpretation of A and D is replaced by any interpretation in which (k) remains true.[13] Thus for Maxwell, (i) has minimal model $\langle \mathrm{dom}(\mathfrak{A}), \psi^{\mathfrak{A}}, \varphi^{\mathfrak{A}}, C^{\mathfrak{A}} \rangle$. The equivalence (for Maxwell) of asserting a common model for (i) and asserting (j) becomes plausible when considering the second paper referred to by Demopoulos and Friedman. Here, Maxwell (1968, 153) argues that

> the only aspects of the nonmental world of which we can have any knowledge or any conception are purely structural (or, in other words, purely formal).

As an example, Maxwell (1968, 154) describes a formal property **F**

> such that any system having the property consists of some set of entities and some relation which is asymmetric and transitive within the set. In other words: A system, U, has the formal property, **F** $=_{\mathrm{def}}$ $\exists S \exists R \big\{ \big(U = \langle S, R \rangle \big)$ and for any x, y, and z in S $\big[(Rxy \rightarrow \neg Ryx)$ and $(Rxy \wedge Ryz \rightarrow Rxz) \big] \big\}$.[14]

This suggests that Maxwell uses existential quantification in the metalanguage of model theory interchangeably with existential quantification in the objection language, which justifies the move from (i) to (j). But of course, what Maxwell is giving here is not the Newman sentence of the theory '$\forall xyz \big[(Rxy \rightarrow \neg Ryx) \wedge (Rxy \wedge Ryz \rightarrow Rxz) \big]$' in our current understanding, but rather a description of a structure up to isomorphism. Thus, while in Maxwell's understanding it makes sense to speak of the Ramsey sentence as expressing the theoretical structure of a theory, in our current formalism it does not.

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13. This holds only almost because contrary to Przełęcki's formalism, Maxwell's formalism allows a renaming of the theoretical terms.

14. The original also contains a superfluous opening curly bracket before the opening square bracket.

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