Brit. J. Phil. Sci. **57** (2006), 561–585

Ramseyfication and Theoretical Content

Joseph Melia and Juha Saatsi

ABSTRACT

Model theoretic considerations purportedly show that a certain version of structural realism, one which articulates the nvtion of structure via Ramsey sentences, is in fact trivially true. In this paper we argue that the structural realist is by no means forced to Ramseyfy in the manner assumed in the formal proof. However, the structural realist's reprise is short-lived. For, as we show, there are related versions of the model theoretic argument which cannot be so easily blocked by the structural realist. We examine various ways in which the structural realist may respond, and conclude that the best way of blocking the model theoretic argument involves formulating his Ramseyfied theories using intensional operators.

1 Introduction

According to Scientific Realists, the empirical success of mature scientific theories gives us good reason to believe what these theories say about the unobservable aspect of the world. After all, if the theoretical content of mature scientific theories were not at least approximately true, then their success would be a miracle. Sceptics counter that we have good reason to doubt the veracity of the theoretical content of our scientific theories, for the history of science gives us abundant examples of successful scientific theories whose unobservable content was later proved to be false. The

doi:10.1093/bjps/axl020

Advance Access published on August 12, 2006

history, say the sceptics, shows it is no miracle at all for empirically successful theories to be wrong about the unobservable world. *Structural Realists* want a middle way. They accept that the history of science undermines the scientific realist's claim to know about the unobservable world but maintain that a certain kind of theoretical content is in fact preserved across successful theories. Roughly speaking, the structural realist allows that the history of science presents problems for our knowledge of the *nature* of the theoretical world, but he claims that it does not undermine our knowledge of the *structure* of the theoretical world. Since structural content is preserved across successful theories, our knowledge of this structural content is not subject to the sceptics' arguments. Thus, the way becomes open for a modest version of realism.

The notion of structure needs clarification. It has been proposed that the way to do this is through *Ramsey sentences*.[1] The intuitive idea is that, instead of using interpreted predicates to say something about the nature of the unobservable world, we replace such predicates with variables and existentially generalise to reach a theory which says only that unobservable objects instantiate *some* property—we know not what—that satisfies such-and-such a description.[2] The rough outlines of this approach run as follows: let θ be a successful scientific theory (regimented in logical notation) containing predicates for both observables and unobservables, a paradigm example of the kind of theory scientific realists think we are warranted in believing. Let $R(\theta)$ (the *Ramseyfication* of θ) be the result of replacing some of the predicates for unobservables in θ by second order variables, and then placing a string of second order existential quantifiers at the start of the resultant formula, one quantifier for each free variable. By construction, $R(\theta)$ has the same content as θ for the observable part of the world, but what it says about the unobservable part of the world is weaker than what θ says. Since $R(\theta)$ is weaker than θ the possibility arises that, even if θ is false, $R(\theta)$ may yet still be true. Though the history of science may have shown that there have been many

[1] In recent work, Worrall and Zahar ([2001]), following Maxwell ([1970]), have endorsed this way of formalising the notion of structure. This relies on construing scientific theories as axiomatic systems. For other ways of developing the idea see Ladyman ([1998]), French and Ladyman ([2003]), French and Saatsi ([forthcoming]). In this paper, we remain neutral as to whether Ramsey sentences are indeed the best way of developing structural realism. Our main aim is to show merely that Ramseyfying structural realists have ways of dealing with the Newman argument and its descendants.

[2] It is an interesting question whether this really captures what we intuitively mean when we talk of structure. In this paper we set this issue aside, however, and take as starting point the fact that there is a live debate about potential use of Ramseyfication specifically in the context of structural realism. This debate is interesting in its own right, independently of terminological issues regarding the notion of structure or the structure versus nature distinction. We acknowledge that, as far as terms go, the latter can be drawn differently; what really matters is whether or not the distinction proposed is potentially fruitful vis-à-vis the realist agenda.

successful but false θs, it does not immediately follow that there have been many successful but false $R(\theta)$s.[3]

There are those who say that this Ramsey sentence approach cannot work. For, it is claimed, certain model theoretic constructions show that Ramsey sentences say virtually nothing about the theoretical world. For these results show that if: (i) $R(\theta)$ is empirically adequate and (ii) $R(\theta)$ is not wrong about the number of theoretical entities, then $R(\theta)$ is true. But this makes structural realism a *massive* retreat from the original realist position. If our structural knowledge of the theoretical world amounts merely to knowledge about the cardinality of theoretical entities, then this position is scarcely a version of realism. Moreover, this theoretical content is so weak it is hard to see how there could be a plausible no-miracles argument here: few interesting scientific propositions are going to be explained by appealing to the cardinality of the theoretical domain!

In this paper we shall examine some of these model theoretic trivialisation arguments and look at some ways in which the structural realist may respond. We begin in Section 1 with a recent version of the model theoretic argument. We show that the formal appearances of this argument hide delicate philosophical assumptions which the structural realist is not obviously required to accept. In particular, the following three assumptions are made: (a) the structural realist must eliminate all predicates that apply to unobservables; (b) quantification over properties is correctly formalised by a model theory which treats the domain of the second order quantifiers as *full*; (c) the scientific theories to be Ramseyfied are formulated in an extensional logical framework.

In Section 2, we discuss assumption (a) and argue that there is no convincing reason to suppose that the structural realist should accept it. However, we go on to show in Section 3 that, even when assumption (a) is rejected, there are model theoretic arguments that show that Ramseyfied theories can come true far too easily. In Section 4, we argue that if the structural theorist restricts the domain of the second order quantifiers, assumption (b) is false, and we examine various restrictions the structural realist could try to impose. Unfortunately, we find that none of the plausible or natural restrictions are entirely satisfactory. Finally, in Section 5, we examine ways of going beyond the second order formalism in which Ramseyfication is usually regimented. We argue that, by appealing to intensional *relations* between properties,

[3] False simpliciter, that is. It would obviously be too optimistic to hope that Ramseyfication by itself would typically yield fully true theories. An idealised theory Ramseyfied is still an idealised theory, of course, and a slightly off-the-mark numerical value of some constant of nature is not (miraculously) corrected by Ramseyfication. A notion of approximate truth is still required by the realist to take care of all this.

the structural realist has a satisfactory way of blocking the various trivialisation results.

2 The model theoretic arguments

The earliest model theoretic argument showing that Ramseyfied theories are trivial is due to Newman.[4] Newman showed that if *all* the non-logical predicates of a theory θ are Ramseyfied away, then $R(\theta)$ is true if θ has a model whose domain has the same cardinality as the intended domain. The basic idea of the proof is as follows: let θ be $\theta(R_1 \ldots R_n)$, where the R_i are the non-logical predicates of the theory. Let S be the intended domain of our scientific theory θ. Suppose that θ has a model $\mathbf{M} = \langle D, R_1 \ldots R_n \rangle$, where the R_i are the interpretations $\mathbf{M}$ assigns to the predicates R_i and the domain D is of the same cardinality as S. Such a model exists by hypothesis. Let **f** be a 1-1 and onto function from D to S. Then $\mathbf{M^*} = \langle S, \mathbf{f}R_1 \ldots \mathbf{f}R_n \rangle$ is isomorphic to $\mathbf{M}$. Since isomorphic models make the same sentences true, $\theta(R_1 \ldots R_n)$ is true in $\mathbf{M^*}$. By the model theoretic clauses for second order existential quantification, $\exists X \exists Y \ldots \exists Z \theta(X, Y, \ldots, Z)$ is true in S. But since S just is the intended domain, it follows that $\exists X \exists Y \ldots \exists Z \theta(X, Y, \ldots, Z)$ is true *simpliciter*.[5]

Philosophically, this proof seems to show that $R(\theta)$ is too easily true. For it shows that the truth of $R(\theta)$ is compatible with there being no concrete entities at all, or with them having any properties one likes, or with them bearing whatever relations one likes to each other. In other words, no matter what the physical world is like, $R(\theta)$ will still be true. This in turn implies that $R(\theta)$ has no physical content.

Of course, this version of Newman's argument has no force at all against structural realism. No structural realist advocates Ramseyfying away *all* of the predicates of a theory. The reason is that structural realists have no problems with the scientific theory's *observational* content: they accept that planets have mass and that snow is white. If the structural realist were to Ramseyfy the observational predicates of θ, he would be left with a theory that had less observational content than θ. However, many believe that Newman's argument can be adapted so that it does have force against the structural realist. Consider an $R(\theta)$ where only *some* of the predicates of θ are eliminated in favour of second order variables and existential quantifiers. Since some predicates in $R(\theta)$ are preserved, $R(\theta)$ is *not* trivially true. Indeed, if the predicates that are preserved are observational ones, as the structural realist allows,

[4] What follows is actually a reconstruction of Newman's informal triviality accusation against Russell's structuralism in The Analysis of Matter ([1927]). The latter was not originally spelled out in terms of Ramseyfication. See Newman ([1928]).

[5] Later, we will question whether the model theoretic clauses for such second order quantification are correct.

then $R(\theta)$ will have genuine empirical content. But (so the argument goes) empirical content aside, $R(\theta)$ still says precious little about the *theoretical* part of the world. For it can be shown that if (i) θ makes no false predictions and (ii) θ says nothing false about the size of the theoretical domain, then $R(\theta)$ is true. This is bad news; structural realism was supposed to be a modest retreat from realism, not a full-scale withdrawal. If the most that $R(\theta)$ can do is put cardinality constraints upon the size of the theoretical domain then $R(\theta)$ is far too weak even to be a theory of *structure*. The result casts doubt upon the whole Ramsey sentence approach towards structural realism.

Let us now look at the details of this model theoretic argument. Ketland ([2004]) contains the most explicit and thorough formulation of the Newman argument aimed against structural realism, and we broadly follow his presentation. We begin by noting the following two details of Ketland's logical framework.

(a) The first order variables of θ and $R(\theta)$ are divided into *two* sorts; variables of the first sort are thought of as ranging over observable objects, variables of the second sort are thought of as ranging over unobservable entities. The predicates of the theory are divided into *three* sorts: O(bservational)-predicates, whose extension is drawn entirely from the observational domain, T(heoretical)-predicates, whose extension is drawn entirely from the unobservable domain, and M(ixed)-predicates, whose extension is drawn from both the observational and the unobservable domain.

(b) With this two sorted framework in place, models **M** for θ are then treated as 4-tuples of the following form: $((D_1, D_2), O_i, M_i, T_i)$. D_1 is the domain over which the variables of the first sort range and can be thought of as the observable entities of the model; D_2 is the domain over which the variables of the second sort range and can be thought of as the unobservable entities of the model. O_i is a sequence of subsets of $D_1{}^n$. These are the extensions of the O-predicates of θ. Sometimes, where an O-predicate of θ is assigned the extension O_i by **M**, we shall indicate this predicate by the symbol O_i and indicate its presence in θ by writing $\theta(O_i)$. Similarly, M_i and T_i are sequences of $(D_1 \cup D_2)^n$ and $D_2{}^n$, respectively—the extensions that **M** assigns the predicates of the language of θ.[6] In the model theoretic clauses, $\exists X\varphi X$ is true in **M** precisely when

[6] We might include an extra place in our 4-tuple for the domain of the second order variables. However, since the second order variables of the theory range over all the n-relations of $(D_1 \cup D_2)$ this set is fixed by $(D_1 \cup D_2)$ itself. Accordingly, technically, there is no need to give the set explicitly in the model. But this technical assumption hides a philosophical one—that the second order quantifiers range over all the properties and relations in the model. We shall later question this.

there is a subset of the $(D_1 \cup D_2)$ which satisfies the open formula φ in **M**. This treatment of the second order quantifiers is worth noting: intuitively, second order quantification is supposed to correspond to quantification over properties—however, the inductive definition of 'truth-in-a-model' treats the quantification as equivalent to quantification over sets. As will become clear, this assumption is philosophically contentious.

We now introduce two pieces of terminology.

Empirical adequacy and correctness: Empirical adequacy is a notion familiar from van Fraassen. Intuitively, a theory is empirically adequate if it has a model which contains all the appearances. Formally, a theory is empirically adequate if it has a model **M** such that (a) the domain D_1 of **M** is D_{Obs}, the set of observable objects, and (b) for all observable predicates $\mathrm{O}x_1 \ldots x_n$ and observable objects $a_1 \ldots a_n$, $<a_1 \ldots a_n> \in \mathrm{val(O)}$ if and only if it is true that $\mathrm{O}a_1 \ldots a_n$. We say that such models are themselves empirically correct.[7]

A T-cardinality correct model is one whose theoretical domain is of the same cardinality as the actual theoretical domain.

Now we can state the main result.

$R(\theta)$ is true if and only if θ has a model which is empirically correct and T-cardinality correct.

The proof is as follows. Suppose that θ is empirically adequate and T-cardinality correct. Then θ has a model $\mathbf{M} = ((D_1, D_2)\ O_i,\ M_i,\ T_i)$ which is both empirically correct and T-cardinality correct. By empirical correctness: (1) the observable domain of **M**, D_1, just is the set of all observable objects D_{Obs}, and (2) for each sequence of observable objects $<a_1 \ldots a_n>$ in D_1, and for each n-place observational predicate O, $<a_1 \ldots a_n> \in O$ if and only if $a_1 \ldots a_n$ really do stand in relation O. For **M** to be T-cardinality correct is for D_2 to have the same cardinality as D_{T}—the set of unobservable entities. Thus, there is a 1-1 function **f** from D_2 to D_{T}.

By hypothesis, $((D_1, D_2), O_i, M_i, T_i) \vDash \theta(O_i, M_i, T_i)$. Let **g** be both an extension of **f** and a 1-1 function from $D_1 \cup D_2$ to $D_{\text{Obs}} \cup D_{\text{T}}$ which leaves every element of D_{Obs} as it is (this is possible as $D_1 = D_{\text{Obs}}$ in this case). Let $\mathbf{g}(O_{\text{i}})$, $\mathbf{g}(M_i)$ and $\mathbf{g}(T_i)$ be the obvious extension of **g** to n-tuples of $D_{\text{Obs}} \cup D_{\text{T}}$. Since g is 1-1 and onto, $\mathbf{M}^* = ((\mathbf{g}D_1, \mathbf{g}D_2), \mathbf{g}(O_{\text{i}}), \mathbf{g}(M_i), \mathbf{g}(T_i))$ is isomorphic to **M**. By the defining properties of **g**, $\mathbf{M}^* = ((D_{\text{Obs}}, D_{\text{T}}), O_i, \mathbf{g}(M_i), \mathbf{g}(T_{\text{i}}))$. Since $\mathbf{M}^*$ is isomorphic to **M**, $((D_{\text{Obs}}, D_{\text{T}}), O_i, \mathbf{g}(M_i), \mathbf{g}(T_i)) \vDash \theta(O_i, M_i, T_i)$. So, by the definition of truth-in-a-model for the second order existential quantifiers, $((D_{\text{Obs}}, D_{\text{T}}), O_i, \mathrm{g}(M_i)) \vDash \exists \mathrm{X}_{\text{i}}\theta(O_i, M_i)$. Again, by the definition

[7] Note that this definition differs slightly from the one employed by Ketland. For Ketland, a model is empirically correct just in case its empirical reduct is isomorphic to the observational part of the world.

of truth in a model for the second order existential quantifiers, $((D_{Obs}, D_T), O_i) \vDash \exists X_j \exists X_i \theta(O_i)$. This final formula is none other than $R(\theta)$. Thus, $((D_{Obs}, D_T), O_i) \vDash R(\theta)$.

Now, $((D_{Obs}, D_T), O_i)$ is not just any old interpretation of $R(\theta)$—it is the *intended* interpretation of $R(\theta)$. The domain of the first sorted variables is exactly the set of observable objects; the domain of the second sorted variables is exactly the set of unobservable objects—but these are simply the intended domains of such variables. Similarly, all predicates of the theory have their intended interpretation—each predicate O_i is assigned the set O_i which is the set of observational objects that satisfy O_i. But if $R(\theta)$ is true in the intended interpretation then $R(\theta)$ is true *simpliciter*, for truth and truth-in-the-intended-interpretation are, at the very least, coextensive. QED

3 On Ramseyfying away predicates

In certain respects, Ketland's model theoretic argument was anticipated by Winnie ([1967]). Winnie's target, however, was not structural realism. Rather, his attack was aimed against those who wished to define theoretical terms via Ramsey sentences. Lewis ([1970]) has shown how Winnie's formal argument may be resisted. We think Lewis' response can be adopted by the structural realist.

Ketland's formalisation of the proof involves gerrymandering the predicates of a scientific theory in a particular way, and then assuming that the structural realist must eliminate all predicates that appear in a certain class. This is not a quirk of Ketland's presentation. In order to get a successful version of the model theoretic argument to work against its intended target, the structural realist will have to be treated as splitting up the vocabulary in some formally similar way, and then Ramseyfying along the lines outlined above. It is a merit of Ketland's argument that he makes such features explicit in his proof.[8]

In the old days, predicates were treated as either observable or unobservable. Ramseyfication was supposed to leave the observable predicates untouched, while the unobservable predicates were to be eliminated. But, as

[8] Ketland's proof is a careful formulation of the argument initially put forward by Demopoulos and Friedman ([1985]). They recall Newman's critique of Russell's structuralism, and draw the general conclusion that Ramseyfication trivialises theoretical content. Demopoulos ([2003]) provides an in-depth analysis of Russell's structuralism, and employes Newman's observation to raise an insurmountable problem for 'the Ramsey-Carnap reconstruction of theoretical knowledge'. Demopoulos explicitly acknowledges Lewis' response to this argument as formalised by Winnie, but recognises this as orthogonal to the general epistemological considerations he is concerned with. It may well be that, for his particular historical and epistemological concerns, gerrymandering the predicates in this way is permissible and correct. But, as we shall argue, adopting Lewis' response is quite appropriate for our realist analysis of Ramseyfication.

is well known today, the predicates of scientific theories do not divide up so neatly. The one-place predicates 'has mass', 'has energy', 'is spatio-temporally located' apply to things that are observable and unobservable alike, whilst two-place predicates such as 'x is a part of y' and 'x is larger than y', can relate observables to observables, unobservables to unobservables and observables to unobservables. Now, no sensible structural realist would simply Ramseyfy away all occurrences of the predicate 'x is a part of y'. Since the predicate applies to observables as well as unobservables, such wholesale Ramseyfication could *rob* his theory of empirical content. Technically, this danger is avoided in the above proof by gerrymandering this and other mixed predicates. A two-sorted language is employed where one sort of variable ranges over observables whilst the other sort of variable ranges over unobservables. Thus, the predicate 'has mass' is treated as *two* predicates in the above formalism: 'x has mass' and 'ζ has mass', where 'x' ranges over observables and 'ζ' ranges over unobservables. In effect, we now have the predicates: 'is observable and has mass' and 'is unobservable and has mass' in our scientific theory. Similarly, 'is a part of' is treated as *four* predicates: 'x is a part of y', 'x is a part of ζ', 'ζ is a part of x' and 'ζ is a part of ξ'. Though this treatment may be unnatural, it does have the advantage of giving the structural realist flexibility in his choice over which predicates get Ramseyfied. For eliminating all occurrences of the predicate 'has mass' would strip his theory of true observational content whilst preserving all occurrences of this predicate would mean his Ramseyfied theory still contained claims about the nature of unobservables. What remains unargued for, however, is that the structural realist will proceed to Ramseyfy away *all* the mixed predicates. But that is exactly what happens in the above proof.

The consequences of adopting this procedure are clearly problematic. Suppose that θ is a simple theory according to which there are unobservable objects located in space-time. Suppose, indeed, that θ is so simple it consists of the single sentence '$\exists\zeta \mathrm{F}\zeta$', where ζ ranges over unobservables, '$\mathrm{F}\zeta$' means that ζ is spatio-temporally located. According to the recipe for Ramseyfication used in the proof, as '$\mathrm{F}\zeta$' contains a variable for unobservables it will get Ramseyfied away and so $R(\theta)$ will be the sentence '$\exists X \exists \zeta (X\zeta)$'—there are unobservable objects which instantiate *some* property. It is quite clear that this is an incredibly weak and virtually trivial thesis. With *all* such predicates for unobservables eliminated there is no clear way for the Ramseyfier to say very much about the theoretical world. Even very weak claims about unobservables, such as that they are located in space and time, or that they make up observable ones, are not expressible when it is insisted that all meaningful predicates involving unobservables must be Ramseyfied away.

So much the worse for structural realism? No. So much the worse for following the above scheme and Ramseyfying away all and any mixed predicates. We do not know of a structural realist who advocates this way of Ramseyfying and no reason or argument has been given for saying that the structural realist is committed to this procedure. Given that the formal proof *demonstrates* that this assumption leads to trouble, the structural realist would do well to drop it. And provided merely that the structural realist leaves at least one predicate which can apply to unobservables unRamseyfied, Ketland's formal proof does not go through.

There is nothing in the spirit of structural realism that implies that *all* predicates which can apply to unobservables should be Ramseyfied away. The structural realist thinks we cannot know certain aspects of the nature of the unobservable world, but that structural aspects of the unobservable world can be known.[9] This is quite compatible with the structural realist retaining some interpreted predicates for unobservables. Consider, for example, the predicate '*x* is part of *y*'. That a is a part of b tells us nothing about the *nature* of a or of b. Whether or not atoms are tiny indivisible Newtonian balls, or whether or not they are complexes of charged and uncharged entities, or whether they are tiny waves oscillating in an aether, it can still be true that these unobservable atoms are parts of observable objects. Or consider the predicate '*x* is located in region r'. That a is located in region r again tells us nothing about the *nature* of a. Whether or not light is a wave or a particle, it may still be true that a light ray is located in a region r. Consider for example '*x* has velocity *v*'. Whatever the nature of light may be it is still true that light can have a particular velocity, or that the velocity may change in certain observable circumstances. By retaining one-place predicates for extrinsic properties and n-place predicates for external relations, structural realists can say definite things about unobservables, such as that they are located or that they form parts of other objects, which does not commit them to any definite thesis about these objects' nature.

Ketland's treatment of Ramseyfication bars the structural realist from formulating the claim that atoms, whatever their nature may be, make up gases, or from saying that light, whatever it may be, is spatio-temporally located, or that it has a particular velocity. Instead, on his scheme, they are transformed into the claims that atoms, whatever they may be like, bear *some* relation to molecules, or that light, whatever it may be like, has *some* property. Indeed, the structural realist is not able even to present an atomic hypothesis and say that all observables are made up of unobservables. Since 'made up of' here relates observables to unobservables, this predicate gets Ramseyfied away.

9 Repeating the earlier terminological point: if 'structure' is understood as referring to that what can be expressed purely by logico-mathematical means, by a Ramsey sentence without any non-logical predicates, then clearly more than structure is known. So much worse for the clearly and undeniably untenable 'purist' structuralism (cf. Psillos [2001]).

We do not need fancy model theoretic arguments to realise that a structural realist who could not even make claims as weak as these is going to have a hard time saying *anything* very much about the unobservable world whether it be its intrinsic nature or the relations unobservables bear to observables. Nothing in the philosophical intuition behind structural realism dictates that the structural realist must follow this path. In our view, the hypothesis that observables are made up of unobservables is such a weak thesis it is absurd to think it offends structuralist principles. There may well be some philosophers who think we cannot know even such a weak thesis as this, but their reasons cannot be based merely on their structuralism.

Of course, structural realism is not merely a formal articulation of a philosophical intuition; it is offered as the solution to a particular philosophical problem: 'how can one accommodate what is right about the no-miracles argument for realism whilst avoiding the pessimistic meta-induction?' It is lessons from the history of science that tell us which parts of a theory we can believe and which parts of a theory we should be agnostic about. Thus, there have been many successful theories that have had very different views about the nature of the electromagnetic field—some theorists believe it is an undulating aether whilst other theorists believe it is a *sui generis* extended vector valued object. Worrall rightly counters that, despite this discontinuity there has nevertheless been a form of *continuity* across the different theories (Worrall [1989]). Whatever the electromagnetic field may really be like, it is still true that it has an *energy*, that it has a *velocity*, that observable charged objects located *in its path* are accelerated, that when *passed through a medium* it is *decelerated*. As before, to talk of its energy, velocity, path or acceleration is to say little about the nature of the unobservable objects. What's common to all these hypotheses is simply that *there is a kind of object*—its nature unknown and unspecified—which has a certain velocity, which is located in certain regions, which changes direction when placed in a magnetic field... and so on.

The elimination of predicates for variables and existential quantifiers captures something that these various theories have in common, but the history of science gives us no reason to think that every single predicate that we once thought applied to these objects is actually incorrect. To reach this conclusion, history would somehow have to show us that *everything* that old successful theories say about unobservables has been undermined by later theories. So far as we know, no historian has so far made a plausible case for this thesis.

Whether our main motivation for Ramseyfying is to articulate a notion of structure or whether it is to avoid the pessimistic meta-induction, there is no reason to think that Ramseyfication must follow the prescription assumed in the above proof and eliminate each and every mixed predicate. The structural realist can and should show discretion in the predicates for unobservables that he chooses to eliminate. In doing so, the structural realist blocks the model theoretic argument.

4 The model theoretic argument bites back

Although the moral of the last section is a happy one for the structural realist, it is not the final word. Even when predicates that apply to observables and unobservables alike are handled with the requisite care, there are still cases where Ramseyfied theories demand too little of the theoretical world. The following example, though artificial, shows that things can still go wrong.

Consider a theory Π. According to Π, there exist observable rays. When these rays are passed through a Grue device, one of two things happens: they turn green or they turn blue. We will suppose that it is part of the theory that all rays get passed through a Grue device (this will simplify the formulation of the theory as it allows us to eliminate a predicate for '*x* goes through a Grue device'). This theory can be formulated by the single axiom: $\exists x(\mathrm{R}x)$ and $\forall x(\mathrm{R}x \rightarrow (\mathrm{G}x \leftrightarrow \neg\mathrm{B}x))$, where 'R*x*' means '*x* is a ray', 'G*x*' means '*x* turns green' and 'B*x*' means '*x* turns blue'.

Clearly, Π is concerned only with the observable part of the world. Now suppose that the theorists get their hands on Π and come up with the following hypothesis: rays are made up of two kinds of unobservable microscopic particles. On the one hand, there are rays that contain *P*-particles; on the other hand, there are rays that contain *N*-particles. The rays that contain at least one *P*-particle turn green when passed through the Grue device, the rays that contain at least one *N*-particle turn blue when passed through the Grue device. No rays contain both *P* and *N*-particles.

We will call this theory Π+. If 'N*x*' means '*x* is an *N*-particle', 'P*x*' means '*x* is a *P*-particle' and 'M*x*' means '*x* is a microscopic particle' then Π+ can be taken as the conjunction of the following axioms:

$$\exists x(\mathrm{R}x)$$

$$\forall x(\mathrm{R}x \rightarrow (\mathrm{G}x \leftrightarrow \neg\mathrm{B}x))$$

$$\forall x((\mathrm{P}x \vee Nx) \leftrightarrow \mathrm{M}x)$$

$$\forall x(\mathrm{R}x \rightarrow (\exists y(\mathrm{P}y \,\&\, y < x) \vee \exists y(\mathrm{N}y \,\&\, y < x)))$$

$$\forall x(\mathrm{R}x \rightarrow \neg(\exists y \exists z(\mathrm{P}y \,\&\, \mathrm{N}z \,\&\, y < x \,\&\, z < x)))$$

$$\forall x((\mathrm{R}x \,\&\, \exists y(\mathrm{P}y \,\&\, y < x)) \rightarrow \mathrm{G}x)$$

$$\forall x((\mathrm{R}x \,\&\, \exists y(\mathrm{N}y \,\&\, y < x)) \rightarrow \mathrm{B}x)$$

Since the predicates 'x is a *P*-particle' and 'x is an *N*-particle' both apply only to theoretical objects, the structural realist will presumably wish to Ramseyfy away these predicates. But since '$x < y$' is a mixed predicate, as argued for in the previous section, the structural realist may leave this predicate untouched. Accordingly, $R(\Pi+)$ eliminates only the predicates for *P* and *N*-particles. Like $\Pi+$, $R(\Pi+)$ has no new observable consequences over and above Π. However, $R(\Pi+)$ does have interesting physical content: it entails that rays have proper parts, something about which Π was completely silent. For all that Π said, rays might have been indivisible objects. So $R(\Pi+)$ cannot be described as a mere trivial or mathematical consequence of Π. Unfortunately, the physical content of $R(\Pi+)$ is nothing more than that rays have microscopic proper parts. If rays have at least one microscopic part, if they are mereologically disjoint from each other and if they behave as Π says they do, then $R(\Pi+)$ will be true.

Assume that rays behave as Π says they do, and suppose that rays have microscopic parts. Then we can construct the following model for $\Pi+$. Let the extension of 'Rx' be **R**, the set of rays. Let the extension of 'Mx' be the set **M**, (disjoint from **R**) the set of microscopic parts. Let the extension of 'Gx' be **G**, the set of rays that turn green, and the extension of 'Bx' be **B**, the set of rays that turn blue. Let '$x < y$' hold between a ray r and microscopic part p precisely when p is a part of r. So far, all predicates have their intended interpretations. Now let the extension of 'Px' be **P**, the set of microscopic parts of rays that turn green and the extension of 'Nx' be **N** the set of microscopic parts of rays that turn blue. It is straightforward to check that all the axioms above are true in $((\mathbf{R} \cup \mathbf{M}), \mathbf{R}, \mathbf{G}, \mathbf{B}, <, \mathbf{M}, \mathbf{P}, \mathbf{N})$ and thus that this is a model for $\Pi+$. Since all predicates other than 'Px' and 'Nx' have their intended interpretation, it follows that the Ramseyfied theory $R(\Pi+)$ is true.

In the original argument, Ramseyfied theories were true provided merely that the theoretical domain had the right cardinality. $R(\Pi+)$ entails that rays have microscopic parts, but that is effectively *all* that it entails about the unobservable world. For provided merely that rays do have microscopic parts and that macroscopic objects behave as Π says they do, then $R(\Pi+)$ is true. It does not matter what these microscopic parts are like, it does not matter how these microscopic parts are arranged, it does not matter what qualitative relations these microscopic parts bear to other things, it does not matter whether these microscopic parts are in any way causally responsible for the behaviour of the rays, it does not matter whether they explain the behaviour of the rays. Provided merely that microscopic parts of the rays exist, the theory is true. We think that this shows that the physical content of the Ramseyfied theory is still too weak. Surely the kinds of states or properties which the structural realist wishes to introduce by means of his Ramsey sentences should require more of the theoretical world. The trouble is that, for all that $R(\Pi+)$ says, the supposedly theoretical properties it existentially quantifies over could be *being a microscopic part of a ray that turns green* and *being a microscopic part of a ray that turns red*. Such properties are instantiated trivially provided merely that the ray does have microscopic parts, and thus the Ramseyfied theory demands very little of the theoretical world.

Of course, the very formulation of the problem suggests solutions. Perhaps we need to add to our theory words to the effect that the *P* and *N*-particles are *natural properties*, or that they are *qualitative properties* or that they are *causal properties*. Perhaps we need to add to our theory the hypothesis that the properties postulated *explain* or *cause* the macroscopic rays to behave the way that they do. Both kinds of suggestion involve a departure from the second order framework in which Ramseyfication has so far been formulated. The first case would involve finding a way of restricting the domain of the second order quantifiers in some way, either by introducing into our language a higher order predicate (i.e. a predicate for predicates) or, equivalently, by removing the assumption that the models for our second order theory be *full*.[10] The second case involves heavier logical machinery: it involves moving to an intensional logic capable of talking about explanatory and causal relations.[11] In either case, the hope will be that in a different logical framework the trivialisation results will be blocked. The question is whether the structural realist can formulate principles which are weak enough to be consistent with his structural realism and yet strong enough to block the trivialisation results. We turn to examine these strategies.

5 Restricting the second order quantifiers

In the model theoretic arguments, the second order quantifiers are treated as ranging over each and every subset of the first order domain. This assumption might be fine in those contexts where the second order quantifiers are unrestricted, but unrestricted quantification rarely happens. If the scientists who assert their Ramseyfied theories intend their quantifiers to range over a restricted domain, the model theoretic arguments fail.[12]

[10] A second order model is full if the second order quantifiers range over all the subsets of the first order domain. If the second order quantifiers are treated as ranging over only some of the properties, then such a semantics is not appropriate.

[11] Some might claim that postulates such as these already form part of the background assumptions of our theory. This may indeed be true, but the question whether the relevant postulates are part of the background or appear explicitly in the scientific formulation of the theory is irrelevant to us. Our question is, wherever it appears, can it block the model theoretic argument, and if so, how does it do it?

[12] So, for instance, in the formal argument, the move from $((D_{\mathrm{Obs}}, D_{\mathrm{T}}), O_i, \mathbf{g}(M_i), \mathbf{g}(T_i)) \models \theta(O_i, M_i, T_i)$ to $((D_{\mathrm{Obs}}, D_{\mathrm{T}}), O_i, \mathbf{g}(M_i)) \models \exists \mathrm{X_i} \theta(O_i, M_i)$ is no longer valid: $\mathbf{g}(T_i)$ may not be in the second order quantifier's domain.

In the first order case, it is a familiar point that the domain of quantification may vary. An utterance of 'all drinkers are yobs' may be true of its intended domain—the set of English people—even though there may exist drinkers in Finland who are not yobs. An utterance of 'There is no way I can jump through the window and live' may be true in a given context—even though I know that there are worlds where the actual laws of physics do not hold—because the quantifier over worlds is *restricted* to those worlds that share the same laws of physics as I do.

That the domain of the quantifier should be thus restricted is true not only of our everyday use of the quantifiers but in more formal contexts also. When the scientist says that everything carries energy, we do not refute him by pointing out the existence of the number two, or the existence of the proposition that all men are bald. When the physicist says that nothing can move faster than the speed of light, we do not refute him by swinging a torch back and forth so that the beam's image on the surface of the moon oscillates faster than the speed of light—even though this image may rightly be regarded as a physical object. Rather, we recognise that the set of objects over which the physicist is quantifying is restricted in some way. A semanticist who insisted on treating the physicist as quantifying over *all* the objects that there are, who insisted that the right models by which to judge the physicist's pronouncements were those whose first order domain contained every single object, would be a bad semanticist.

Just as there are distinctions to be drawn between individuals, so there are distinctions to be drawn between properties. Some properties are *intrinsic* whilst others are *extrinsic*; some properties are *observable* whilst others are *unobservable*; some properties are *disjunctive* whilst others are perfectly *natural*; some properties are *causal* whilst others are *inert*; some properties are *qualitative* whilst others are *non-qualitative*. Just as the range of our first order quantifiers may be different sets of individuals in different contexts, so the range of our second order quantifiers may be different sets of properties in different contexts. When studying logic, properties such as *being identical to a or b*, or *being a member of set* $\{a, b\}$ may appear in the domain of our second order quantifiers, but when studying physics, biology or ethics, such properties may be excluded from our domain. The physicist who urges that no two space-time points share all their properties is not making a claim which is trivially true. It may turn out that there are properties such as *being identical to a or b*, strange as they may seem to the metaphysically innocent; and there may even be interesting truths about these properties to be told. But such truths are not part of the discourse of physics. Just as the intended domain of the physicist's first order quantifiers is less than all the objects that there are, so too the intended domain of the physicist's second order quantifiers is less than all the sets of objects that there are. But this means that it is incorrect to assume that the right semantics for this discourse is the set of models where the domain of the second order quantifiers is full. Yet the model theoretic arguments assume just this.

Dialectically, this is enough to block the model theoretic arguments so far examined. But it is not yet enough to articulate a precise version of structural realism. If the structural realist is to block the model theoretic arguments by restricting his second order quantifiers, then he owes us an account of the nature of this restriction. In particular, he needs to tell us where the boundary is to be drawn. Though we noted that there were many options open to the structural realist, we did not say which of these options he should prefer. Should he, for instance, include in the domain only those properties that are *natural, intrinsic, causal, contingent*, or *qualitative* or some combination of the above? Whichever way he chooses, the usual dangers face him: too strong a restriction and his $R(\theta)$ may not after all be preserved across successful theories; too weak a restriction and his theory runs the risk of being true too easily. Let us examine some of the more obvious ways of restricting the quantifier and see whether any suits his purposes.

5.1 Naturalness

Though it has recently become respectable to admit an objective distinction between natural and unnatural properties,[13] we think that restricting the quantifiers to the set of natural properties would be a mistake. Intuitively, natural properties are properties that cut nature at the joints, that unify their instances in some objective way. The property *being green until the year 2005 and red thereafter*, the property *being blue or square*, the property *being identical to Joseph or Juha* are all examples of unnatural properties. Giving examples of natural properties is harder because future empirical discoveries can show that properties we currently think are natural are in fact unnatural. A long time ago, it might have been natural to think that *being green* was a natural property, but scientific discoveries have shown that this property is in fact a disjunctive one. Currently *having a unit charge* or *having a unit spin* are thought to be natural properties, but future discoveries may overturn this. Since it is false that there is a *natural* property corresponding to every set of objects, second order quantification over natural properties should not be modelled by the standard second order semantics. Restricting our quantifiers to the natural properties genuinely restricts the second order quantifier, and thus rules in favour of something like a Henkin semantics.

[13] See Lewis ([1983]).

Although this suggestion enables the structural realist to avoid the model theoretic argument, we do not think it is advisable for two reasons. First, despite its newfound respectability, there still remains much controversy about whether the natural/unnatural property distinction is a legitimate one to draw.[14] There are still many philosophers who believe that the distinction is ill motivated or ill understood or merely theory-relative.[15] Second, and more central to the structural realist's concerns, the structural realist *shouldn't* take the second order quantifiers to be the natural properties if he wants his Ramseyfied theories to avoid the pessimistic meta-induction. One way in which new theories can overthrow old theories is by showing that properties that were once thought to be absolutely fundamental are in fact not. *Being green, being hot, being hydrogen* have all turned out to be *disjunctive* properties. Future developments in physics may show that *having a mass* is a disjunctive property. But the structural realist wants his Ramsey sentences to be *preserved* across theory change—they are supposed to capture something that is *constant* between theories, else the structural realist does little better than the full blown realist in dealing with the pessimistic meta-induction. If the intended domain of the second order quantifier is the set of natural properties, then the discovery that the properties postulated by the previous generation of theories are *not* natural will refute the structural realist's Ramsey sentence as much as it refutes the old realist theory.

5.2 Intrinsic

A less contentious distinction between properties is the distinction between *intrinsic* and *extrinsic* properties. Roughly, an object's intrinsic properties are those it possesses in virtue of the way it is in itself, whilst its extrinsic properties are those it possesses in virtue of the relations in which it stands to other things. Some believe that *intrinsic* explanations are better than *extrinsic* ones[16] and that intrinsic explanations should be given wherever possible. This line of thought suggests that the intended domain of the second order quantifiers should be the *intrinsic* properties of objects rather than the extrinsic ones.

But again, we do not think that this is the correct path for the structural realist to follow. First, it seems rash to insist on intrinsic explanations

[14] Note, though, that even if the structural realist were to rely on this distinction, this would not necessarily commit him to any kind of metaphysical theory of properties. True, the distinction between natural and unnatural can be easily drawn if we accept a theory of immanent universals along Armstrong's lines—so the choice of metaphysics can allow the theorist to capture the notion of naturalness. But the distinction can also be simply taken as primitive if need be. The issue for the structural realist here is finding the ideological resources to make certain distinctions. A structural realist who decides to rely on the natural/unnatural property distinction does not violate his desire to stay clear of metaphysical issues.

[15] See, for example, Taylor ([1993]).

[16] See, for instance, Field ([1980], chapter 5).

wherever possible. Consider, for instance, the difference between the rays that turn blue and the rays that turn green discussed in Section 4. Maybe these different effects are due to there being two different intrinsic properties that the different rays have. But surely it is equally possible that the difference is down to the fact that the rays that turn blue are all being orbited by electrons that circles the ray in a *clockwise* direction (relative to the motion of the particle), whilst the rays that turn green are all being orbited by electrons that circle in an *anticlockwise* direction. As long as the precise nature of the cause is unknown and the Ramsey sentence is all we wish to assert, it seems rash to say something that rules out an explanation in terms of the rays' extrinsic properties.

Second, the restriction to intrinsic properties is not clearly sufficient to block the trivialisation proof. For it is arguable that properties such as *being identical to a or b or… c* are intrinsic properties. But if the structural realist does not exclude such properties from the domain of his second order quantifiers, then the door is once again open for the trivialisation argument. For if properties such as these are intrinsic then it follows that to every set of objects there is an intrinsic property had by all and only those objects in the set. So the standard second order semantics is *correct* after all, even when the quantifier is restricted to intrinsic properties.

5.3 Qualitative

One thing deeply suspect about the Newman arguments is that, according to the model theoretic treatment of the second order quantifier, for every subset of the theoretical domain, there is a property which all and only the elements of that subset have in common. This is true independently of what the elements in the domain may be like. Some of them may be blue, others may be red; some of them may be heavy whilst others are light; some of them may be big whilst others may be small; some of them may be hot whilst others may be cold. But all of this is irrelevant on the second order model theory—according to the model theory there is a property which they, and only they, all have in common. Whether all the objects in a set are featureless blips, or whether all the objects are as diverse and varied as you could imagine, it remains true that there is a property unique to all the objects in the class.

This seems wrong. For many purposes, whether or not all the objects in a class are the same colour, whether they are all heavy, whether they are all hot are exactly the kinds of facts that are directly relevant to whether or not they share a property. The sharing of properties is a matter which should be tied to what the objects are *like*, the kinds of *features* that they have, the *qualities* that they possess. This suggests that, at the very least, the structural realist's second order quantifiers should be restricted to the set of qualitative properties instantiated by the first order domain. Of course, if {a, b, c} satisfies 'φX', then the property *being identical to a, b or c* is quite trivially shared by all the things that φ—but, from a scientific point of view, this is not an interesting property to ascribe to a, b and c. But if the structural realist insists that his existential quantifier is restricted to the domain of *qualitative* properties, then '$\exists X\varphi X$' is no longer made true by the fact that all these things share the property *being identical to a, b or c*.

The restriction to qualitative properties overcomes the formal argument. For under this restriction, it does not follow that, for every set of objects, there is a qualitative property which they and only they instantiate. This can be shown by considering a symmetric world. Consider a symmetric world containing three perfect spheres, each the same size, each of one unit mass, each precisely 1 m away from the other two, and all perfect duplicates of each other. Consider two of them, a and b. There is no *qualitative* property, intrinsic or extrinsic, that a and b have that is not also possessed by c. Of course, there are *non-qualitative* properties that distinguish a and b: they, and *only* they instantiate the property *being identical to a or b;* they and only they have the property *being a member of the set* {*a, b*}; they and only they have the property *being a part of the mereological sum of a and b*. But if we restrict our attention to qualitative properties, then there is no way to discriminate between the three objects. Accordingly, a semantics which assumed that the domain of the second order quantifiers was *all* the subsets of the first order domain would simply not be a good semantics for our quantification over qualitative properties.

Unfortunately, though attractive, restricting the quantifiers to qualitative properties is too weak to stave off Newman-style arguments for very long. True, restricting the second order quantifier in this manner implies that it is not necessarily true that whenever you have a set of objects there is one and only one property that those objects instantiate. The possibility of symmetric worlds demonstrated that. But worlds showing such symmetry are extremely rare. Where a world lacks this level of symmetry, it will be the case that, again, for every set of objects there is a qualitative property that the members of this set, and only the members of this set, instantiate. If the world is such that every object has a unique qualitative property then, by forming the relevant disjunction, every set of objects will correspond to a unique qualitative property too.

To see how this can happen, consider the following world. First, suppose that the space of this world is a Euclidean two-dimensional plane. Second, suppose there happen to be three objects each of which has a unique charge (call them q1, q2 and q3). Finally, suppose that these objects happen not to lie upon a straight line. It now follows that every object has a unique qualitative property: *being n metres away from q1 and being m metres away from q2 and* *o metres away from q3*. (Proof: *being n metres away from q1* is had by any object lying on a circle of radius n, centre q1; similarly, *being m metres from q2* and *o metres from q3* are had by any object lying on a circle of radius m, centre q2 and of circle o centre q3. If there is a point in common to all three circles, this point is unique). Thus, for every set of objects, there will be a unique qualitative property had by those objects—the disjunction of the conjunctive properties of the above form.

This example shows that, whilst it is no longer trivial that every set of objects has a unique qualitative property, it is still too easy. Provided the world isn't too symmetric, objects will still have unique qualitative properties, and so there will be unique qualitative properties corresponding to *sets* of objects also.

5.4 Contingent and causal

The argument that showed that the restriction to qualitative properties is too weak shows also that the restriction to contingent and causal properties is also too weak. The disjunctive distance properties above are all contingent properties of the objects that possess them. They are all causal properties too. Sadly then, restricting the range of the second order quantifiers to such properties fares no better.

Our search for a satisfactory way of restricting the second order quantifiers has not been successful. Those restrictions on the existential quantifier which block the Newman argument seem too restrictive and ask us to accept too much; but weaker and more acceptable restrictions on the second order quantifier are *too* weak, and Ramsey sentences expressed with such restrictions are still true too easily. We do not pretend to have exhausted the ways in which the second order quantifiers can be restricted, but we have not seen a reasonable or natural way of doing it which suits the structural realist. Accordingly, we suggest that the structural realist turn elsewhere for a solution.

6 Intensional operators and relations between properties

In this section, we examine what happens when the structural realist departs from a second order extensional framework. We argue that a number of possibilities open up when intensional notions are permitted and that one option in particular offers a promising escape from the trivialisation results so far considered.

The properties postulated in scientific theories are typically taken to stand in certain intensional relations to various other properties. Some properties *counterfactually depend* on others, some are *correlated in a law-like manner* with others, some are *independent* of others, and some are *explanatory* of others. In the model theoretic arguments considered so far, the logical framework in which Ramseyfication takes place is not capable of saying that such relations between properties hold. Though quantification into predicate position is permitted, the languages hitherto examined contain no higher order predicates capable of relating first order properties, nor do the languages contain any intensional operators. Yet by appealing to such relations, the model theoretic arguments considered so far may be blocked.

Recall the theory $R(\Pi+)$ from Section 4. One reason for the weakness of this theory was that, for all it said, the two properties postulated by the Ramseyfied sentences were nothing more than the properties *being a microscopic part of a ray that turns green* (P) and *being a microscopic part of a ray that turns blue* (N). Provided merely that rays do indeed have microscopic parts, such properties are automatically instantiated and so the theory is true too easily. But the theoretical properties that we postulate should earn their keep by doing serious explanatory work. In this case, the possession of these theoretical properties should explain the colours of the rays that emerge from the Grue device. The properties P and N do not do this. By extending our logical framework so that our scientific theories can say that there is an explanatory link between the possession of the properties postulated by the Ramseyfied theory and the colours possessed by the emerging macroscopic rays, then the existence of the properties P and N would no longer be enough to guarantee the truth of the Ramseyfied theory.

In fact, in the case under consideration, the properties P and N can be ruled out by employing a relatively simple intensional relation. Allowing the theorist to say that the postulated theoretical properties are *independent* of the relevant observation properties suffices in this case. By including the principle that it is strictly possible (though maybe not lawfully possible) that an atom possesses the property postulated by the Ramsey sentence without being an atomic part of a ray that turns blue or green, P and N are excluded. Again, this condition cannot be formulated in the logical formalism assumed in the trivialisation arguments.[17]

There are a number of ways to formalise intensional relations between properties. The simplest way would be to introduce new higher order relational predicates into one's theory. Alternatively, since many of the relations

[17] This feature spells trouble for the standard set-theoretic model theory of second order logic: by modelling quantification over properties by quantification over sets, any two coextensive properties are represented by one and the same set. Since the second order languages examined by Newman and his followers do not contain the wherewithal to express identity or distinctness between properties, this limitation does not manifest itself for such languages. Once we go beyond such languages, a different model theory will need to be adopted. Of course, in Newman's day, there was no model theory for quantification over properties. Today, however, with the advent of possible worlds semantics, logicians have to hand a reasonable model theory for modelling talk of identity and distinctness between properties.

between properties that are of interest to us are certain kinds of *modal* associations, one could augment the relevant formal system with modal operators and use them to express these modal relations. So, for instance, let L_P express 'it is physically necessary that...'. Then $\exists X L_P \forall x(Xx \leftrightarrow Gx)$ says that there is a property which is *lawfully* coextensive with G. Allowing the structural realist to talk of such relations between properties in his Ramsey sentence gives him new ways of cutting down on trivial interpretations of his Ramseyfied theory. Moreover, the appeal to such relations is a natural part of scientific theorising. The unobservable spin of electrons is not coincidentally correlated with the magnitude of the force these electrons feel in a magnetic field, it is *lawfully* correlated. The property *being water* is not coincidentally correlated with the property *being* H_2O, it is *strictly necessarily* correlated. And, significantly for the structural realist, whether you think the electromagnetic field consists of a vibrating aether, whether it is a primitive vector valued entity or whether it is a four-dimensional field, in every case the properties that are postulated are *lawfully* correlated with certain properties of observable objects.

None of the above moves require the structural realist to take a particular stance on the metaphysics of laws of nature. The structural realist can remain neutral between regularity theorists and those who believe that there are objective physical necessities in nature. Of course, it must be *true* that certain properties are lawfully correlated with others (else asserting such sentences will not go any way towards narrowing down the possible interpretations) so the structural realist who uses laws in his Ramseyfied theory will be committed to this much—but it is perfectly legitimate for him to make these moves whilst remaining neutral on these deep metaphysical issues.

Let us see in detail how an appeal to physical modalities solves the problem we faced earlier. In the previous section, we ran into difficulties with certain asymmetric worlds. In worlds where every object has a unique qualitative property, every set of objects has a unique qualitative disjunctive property, and thus the standard model theoretic clauses turn out to be correct. We could have restricted our Ramsey sentences to apply only to non-disjunctive properties, but the structural realist would prefer to leave open the idea that the properties postulated *are* disjunctive. Now, typically in scientific practice, new properties and new laws are postulated *together*. The physicist does not just hypothesise the existence of a new property, *quantum spin*, which certain electrons may or may not possess; rather, the property is postulated along with a certain law telling us how things with this property interact with things with other properties. Now, our previous problem was that, provided the world was not too symmetrical, any old set of objects had a property in common. So, for instance, it turns out that any set of objects has a very disjunctive qualitative property in common. Whilst this property may satisfy the Ramsey sentence the structural realist has written down, it seems to be merely a matter of chance, a mere fluke, that our quantifier has picked out such a property. This is because properties are typically hypothesised in science in order to *explain* other phenomena. This requires more than just an association—there should also be a *counterfactual connection* or *law-like association* between the two properties. Consider again a world where every set of things happens to have a unique qualitative property. Though it may be tempting, it is *not* that we want to rule this property out as being too disjunctive. For if it were true that there were a law-like connection between this incredibly disjunctive property and the phenomena that the property was hypothesised to explain, then we would not have any qualms about accepting this disjunctive property as the satisfier of the relevant Ramsey formula. If, incredibly, it turned out that there was a law-like connection between *being n metres away from o and being m metres away from o* and…* and the phenomenon of being a ray that turns blue then, surprising though it may be, this is the property that we would rightly have postulated to explain the fact that the ray turns blue. But it is the law-like connection between the two that is here doing the job—not the fact that the property is too disjunctive.

Structural realism has come to be articulated in two apparently different ways. The version of structural realism that has been investigated here expresses the relevant notion of structure in terms of Ramsey sentences; other versions of structural realism have been articulated as expressing our structural knowledge as knowledge of *relations* holding between theoretical objects and observables ones.[18] Of course, in both cases, knowledge of the *nature* of theoretical objects is not always possible; this is why both versions are retreats from full-blooded scientific realism, but there has never been any emphasis on *relations* in the Ramsey sentence version of structural realism. Nevertheless, law-like connections did play a significant role in Worrall's original examples to motivate structural realism (Worrall [1989]). In these examples, the electromagnetic properties associated with various observable phenomena could be associated in a law-like manner with *vibrations in a mechanical aether*, or with *variations in a primitive field*, or with some other unknown property. Just like normal associations, law-like associations allow for multiple realisations too. The difference is: law-like associations require a little more from the real world than mere associations, and thus limit the number of ways the world could be for there to be a property associated with some observable phenomena in a way which avoids trivialisation. Whilst mere properties of properties seemed to be insufficient to do the job, *relations* between properties are

[18] See, for instance, French and Ladyman ([2003]).

capable of doing the relevant work. This is very fitting for, although we began by examining the structural realist who emphasised only Ramsey sentences it transpires that, to avoid trivialisation, he had to appeal to relations after all. The difference is that, in this case, these are relations between *properties* rather than relations between *individuals*, as is traditionally advocated by such structuralists.[19] Nevertheless, the fact that it is relations that do the important work indicates that the two notions of structure might find a sort of synthesis in the version of structural realism that emerges from a response to the model theoretic argument.

7 Conclusion

The model theoretic arguments considered in this paper contain valuable lessons for those who wish to articulate their structural realism via Ramsey sentences. But since the model theoretic arguments contain questionable assumptions about the precise logical form that Ramseyfication must take, the correct lesson to be learned is *not* that such a Ramsey-theoretic approach to structural realism is impossible. Rather, the structural realist must reject the questionable assumptions. By taking proper care of the predicates he eliminates in favour of variables and quantification, by rejecting the assumption that the domain of his second order quantifiers must be full, and by employing meaningful predicates for relations between properties he can articulate his version of Ramseyfication in a way which is consonant with his aims and ideals. Whether such an articulation of structural realism fully meets the aims and objectives of the structural realist, or whether it is the *best* way of presenting structural realism is still a live and open topic. But as far as the trivialisation arguments go, Ramseyfied versions of structural realism are still a live and, we think, attractive option.

Acknowledgements

Thanks to Angelo Cei, Steven French and particularly Andrew McGonigal for much helpful feedback and encouragement during the writing of this article. Thanks also to John Worrall and an anonymous referee for their constructive comments on an early draft. Thanks are due also to audiences in seminar groups at Leeds, Manchester and Glasgow, where versions of this paper were presented. A big thank you to Jeffrey Ketland for helpful discussions about his original paper and useful comments on early drafts.

[19] See French and Ladyman ([2003]).

The research for this paper was partly supported by the Finnish Cultural Foundation.

Joseph Melia
University of Leeds
Leeds LS2 9JT, UK
j.w.melia@leeds.ac.uk

Juha Saatsi
Philosophy
School of Social Sciences
University of Manchester
Manchester M13 9PL, UK
Juha.Saatsi@Manchester.ac.uk

References

Demopoulos, W. [2003]: 'On the Rational Reconstruction of our Theoretical Knowledge', *British Journal for the Philosophy of Science*, **54**, pp. 371–403.

Demopoulos, W. and Friedman M. [1985]: 'Critical Notice: Bertrand Russell's *The Analysis of Matter*: Its Historical Context and Contemporary Interest', *Philosophy of Science*, **52**, pp. 621–39.

Field, H. [1980]: *Science Without Numbers*, Oxford: Basil Blackwell.

French, S. and Ladyman, J. [2003]: 'Remodelling Structural Realism: Quantum Physics and the Metaphysics of Structure', *Synthese*, **136**, pp. 31–56.

French, S. and Saatsi, J. [forthcoming]: 'Realism about Structure: Semantic view and Non-linguistic Representation', *Philosophy of Science*.

Ketland, J. [2004]: 'Empirical Adequacy and Ramsification', *British Journal for the Philosophy of Science*, **55**, pp. 287–300.

Ladyman, J. [1998]: 'What is Structural Realism?', *Studies in History & Philosophy of Science*, **29A**, pp. 409–24.

Lewis, D. [1970]: 'How to define theoretical terms', *Journal of Philosophy*, **67**, pp. 427–46.

Lewis, D. [1983]: 'New Work for a Theory of Universals', *Australasian Journal of Philosophy*, **61**, pp. 343–77.

Maxwell, G. [1970]: 'Structural Realism and the Meaning of Theoretical Terms', in S. Winokur and M. Radker (*eds*), *Analysis of Theories and Methods of Physics and Psychology: Minnesota Studies in the Philosophy of Science*, Vol. IV, Minneapolis, MN: University of Minnesota Press, pp. 181–92.

Newman, M. H. A. [1928]: 'Mr Russell's Causal Theory of Perception', *Mind*, **37**, pp. 137–48.

Psillos, S. [2001]: 'Is Structural Realism Possible?', *Philosophy of Science (Supplement)*, **68**, pp. 13–24.

Russell, B. [1927]: *The Analysis of Matter,* London: George Allen et Unwin.

Taylor, B. [1993]: 'On Natural Properties in Metaphysics', *Mind,* **102**, pp. 81–100.

Winnie, J. [1967]: 'The Implicit Definition of Theoretical Terms', *British Journal for the Philosophy of Science*, **18**, pp. 223–9.

Worrall, J. [1989]: 'Structural Realism: The Best of Both Worlds?', *Dialectica*, **43**, pp. 99–124; reprinted in D. Papineau (*ed.*) 1996, *Philosophy of Science*, Oxford: Oxford University Press.

Worrall, J. and Zahar, E. [2001]: 'Ramseyfication and Structural Realism', Appendix in Zahar, E. (2001): *Poincare's Philosophy: From Conventionalism to Phenomenology,* Chicago, IL: Open Court Publishing Co, pp. 236–51.