Philos Stud (2014) 171:289–311
DOI 10.1007/s11098-013-0272-x

The inscrutability of colour similarity

Will Davies

Published online: 18 January 2014

Abstract This paper presents a new response to the colour similarity argument, an argument that many people take to pose the greatest threat to colour physicalism. The colour similarity argument assumes that if colour physicalism is true, then colour similarities should be scrutable under standard physical descriptions of surface reflectance properties such as their spectral reflectance curves. Given this assumption, our evident failure to find such similarities at the reducing level seemingly proves fatal to colour physicalism. I argue that we should dispense with this assumption, and thus endorse the inscrutability of colour similarity. This strategy is inspired by parallels between the colour similarity argument and the explanatory gap between mind and body made vivid by Jackson's (1986) knowledge argument, and in particular by type-B physicalist responses to that argument. This inscrutability response is further motivated by cases in chemistry and biochemistry in which analogous scrutability theses fail to hold. Along the way, I present a challenge to standard formulations of the colour similarity argument based on the extreme context sensitivity of the similarity relation. Most presentations of the argument fail to control for such contextual variation, which raises the distinct possibility that the argument equivocates on the similarity relation across its premises. Although ultimately inconclusive, this context challenge forces a significant reformulation of the colour similarity argument, and highlights the need for much greater care in handling claims about colour similarity.

Keywords Colour · Perception · Colour ontology · Physicalism · Similarity · Mind–body problem

W. Davies (✉)
University of Antwerp, Antwerpen, Belgium

This paper presents a new response to the *colour similarity argument*, an argument that many people take to pose the greatest threat to colour physicalism. Very roughly, the argument claims that the colours could not be type-identical to surface reflectance properties, because reflectances seemingly fail to stand in the same characteristic similarity relations as the colours. After setting out the argument in more detail in Sect. 1, Sect. 2 presents an initial challenge to standard formulations of the argument. As authors such as Quine and Lewis have noted, the similarity relation exhibits extreme *context sensitivity*. Most presentations of the colour similarity argument fail to control for such contextual variation, however, which raises the distinct possibility that the argument equivocates on the similarity relation across its premises. Although this challenge is ultimately inconclusive, it forces a significant reformulation of the argument and thereby highlights the need for much greater care and precision in presenting claims about colour similarity.

My main response to the argument focuses on features of our *knowledge* of facts about colour similarity. The colour similarity argument depends for its cogency on the assumption that if colour physicalism is true, then colour similarities should be evident or *scrutable* under standard physical descriptions of reflectance properties such as their spectral reflectance curves. Without this assumption, the fact that ordinary colour similarities are not evident under such presentations provides no conclusive reason to reject colour physicalism. In Sect. 4 I argue that the colour physicalist should reject this assumption and endorse the *inscrutability of colour similarity*. This strategy is motivated in Sect. 5 by parallels between the colour similarity argument and the explanatory gap between mind and body made vivid by Jackson's (1986) knowledge argument, and in particular by so-called type-B physicalist responses to that argument. The response is further motivated in Sect. 6 by cases in chemistry and biochemistry in which analogous scrutability theses fail to hold.

1 The colour similarity argument: an initial formulation

Colour physicalism is the view that colours are type-identical to surface spectral reflectance properties.[1] Surface reflectances are dispositions to reflect incident light at varying wavelengths. Reflectances feature prominently in optics, the physics of light and its interaction with matter. The canonical way to represent an object's reflectance is by its reflectance spectrum or spectral reflectance curve, which charts the proportion of incident light reflected from its surface at all wavelengths in the visible spectrum. Figure 1 shows the reflectance curves for paradigmatic blue, purple, and green objects.

The best known form of colour physicalism does not identify the colours with super determinate reflectances but rather with anthropocentric classes or sets of reflectances known as reflectance-types. This is intended to handle the existence of

[1] Hilbert (1987), Byrne and Hilbert (2003). As standard in debates about colour ontology, I shall limit discussion to the hues and ignore aspects of colour such as saturation and lightness; see Byrne and Hilbert (2003, p. 14).

metamers, objects with sometimes widely differing reflectance properties that can be visually matched in respect of colour under some illumination conditions.[2] Despite their largely anthropocentric interest, reflectance-types are nonetheless ontologically independent of perceiving subjects, as Byrne and Hilbert (2003, p. 11) point out,

> The reflectance-types that we identify with the colours will be quite uninteresting from the point of view of physics or any other branch of science unconcerned with the reactions of human perceivers. This fact does not, however, imply that these categories are unreal or somehow subjective… It is just a plain matter of fact that an object has a particular type of reflectance, and this fact need not depend in any interesting way on the existence of creatures with colour vision.

While reflectance-types are therefore, in a sense, interest-relative properties, this does not imply that they are metaphysically constituted by relations between objects and the characteristic colour experiences of normal subjects, or by dispositions to produce such experiences.[3]

Colour physicalism has some very attractive features. Perhaps most importantly, it preserves our default or naive view of colour ontology, which involves a commitment to some sort of objective realism. As Kalderon (2007, p. 569) remarks, 'we tend to conceive of the colours as mind independent qualities of material objects. We should not revise our commitment to the existence of the colours, so conceived, without compelling reason.' While it is by no means the only available form of objective realism, colour physicalism is a reductive and ontologically parsimonious view that identifies the colours with well understood and clearly efficacious properties of the surfaces of objects. An attendant virtue of the view is that it avoids convicting subjects of global perceptual error in visually attributing colour properties to ordinary objects. According to colour physicalism, colour vision involves typically (or at least often) veridical perception of genuine physical properties of objects in the environment.

---

[2] Byrne and Hilbert (2003, pp. 10–11). Colour physicalists such as Hilbert (1987), Armstrong (1978), and Smart (1975) consider super determinate reflectances to be colours proper. This view entails that determinable categories such as red are strictly speaking not colours but rather classes of colours. For discussion of colour categorisation and its relationship to colour vision, see my 'Colour Vision and Seeing Colours' (ms.).

[3] See Byrne and Hilbert (1997, pp. xx–xxii) for a brief overview of dispositionalist theories of colour. Cohen (2009, Chap. 8.1) discusses the contrast between dispositionalist and functionalist theories of colour. Briefly, realiser forms of colour functionalism use subject-involving descriptions or functional roles to fix the reference of colour terms on their physical realisers, with which the colours are deemed strictly identical (Jackson 1998; McLaughlin 2000). If these realisers turn out to be surface reflectances, and if the relevant identities are type rather than token identities, then realiser functionalism will end up looking very much like the colour physicalist's type-identity theory of colour. See Cohen (2009, pp. 187–188), and compare Braddon-Mitchell and Jackson (1996) on realiser functionalism as a route to the identity theory of mind. In contrast, role functionalism takes colours to be identical with subject-involving functional roles (Cohen 2009, Chap. 7). Given the role played by subject responses in individuating colour properties, role functionalism is not in my view a form of colour physicalism. See Cohen (2003, §2) for contrasting discussion.

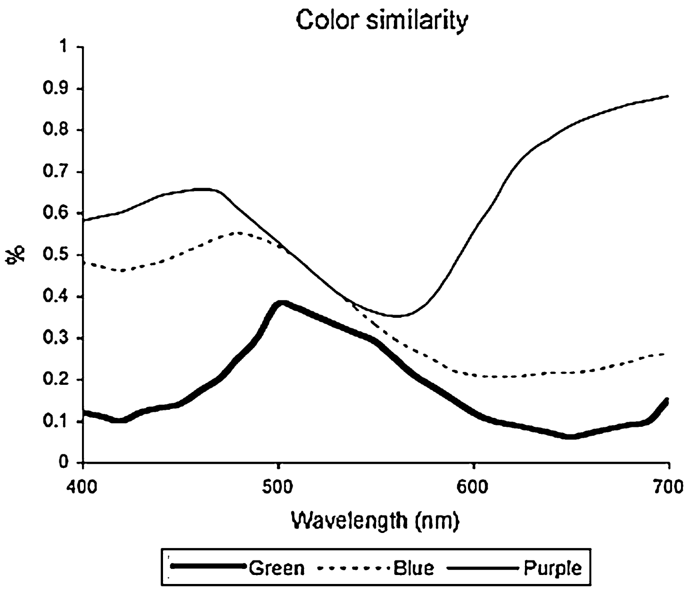

Fig. 1 Reproduced (with permission) from Byrne and Hilbert (2003, p. 13)

Despite the evident appeal, it is extremely difficult to reconcile colour physicalism with three important structural features of the colours. First, some hues are binary, in the sense that they are composite in nature: shades of orange, for example, always have both a reddish and yellowish component. In contrast, some hues are unique in that they are not composite but rather unitary or pure in nature. There exist shades of yellow, for example, which have absolutely no reddish or greenish component. Second, some hues bear opponent relations to one another, in the sense that they 'cancel each other out' and cannot together form components of a binary hue.[4] Third, the colours stand in various characteristic similarity relations. For example, it is characteristic of red that it is more similar to orange than green, and likewise of scarlet that it is more similar to fire engine red than vermilion. These structural features form the basis for the colour structure argument, which was introduced to the contemporary literature by Hardin (1988). This argument is generally taken to pose the greatest threat to colour physicalism.[5] The basic thrust of the argument is that none of the aforementioned structural properties seems to be shared by surface reflectance properties, which provides strong reason to doubt that

[4] The locus classicus for opponent colour theory is Hering (1920/1964). See also Hardin (1988, pp. 26, 30, 37–39, 52). The opponent hue pairings are red and green, and yellow and blue. It is important to recognise that the terms 'composite' and 'component' do not imply that binary hues are physically constituted by mixtures of different hues. See Byrne and Hilbert (2008) for relevant discussion.

[5] On the seriousness of the threat, see McLaughlin (2003, p. 111), Byrne and Hilbert (2003, p. 7), and Pautz (2006, p. 536). The colour structure argument is presented and endorsed by Maund (1995, pp. 42, 141), Thompson (1995, pp. 128–130, 135–139), Clark (1996, pp. 145–146), and Pautz (2006). Boghossian and Velleman (1991) and Johnston (1992) offer epistemological versions of the argument.

reflectances are the colours as colour physicalism claims. It is worth noting that parallel arguments threaten to undermine reductive physicalist accounts of other sensible qualities such as smells and tastes. The arguments of this paper, if sound, therefore will have much wider significance beyond the philosophy of colour.

Cohen (2003, p. 81) presents the standard formulation of the colour structure argument as follows,

> The argument… is a simple instance of Leibniz's law: colours have these structural properties, and therefore any set of properties that is identical with the colours must have them as well. However, it is suggested, the only plausible candidates proposed by [colour physicalists] for being identical with the colours lack the structural properties in question, and therefore the purported identities cannot be sustained.

Here I shall be focusing on the similarity component of this argument, which can be unpacked as follows:

1. Blue $= R_b$, purple $= R_p$ and green $= R_g$ (**Colour Physicalism**)
2. Blue is more similar to purple than green (**Colour Similarity**)
3. If blue $= R_b$, purple $= R_p$ and green $= R_g$, then blue is more similar to purple than green iff R_b is more similar to R_p than R_g (**Leibniz's Law**)
4. R_b is not more similar to R_p than R_g (**Reflectance Dissimilarity**)
5. Therefore, Colour Physicalism is false.

Suppose that colour physicalism claims that blue is type-identical with reflectance-type R_b, purple with R_p, and green with R_g. From our visual experience of colour, it seems obvious that blue is more similar to purple than green. By Leibniz's Law, if colour physicalism is true, then this colour similarity holds just in case the reflectances R_b, R_p, and R_g stand in the corresponding similarity relation. The problem, however, is that given everything we know about these reflectance properties from optics, there simply seems to be no evidence that R_b, R_p, and R_g stand in the required similarity relation. The representations of these properties in Fig. 1 provide a seemingly compelling illustration of this fact: as Pautz (2006, p. 539) remarks, 'the case for [Reflectance Dissimilarity] is that it is obvious when we look at [these] reflectance curves' that R_b, R_p, and R_g do not stand in the right similarity relation. Colour Similarity, Reflectance Dissimilarity, and Colour Physicalism thus form an inconsistent triad, and the argument concludes that Colour Physicalism ought to be rejected.

2 The context challenge: reformulating the argument

One challenge to the colour similarity argument which to my knowledge has not yet been explored is to question the validity of the argument on the grounds of a probable equivocation on the similarity relation across premises 2 and 4, Colour Similarity and Reflectance Dissimilarity. An analogy will help to illustrate this challenge. Suppose that I encounter a larger than average mouse in my kitchen and utter the following,

6. That mouse is big.

I then ponder the following identity claim,

7. That mouse = that animal.

I know by Leibniz's Law that,

8. If that mouse = that animal, then that mouse is big iff that animal is big.

Knowing what I know about animals, however, I confidently assert,

9. That animal is not big.

Presented with the inconsistent triad of 6, 7, and 9, I conclude that that mouse ≠ that animal. My reasoning here exactly mirrors that of the colour similarity argument, but in this case it seems clear that something has gone seriously awry. The problem here surely is not the absence of identity, but rather the tacit assumption that the predicate 'big' is semantically univocal across premises 6 and 9. A far more plausible diagnosis is that the change from a mouse-y context in 6 to an animal-y context in 9 shifts the interpretation of the predicate 'big', and that the argument therefore turns on an equivocation.[6]

Extending this thought to the colour similarity argument, the colour physicalist could argue that the change from an ordinary colour context in Colour Similarity to a reductive reflectance context in Reflectance Dissimilarity is likely to shift the interpretation of the similarity relation. Note that the likelihood of such contextual variation is all that is needed to get this challenge up and running, as this would establish a burden of proof on advocates of the argument to eliminate that possibility. Why think that such contextual variation is likely in this case? A quite general reason is that similarity relations are notoriously context sensitive, as Lewis observes (1986, pp. 254–255),[7]

> Many different relations, some more stringent and some less, some stressing some respects of comparison and others stressing others, have a claim to be called "similarity". The exact meaning of… "similar" is neither constant nor determinate… I can say that Ted and Fred are very much alike, yet very different. Uniform resolutions [of these similarity relations] would make that a contradiction – so much the worse for them!

[6] One plausible explanation is that the different terms shift the comparison class for the predicate from mice to elephants: whereas that mouse is big {for a mouse}, that elephant is not big {for an elephant}. See Kennedy (2007).

[7] Goodman (1970, p. 444) likewise argues that similarity, like motion, requires a frame of reference. Empirical studies confirm the extreme variability of ordinary judgements of similarity. Medin et al. (1993, p. 271) report experiments which 'show similarity to be dynamic and context dependent'. Murphy and Medin (1985, p. 296) say that 'the relative weighting of a feature… varies with the stimulus context and task, so that there is no unique answer to the question of how similar is one object to another'. See also Barsalou (1982) and Tversky (1977).

Adapting Lewis's reasoning, the context challenge holds that we can truly say that certain colours (qua colours) are very much alike, as in Colour Similarity, and yet that those very colours (qua reflectances) are very different, as in Reflectance Dissimilarity. Uniform interpretations of the similarity relation would imply an inconsistency with colour physicalism—but then so much the worse for the assumption that these relations are to be uniformly interpreted!

A second reason to suspect that different notions of similarity are operating in Colour Similarity and Reflectance Dissimilarity is that these premises differ in their use of non-reductive and reductive terms, respectively, in referring to the colours. Co-referring terms are often associated with different systems of theoretical classification, description, and explanation, and these systems in turn often invoke different standards for comparative similarity. Here is Quine (1969/1999, p. 238) on this point,

> [A] taxonomic example is the grouping of kangaroos, opossums, and marsupial mice in a single kind, marsupials, while excluding ordinary mice. By primitive standards the marsupial mouse is more similar to the ordinary mouse than to the kangaroo; by theoretical standards the reverse is true.

The context response likewise holds that despite the putative type-identity of *blue* and R_b, the terms '*blue*' and 'R_b' are associated with different systems of classifying the colours—the ordinary folk classificatory system, on the one hand, and the scientific classificatory system of optics, on the other. Moreover, these different classificatory systems have different associated, proprietary, standards for comparative similarity, such that while it is true according to the first set of standards to say that blue is more similar to purple than green, it is not true according to the second, more refined theoretical set of standards to say that R_b is more similar to R_p than R_g. The colour physicalist thus could grant the truth of both Colour Similarity and Reflectance Dissimilarity, but resist the conclusion of the colour similarity argument on the grounds of equivocation on the similarity relation across these premises.

The idea that different terms for the same colour can be associated with different standards for comparative similarity is interestingly related to a feature of Lewis's (1986) counterpart theory.[8] According to counterpart theory, different names for the same object can have different associated counterpart relations. As a consequence, modal sentences of the form $\ulcorner \Diamond Fa \urcorner$ and $\ulcorner \Diamond Fb \urcorner$ can differ in truth value even when $a = b$. Let 'Goliath' refer to the statue and 'Lumpl' refer to the lump of clay from which the statue is made. Now consider a counterfactual world w in which the statue has been deconstructed and the clay put to some other use.

10. Lumpl would have survived in w.
11. Goliath would not have survived in w.
12. Therefore, Lumpl $\neq$ Goliath.

[8] Here I am indebted to Adam Pautz, who brought to my attention the comparison with counterpart theory.

This argument is not valid on counterpart theory because the names 'Lumpl' and 'Goliath' have different associated counterpart relations. For Lewis this means that the names have different associated transworld similarity relations, for counterpart relations are defined in terms of similarity (1986, p. 256, n. 40). Now, while I am by no means recommending that the colour physicalist endorse counterpart theory, the above account is analogous in claiming that different terms for the same property can be associated with different similarity relations, on account of their being associated with different systems of theoretical classification. The context challenge thus claims that while the terms 'blue' and 'R_b' represent the very same property (de re, no less), each term is associated with a different similarity relation and hence the inference from Colour Similarity and Reflectance Dissimilarity to the falsity of colour physicalism is invalid.

Although the context challenge opens up interesting lines of discussion, I do not think that it provides a conclusive response to the colour similarity argument. This is because advocates of the argument can reply simply by *making the argument more precise*, thereby eliminating the possibility of contextual variation. One such reformulation would run as follows:

1*. 'Blue is more similar to purple than green' as said by S in w at t is true. (**Colour Similarity***)
2*. 'Blue is more similar to purple than green' as said by S in w at t is true iff <blue, purple, green> satisfies the relation X that is the semantic value of 'x is more similar to y than z' as said by S in w at t. (**Simple Truth Conditions**)
3*. If colour physicalism is true, then 'blue is more similar to purple than green' as said by S in w at t is true iff $<R_b, R_p, R_g>$ satisfies this relation X.
4*. $<R_b, R_p, R_g>$ does not satisfy this relation X. (**Reflectance Dissimilarity***)
5*. Therefore, if colour physicalism is true, then 'blue is more similar to purple than green' as said by S in w at t is false.
6*. Therefore, colour physicalism is false.[9]

By stipulating a univocal interpretation of the similarity relation, this formulation of the similarity argument seemingly eliminates the risk of contextual variation. This comes at the cost of a degree of artificiality arising from the metalinguistic ascent, but this nonetheless seems like the right way for my opponent to go. Despite the availability of this reply, the context challenge brings to light two important interim conclusions. First, the standard Leibniz's Law formulation of the colour similarity argument is inadequate and should be avoided due to its failure to control for contextual variations in the similarity relation. Second, and more generally, all parties to this debate need to be far more cautious and precise when making claims about colour similarity. The similarity relation is a slippery customer and needs to be handled with care.

[9] This formulation of the argument is essentially the same as that presented by Pautz (2006, p. 540).

3 The experiential response

What options does this leave the colour physicalist? Denying Colour Similarity* presumably should be a last resort. As noted above, one of the main attractions of colour physicalism is its thoroughgoing realism about the colours, and it would be a huge disappointment if the view could only be sustained by adopting an error theory about colour similarity claims (and likewise for other aspects of colour structure). A more promising strategy would be to deny Simple Truth Conditions. The popular experiential response, for example, claims that ordinary colour similarity claims are not made true by similarities among the colours after all, but rather by similarities among our *visual experiences* of colour; more precisely, by similarities among the *phenomenal characters* of these experiences.[10] Taking the value of E(x) to be the type of phenomenal character of experiences typically caused by x, premise 2* is replaced by the following:

> 2**. 'Blue is more similar to purple than green' as said by S in w at t is true iff <E(blue), E(purple), E(green)> satisfies the relation X that is the semantic value of the relation 'x is more similar to y than z' as said by S in w at t.

And in place of premises 3* and 4* we now have,

> 3**. If colour physicalism is true, then 'blue is more similar to purple than green' as said by S in w at t is true iff <E(R_b), E(R_p), E(R_g)> satisfies this relation X.
> ?? 4**. <E(R_b), E(R_p), E(R_g)> does not satisfy this relation X.

The colour similarity argument now can be easily defused, for 4** seems quite implausible. Whereas the reflectance curves for R_b, R_p, and R_g suggest that these properties do not stand in the same similarity relations as blue, purple, and green, there is no good reason to deny that the phenomenal characters E(R_b), E(R_p), and E(R_g) bear the right similarities.

The experiential response has significant appeal. First, it avoids an error theory about colour similarity claims, preserving the truth of our ordinary thought and talk about the colours. Second, the response captures the extremely plausible thought that colour similarities (and other aspects of colour structure such as uniqueness of hue) surely depend in some sense on the nature of our visual systems.[11] According to the experiential response, the dependence is metaphysical or constitutive: on this view, despite superficial linguistic appearances to the contrary, colour similarity facts just are facts about the qualitative characters of our visual experiences of colour. As Pautz (2006, p. 554) usefully notes, the experiential response thus couples a physicalist or subject-independent account of first-order colour properties with a dispositionalist or subject-dependent account of second-order facts about colour structure.

[10] Shoemaker (1991), Lewis (1997, pp. 339–340), McLaughlin (2003), Cohen (2003, 2009).

[11] Shoemaker (2003, p. 256).

For all its promise, however, the experiential response has extremely unattractive epistemic, linguistic, and metaphysical consequences. First, the response presents an unappealing view of the epistemology of colour structure facts. The fact that blue is more similar to purple than green seems to be a paradigmatic example of something that we learn by visually perceiving—visually representing, or being visually presented with—the colours. According to the experiential response, however, this fact actually must be learned by introspecting and attending to the qualitative character of our visual experiences of colour, rather than the colour properties themselves. Second, by denying Simple Truth Conditions the experiential response implies that ordinary language colour similarity claims do not predicate relations among the colours, as we pretheoretically think that they do, but rather as holding among our experiences of the colours. As Pautz (2006, p. 541) notes, on this view 'the claims in question do not really say what they seem to say'. A third and related metaphysical worry is that the experiential response thus seems to locate colour similarity facts in the wrong place.[12] Byrne (2003, p. 645) expresses this concern as follows,

> Intuitively, [the experiential response] gets things the wrong way round. If we have opinions at all about salient similarities… holding between our colour experiences, that is surely because we take such similarities to be induced by the apparent similarities between the colours. Why is the experience as of a teal object similar to the experience as of a turquoise object? Because teal is similar to turquoise.

The experiential response thus fails to respect the plausible physicalist supervenience thesis that there could be no difference in colour similarities without a difference in the underlying physical nature of the colours themselves. Taken together, these issues spell serious trouble for the experiential response and another strategy therefore is required.

4 The inscrutability of colour similarity

The last remaining option for the colour physicalist is to deny Reflectance Dissimilarity*, the claim that the reflectances R_b, R_p, and R_g do not stand in the 'right' similarity relation X, whatever exactly that might be.[13] There are two approaches that one could take in denying this premise. The first, direct, approach would be to propose some specific interpretation of X such that a) X is a plausible

[12] Lewis (1997, p. 330) seems happy to bite this bullet, remarking that 'we might have had an offhand opinion that these relations originated as relations among surface properties. If so, we were wrong.'

[13] There might initially seem to be some tension between this response and the context challenge explored above. Whereas the context challenge granted the truth of both Colour Similarity and Reflectance Dissimilarity, the response now under consideration involves denying Reflectance Dissimilarity*. There is in fact no formal tension here, however, because the whole point of the context challenge was that Reflectance Dissimilarity and Colour Similarity involved different similarity relations, and that Reflectance Dissimilarity thus did not have the truth conditions specified in Reflectance Dissimilarity*.

candidate for the semantic value of 'similar' in the mouths of ordinary folk when they make colour similarity claims, and b) X is evidently satisfied by $<R_b, R_p, R_g>$. Colour physicalists have been united in their scepticism about the prospects for this direct approach. Byrne and Hilbert (2003, p. 13) observe that 'there does not seem to be an obvious respect in which the ['blue'] reflectance-type is more similar to the ['purple' type] than it is to the ['green' type]', and Byrne (2003, p. 648) goes so far as to conclude that 'we can be completely confident that any plausible physicalist candidates for the colours do not stand in the required genuine similarity relations'.

The prospects for denying Reflectance Dissimilarity* might therefore seem rather bleak. This is to overlook a second, indirect, approach, however, which is to question the motivation for Reflectance Dissimilarity* provided by advocates of the colour similarity argument. As with Reflectance Dissimilarity, Reflectance Dissimilarity* is motivated by the observation that when we examine standard scientific representations of the reflectances R_b, R_p, and R_g such as the reflectance spectra presented in Fig. 1, there does not seem to be any obvious sense in which R_b is more similar to R_p than R_g. Given what we know about reflectances from optics—and let's just suppose that this includes everything that could possibly be relevant to understanding the physical nature of these properties—we simply have no reason to think that R_b, R_p, and R_g stand in the required similarity relation.

It is crucial to note, however, that this observation only provides compelling reason to accept Reflectance Dissimilarity* if we assume that if colour physicalism were true, then the colour similarities that are evident in ordinary visual perception also should be evident under standard scientific representations of the corresponding reflectance-types. In other words, Reflectance Dissimilarity* depends for its cogency on the following scrutability thesis:

> **Scrutability**: If colour physicalism is true, then if blue is more similar to purple than green, then it should be possible to acquire knowledge that R_b is more similar to R_p than R_g under standard physical presentations or descriptions of these reflectances.

The role of this scrutability assumption in the colour similarity argument is highlighted by Byrne (2003, p. 642, fn. 5),[14]

> The argument from similarity assumes that if physicalism about colour is true, then any genuine respects of similarity between the colours will be evident at the level of the canonical physical description of those properties. Absent this assumption, the failure of colour science to find the appropriate genuine respects of similarity would not show that such respects did not exist, thus blocking the argument.

To put this point another way, the argument rests on the assumption that endorsing colour physicalism requires facts about colour similarities to be physical facts, that

[14] Strictly speaking, Byrne (2003) is discussing an epistemological version of the argument, but his point also applies here given that the stated motivation for Reflectance Dissimilarity* clearly depends on the assumption that colour similarities ought to be evident at the level of physical descriptions of reflectance properties.

is, facts that would be evident to anyone provided only with the descriptive and explanatory resources of the relevant reducing theory, which in this case would be optics. As Byrne notes, without this assumption, the fact that it is not immediately evident from their reflectance spectra that R_b is more similar to R_p than R_g would not decisively establish that this similarity did not in fact obtain, thus undercutting the desired support for Reflectance Dissimilarity*.

To be clear, then, my proposal is that the colour physicalist should reject Scrutability, thus taking an indirect approach to resisting Reflectance Dissimilarity*. Let's call this the inscrutability response. The claim is that, contrary to initial appearances, the reflectance-types R_b, R_p, and R_g do in fact stand in the same similarity relations as blue, purple, and green, and that Reflectance Dissimilarity* therefore is false. The reason why Reflectance Dissimilarity* seems true is that these similarities are not scrutable from standard, canonical, scientific presentations of reflectances such as their reflectance spectra.[15] Quite reassuringly, the inscrutability response thus explains the unavailability of the direct approach to denying Reflectance Dissimilarity*. It is precisely because of the inscrutability of colour similarity that it is, in the end, futile to expect a direct or explicit account in physical terms as to how 'R_b is more similar to R_p than R_g' comes out true on the colour physicalist's view.

It is perhaps helpful to think of the inscrutability response as the epistemic analogue of the context challenge. The context challenge held that attributions of similarities among the colours can be true as interpreted in ordinary linguistic contexts (as in Colour Similarity) and false as interpreted in reductive scientific contexts (as in Reflectance Dissimilarity). Somewhat analogously, the inscrutability response claims that some facts about colour similarity are knowable or evident in some epistemic contexts (exercising our ordinary colour vision capacities would be a paradigm example, but presumably we can also come to know such facts via reliable testimony, graphical representations of the colour space, and so on), but not knowable in other epistemic contexts (examining theoretical descriptions of reflectances in optics being the crucial case in point).

In what follows, I shall motivate and develop the inscrutability response first by considering some parallel moves that have been made in response to the mind–body problem, and then by examining some cases from chemistry and biochemistry in which related scrutability theses fail to hold. These philosophical and empirical precedents should, in the end, demonstrate both the viability and attractiveness of the inscrutability response as a defence against the colour similarity argument.

5 The mind–body problem

In order to provide some context and motivation for the inscrutability response, I want to highlight an analogous physicalist solution to the mind–body problem. A

[15] For recent discussion of a wide range of scrutability theses and their relationship to physicalism, see Chalmers (2012). Unfortunately, limitations of space dictate that I cannot engage with Chalmers' work on this topic here.

common way to think about the mind–body problem is as presenting an explanatory gap between mind and body, the mental and the physical. Very roughly the thought is that there is something so peculiarly subjective or first-personal about phenomenal consciousness that it seems that one could never provide a fully adequate account or explanation of the distinctive nature of conscious states within a purportedly objective or third-personal scientific theory of the brain. One of the most vivid illustrations of this putative gap is provided by Jackson's (1986) knowledge argument. As I assume will be familiar, Mary is assumed to have encyclopaedic knowledge of neuroscience, in particular the neural facts concerning the visual processing of colour. For all her neuroscientific knowledge, however, Mary in her black and white room seemingly lacks any knowledge as to the phenomenal character of visual experiences as of red: when Mary leaves her room and sees red for the first time, it seems intuitive (to many) to think that she learns a new fact concerning the qualitative nature of her colour experience, that is, concerning what it's like to undergo an experience as of red. Given that ex hypothesi Mary already has knowledge of all the relevant physical facts concerning visual processing, it is supposed to follow that the fact that Mary learns regarding her experience as of red is a non-physical fact.

As is widely recognised, the anti-physicalist conclusion of the knowledge argument only follows given an assumption about the scrutability of mental facts from physical facts. To be clear, the assumption is that if physicalism about the mental were true, then Mary would be able to acquire the relevant piece of psychological knowledge in her black and white room, equipped only with her knowledge of neuroscientific facts, plus her a priori deductive capacities. In the jargon, those that accept this scrutability assumption but deny the conclusion of the knowledge argument are known as type-A physicalists. One popular type-A strategy is to argue that when Mary leaves her black and white room, she does not gain a new piece of factual knowledge after all, but rather a new ability.[16] Others have responded to the knowledge argument by denying the scrutability assumption, yielding what is known as type-B physicalism. Type-B physicalists claim that while there is an intimate metaphysical relation between mind and body—as it might be, type-identity—there nonetheless exist genuine epistemic barriers to acquiring knowledge about the nature of mental state types given only the explanatory resources of physical theories. According to type-B physicalism, upon leaving her black and white room, Mary does acquire new knowledge regarding what it is like to see red, but this knowledge nonetheless concerns some more or less complex neuroscientific fact. As the saying goes, Mary learns an old fact, but in a new way, or under some new mode of presentation.[17]

There are important but perhaps underappreciated parallels between the mind–body problem and the colour similarity argument. Just as the mind–body problem presents a subjective explanatory gap between qualitative features of conscious

[16] Lewis (1988).

[17] For an example of such a view, see Loar (1997). See Chalmers (2002) for a detailed taxonomy of the different varieties of physicalism.

experience and physical features of brain states, so the colour similarity argument presents what Shoemaker (2003, p. 254) calls an objective explanatory gap between features of the world that are presented or represented in visual experience and features of the world attributed by our best physical theories,

> [The] objective explanatory gap problem… is in some ways more fundamental and certainly of much greater antiquity [than the subjective explanatory gap problem]. This is the problem of how colours, given their perceived nature, can be, or be realized in, physical properties of things, given what we know about these physical properties. This is a central case of the problem Wilfrid Sellars raised by asking how, if at all, we can reconcile the "manifest image," embodied in the common sense view of the world and our ordinary experience of it, with the "scientific image."

Shoemaker (2003, pp. 257–258) continues,

> A central part of the objective explanatory gap problem is explaining how it is that what are physically very diverse properties can be realisers of the same shade of colour, and, more generally, how it is that physical properties can have a similarity ordering, qua colour realisers, that bears no apparent relation to any similarity relations that would seem salient to someone who was taxonomising them simply as physical properties.

Johnston (1996, p. 226) draws a similar comparison,

> It is no easier to make intelligible how the colour properties as we represent them could be constituted by reflectance profiles then it is to make intelligible how the property of being in pain could be constituted by the property of having one's C-fibres firing. The [colour physicalist's] account leaves us with a variant of the mind–body problem at the surfaces of objects.

As does Kalderon (2007, pp. 595–596),

> The problem of the manifest [i.e. the objective explanatory gap] and the mind–body problem are structurally parallel… just as the limitations of what could be known solely on the basis of our knowledge of the material world can pose the problem of the manifest, so too can these limitations pose the mind–body problem.

In much the same way as the subjective explanatory gap generates problems for physicalist views of the metaphysics of mind, so the objective explanatory gap presents the deepest puzzle for physicalist views of colour ontology. How could the mind be purely physical in nature, given that even complete knowledge of neuroscience seemingly would fail to provide us with knowledge of the qualitative character of ordinary conscious experience? How could the colours be physical properties such as surface reflectances, given that our best scientific accounts of these properties completely fail to account for the characteristic patterns of similarity and dissimilarity that we perceive among the colours?

As we have seen, the knowledge argument rests on an assumption about the scrutability of the mental from the physical, and the colour similarity argument likewise depends for its cogency on an assumption about the scrutability of colour similarity facts from physical reflectance facts. If you like, Scrutability implies that if colour physicalism were true, then Mary should be able to acquire knowledge of all facts about colour structure equipped only with knowledge of the facts about reflectances that one can garner from optics, plus her a priori deductive capacities. Extending the terminology introduced above, colour physicalists who accept Scrutability can be termed type-A colour physicalists and those who deny it type-B colour physicalists. In its starkest form, then, my proposal is that colour physicalists should be type-B rather than type-A. Like their mind–body cousins, type-B colour physicalists hold that while there is an intimate metaphysical relation between the colours and the reflectances—as it happens, type-identity—there nonetheless exist genuine epistemic barriers to acquiring knowledge about the structural features of colour properties given only the descriptive, representational, and explanatory resources of optics. On this view, when Mary visually perceives blue, purple, and green, she is able to acquire knowledge regarding their comparative similarities that could not be acquired given even a complete knowledge of optics. The knowledge that Mary acquires nonetheless concerns some more or less complex physical fact. To coin a saying, in perceiving these colours for the first time, Mary would learn an old fact about their comparative similarities, but in a new way, or under some new mode of presentation.

Type-B colour physicalism implies that there exist genuine physical facts regarding colour similarities that are not evident under standard physical representations of these properties. One might wonder, however, whether structural facts about reflectance properties that cannot be learned by consulting optics truly deserve the title ‘physical’. This issue forms the basis for an objection to the inscrutability response, pressed by Byrne (2003, p. 642, fn. 5) as follows,

> So the physicalist might reply by denying [Scrutability]. He might say that, although colours are physical properties, some genuine respects of similarity between them can only be detected by vision. Put another way, although the colours do not stand in the intuitive genuine similarity relations qua physical properties, they do stand in these relations qua visible properties. Thus, according to this reply, there is a sense in which the nature of certain physical properties is not wholly physical, and so the view is more a kind of dual aspect theory than full-blooded physicalism. For this reason, I shall not explore this reply further.

Summarising somewhat, Byrne’s objection is that by denying Scrutability, the colour physicalist would surrender any claim to being a genuinely reductive theory, and would thereby find herself in the mire of a dualist theory of colour structure.[18]

In evaluating this objection, we should note that the charge of closet property dualism can also be levelled against type-B physicalism about the mental. The type-B response to the knowledge argument is that upon leaving her black and white room, Mary learns an old physical fact about brain processing, but in a new way, or

[18] Thanks to Alex Byrne for confirming the accuracy of this interpretation in personal correspondence.

under some new mode of presentation. One might object, however, that having a new way of knowing, or some new mode of presentation of a fact, surely implies the existence of some new property that is being presented. As Block (2007, p. 6) puts it, the worry then is that 'when [Mary] acquires a subjective concept of the property that she used to have only an objective concept of, a new unreduced subjective property is required to "pin down" the old objective property.' The details of this debate are well beyond the scope of this paper. The point of the comparison, however, is to establish a sort of good company response to Byrne's objection. In the fullness of time, the type-B colour physicalist can adapt and apply strategies already developed by type-B mental physicalists in responding to this issue, and to that extent I believe can be confident of mounting a defence against the property dualism objection.[19]

Having presented some initial context and motivation for the inscrutability response, we can now fully appreciate the benefits of the view by comparing it with the experiential response. Rather satisfyingly, the inscrutability response retains all of the advantages of the experiential response while avoiding the problems that led to its demise. Like the experiential response, the inscrutability response allows us to retain commonsense objective realism about the colours and thus avoids a perceptual error theory. Somewhat interestingly, the inscrutability response also allows us to respect the plausible thought that facts about colour structure surely depend in some sense on the nature of our visual systems. Whereas the experiential view took this dependence to be metaphysical or constitutive, the inscrutability response posits a specific and limited sort of epistemic dependence. On this view, there exist some structural facts about the colours that, although not evident under physical theoretical descriptions of these properties, are nonetheless evident or knowable on the basis of ordinary visual perception of colour. The inscrutability response also avoids the three major problems for the experiential response noted above. On the epistemic front, the inscrutability response holds that our knowledge of facts about colour structure derives primarily from our visual perception of the colours themselves, and not from introspection on the character of our visual experiences, exactly as one should expect. On the linguistic front, the inscrutability response retains Simple Truth Conditions and thus respects our commonsense view of the content of colour similarity claims. On the metaphysical front, the inscrutability response situates second-order structural and relational features of the colours as mind- and response-independent features of the surfaces of objects, exactly as they intuitively seem to be. What more could one ask for?

6 Chemistry, biochemistry, and the presentation sensitivity of knowledge

In this final section, I shall present some additional, independent, reasons to adopt the inscrutability response, deriving from more general considerations regarding the presentation sensitivity of knowledge of similarity. As everyone knows, all

[19] See Block (2007) for relevant discussion and White (2007) for objections.

knowledge is presentation sensitive.[20] I can know that Dame Edna is glamorous while disbelieving that Barry Humphreys is glamorous, even though Barry Humphreys is Dame Edna. Knowledge of similarities among properties is no exception, of course. Suppose that blue is Cameron's favourite colour, purple is Brown's favourite colour, and green is Blair's favourite colour. While it is common knowledge that blue is more similar to purple than green, absenting auxiliary knowledge of the chromatic preferences of Cameron, Brown, and Blair, I am not in a position to know that Cameron's favourite colour is more similar to Brown's favourite colour than Blair's favourite colour. As presented under these descriptions, the comparative similarities among the colours blue, purple, and green are simply not evident to me.

It is obviously implausible, then, to think that colour similarities should be evident or knowable under all presentations of these properties. In evaluating Scrutability, however, we need to consider whether it is nevertheless plausible to expect that colour similarities should be evident under all presentations of a very particular and privileged sort: namely, canonical physical representations of surface reflectances such as the spectral reflectance curves employed in optics. Does this principle generalise? That is, do successful inter-theoretic reductions on the whole guarantee that genuine similarities among the reduced kinds will be evident under representations of those kinds at the reducing level?

It is relatively straightforward to show that not all genuine similarities among reduced kinds are evident under all presentations of those kinds at the reducing level. Here is an example from chemistry. Many people would judge intuitively that there is some genuine sense in which diamonds are more similar to sapphires than coal. It is presumably uncontroversial that these kinds are type-identical to chemical compounds: diamond and coal are allotropes of carbon—tetrahedrally bonded and amorphous carbon, respectively—and sapphire is a form of aluminium oxide. Hence chemical representations of these compounds would constitute standard, canonical, ways of representing diamond, sapphire, and coal at the reducing level. One common way of representing these compounds is by their chemical or molecular formulae, which represent facts about the type and number of atoms constituting each compound. Under these presentations, however, it is not at all evident that diamond is more similar to sapphire than coal. On the contrary, relative to the respects of comparison made evident by their chemical formulae, we would have reason to think that diamond is more similar to coal than sapphire.

Now of course, this is not to say that the intuitive similarity between diamond and sapphire is not evident under any chemical presentation. Another standard way of presenting chemical compounds is by their structural formulae, which additionally represent the type of bonding between atoms. Unlike their molecular formulae, the

[20] The following discussion has been inspired and informed by Williamson's (1990) discussion of the presentation sensitivity of discrimination, the acquisition of knowledge of distinctness. 'Presentation' is to be understood here in a broad and inclusive way. A single property type (scarlet) can be presented by terms ('scarlet'), linguistic descriptions ('the colour of my armchair'), and visual perceptual states (my state of visually perceiving the colour of my armchair), but can also be presented simply by its instances at particular places and times (my armchair).

structural formulae for diamond, sapphire, and coal would make evident the noted similarity between diamond and sapphire. There are other cases, however, in which genuine chemical similarities are evident under neither molecular nor structural formulae. For example, stereoisomers are compounds with exactly the same atomic composition and bond structure but different geometrical profiles. Geometrical differences in the relative rotation of bonded atoms can affect the potential energy of a compound. Similarities or dissimilarities in potential energy would not be evident or predictable from the structural or molecular formulae for stereoisomers, as these do not represent the spatial position of atoms within molecules. Chemists accordingly have developed different ways of representing compounds that are better suited to predicting such similarities. For example, in addition to representing chemical bonds, Newman projections also represent the angles between atoms, which are a crucial determinant of potential energy. The issue simply iterates, however, for it is certain that there will be other genuine chemical similarities that are not evident under any of the representations mentioned above.[21] In any case, it seems clear that given any genuine chemical similarity, there will be at least some theoretical presentation of the relevant chemical compounds under which that similarity will not be evident.

The conclusion of the last paragraph takes us some way to our destination, but the key issue at hand is whether there exist similarities between indisputably physical kinds that are not evident under any standard reductive representations of those kinds. In tackling this issue, I want to consider the case of reductions between biochemistry and chemistry. Biochemistry is the study of the chemical structures and processes involved in biological activities such as digestion and cell creation or duplication. Biochemistry groups or classifies chemical compounds according to their biological activities; more specifically, according to the ways in which these compounds interact or bond with biological macromolecules or biomolecules, the proteins, nucleic acids, carbohydrates, and lipids that make up living cells. Let’s call these groupings biochemical-types. These biologically inspired kinds might be quite uninteresting from the perspective of a structural chemist, but this does not mean that they are any less chemical in nature.[22] Even if no biomolecules had existed, there still would have been biochemical-types.

Biochemical-types stand in distinctive relations of biochemical similarity and dissimilarity. As an initial gloss, the biochemical similarity of two molecules is determined by their relative biological activity, particularly the ways in which the molecules interact and bond with biomolecules. Biochemical similarity ought not to be confused with mere similarity in respect of biological effects or responses,

[21] One only need peruse the vast literature on quantum similarity measures (for example, Carbó-Dorca and Mezey 1996), to appreciate the variety and complexity of representations developed to reflect aspects of chemical structural similarity.

[22] Important aspects of chemical structure are molecular constitution, configuration, and conformation. Constitution relates to the manner and sequence of bonding between atoms in a molecule. Configuration concerns the 3D arrangement of atoms in the molecule, particularly the valence angles of atoms as discussed above in connection with stereoisomers. Conformation relates to the thermodynamically stable spatial arrangements of atoms within a molecule.

however, which would make it an entirely extrinsic matter. As it is understood here, the biochemical similarity of two molecules rather is determined by complex aggregations of intrinsic chemical features, such as their geometrical and topological features, functional groupings, and overall molecular size, which determine the bonds that will form between the molecule and biological macromolecules. To put this point in terms of supervenience, there could be no difference in the comparative biochemical similarity of two compounds without some difference in their underlying chemical structure.

Now, crucially, there exist some biochemical similarities between compounds that are not evident under any standard chemical structural descriptions or representations of those compounds. This fact has appeared in the literature in discussing apparent violations of one of the fundamental assumptions of biochemistry known as the 'structure–activity relationship', described by Kubinyi (1998, p. 225) as follows,

> The underlying concept is that chemical similarity is reflected by similar biological activities—i.e. chemically closely related analogues should be related in their mode of action, as well as in their relative potencies. This fundamental assumption has, indeed, been used in medicinal chemistry research, and has led to many valuable drugs.

The assumption, then, is that the comparative biochemical similarity of two molecules will be predictable or evident under some presentation of the chemical structure of those molecules. There are seemingly many cases, however, in which genuine biochemical similarities are not at all evident under such reductive presentations of the relevant kinds.[23] Nikolova and Jaworska (2003, p. 1016) report that 'several surprising structure–activity relationships demonstrate that chemically similar compounds may have significantly different biological actions and activities and different molecules can be very similar in their biological activities…' Bajorath (2002, p. 890) refers to such cases as 'similarity paradoxes', whereby 'minor chemical modifications of otherwise similar molecules can render them [biochemically] either active or inactive'.

Bringing the discussion back to the inscrutability response, there are instructive parallels between the biochemist's unsuccessful attempts to recover all biochemical similarities at the level of chemical structural descriptions, on the one hand, and the colour physicalist's inability to find evidence for colour similarities at the level of optical representations of reflectance properties, on the other. As we have seen, both the biochemist and the colour physicalist group or classify underlying chemical or physical kinds in ways that reflect their particular theoretical interests—understanding biological processes in the former case, and human colour vision abilities in the latter—yielding biochemical-types and reflectance-types respectively. Both of these categories are perfectly objective, response-independent, chemical or physical kinds, and are not constituted by relations to biological or perceptual effects. Recalling Byrne and Hilbert's (2003, p. 11) comments, however, reflectance-types

[23] For example, Kubinyi (1998, p. 228; 2002, p. 244) reports that 'the [biochemical] selectivity of these analogues against the two [adrenergic] receptors differs by nearly eight orders of magnitude, despite their close chemical similarity!'

'will be quite uninteresting from the point of view of physics or any other branch of science unconcerned with the reactions of human perceivers,' and the same could be said, mutatis mutandis, regarding the structural chemist's disinterest in biochemical-types. Now, generalising on the foregoing discussion of biochemical similarity, we have good reason to think that not all similarities that are characteristic of such interest-relative (but nonetheless fully objective and response-independent) kinds will be evident under reductive descriptions or presentations of their underlying physical bases. Rather it seems that some similarities of this sort will only become evident once these kinds enter into the relations that endow them with human interest, such as biological interactions in the case of biochemical kinds, and visual perceptual relations in the case of the colours. This does not make these similarities any less physical, that is, any less dependent on the physical or chemical nature of the kinds in question. These inscrutability phenomena simply seem to reflect a quite general feature of our knowledge of similarities among such interest-relative physical kinds. In denying Scrutability, then, the type-B colour physicalist is in much the same position as the biochemist who rightly maintains her reductive view of biochemical-types in the face of the biochemical similarity paradoxes.

Before concluding the paper, it is necessary to note a complication with the above account. I have argued that some biochemical similarities are not evident under any standard chemical structural descriptions of the relevant biochemical-types. This conclusion has in turn provided some justification for the inscrutability response to the colour similarity argument. It is not strictly accurate, however, to say that biochemical similarities are not evident under any chemical descriptions whatsoever. The so-called similarity paradoxes in biochemistry have triggered a cottage industry in developing representations that capture the patterns or regularities in chemical structure most relevant to biological activity, and which are thus better suited to predicting biochemical similarity. Kubinyi (1998, p. 249) calls these 'target-dependent' descriptions, as contrasted with the 'target-independent' descriptions geared towards understanding chemical structure in its own right.[24] This raises the question as to whether analogous 'target-dependent' descriptions of surface reflectance properties might, after all, make ordinary colour similarities evident at the reducing level. This line of inquiry certainly seems promising, and might eventually prove fruitful.[25] Even if this ultimately proved possible, however, this would not undermine the central point of the inscrutability response, which is to deny the heretofore unarticulated assumption that colour physicalism requires all ordinary colour similarities to be evident under standard or canonical physical representations of reflectances such as the spectral reflectance curves presented in Fig. 1. This was the assumption that we have seen to lie behind

[24] See also Patterson et al. (1996, p. 3049) on so-called 'pharmacophoric descriptors'. The complex aggregations of chemical features represented by such descriptors are selected specifically on the basis of their ability to predict biological activity.

[25] One could perhaps view Byrne and Hilbert's (2003, p. 15) hue magnitudes response to the colour similarity argument along these lines. Very roughly, this response sketches a way of representing reflectance-types that reflects the opponent coding employed by the colour vision system. I hope to discuss this approach in more detail in forthcoming work.

Reflectance Dissimilarity*, and in rejecting it the colour physicalist acquires an indirect but forceful and novel response to the colour similarity argument.

7 Conclusion

In many people's eyes, the colour similarity argument poses the greatest threat to colour physicalism. This paper started out by presenting a challenge to standard formulations of the colour similarity argument, centring on the extreme context sensitivity of the similarity relation. Although ultimately inconclusive, the context challenge forced a significant reformulation of the argument, and highlighted the need for considerably greater care in handling claims about similarity. After presenting some problems for the popular experiential response to the colour similarity argument, I turned to my own inscrutability response. This response begins with the observation that the motivation for the premise Reflectance Dissimilarity* rests on an epistemic assumption regarding the scrutability of colour similarity from standard physical descriptions of surface reflectance properties. In rejecting this assumption, the inscrutability response provides an indirect route to rejecting Reflectance Dissimilarity*, a strategy that has not been attempted by colour physicalists to date. The response was motivated via consideration of analogous manoeuvres executed by type-B physicalists in response to the mind–body problem, and by cases in chemistry and biochemistry in which related scrutability theses seemingly fail to hold. The resulting view is that despite an extremely tight metaphysical relationship between colours and reflectance properties, there nonetheless exist genuine epistemic barriers to acquiring knowledge of facts about colour structure at the level of the reducing physical theory.

Acknowledgments Thanks to John Hawthorne, Tim Williamson, and two audiences at the University of Cambridge for extremely helpful feedback on earlier versions of this paper. I am most grateful to the referee for Philosophical Studies, who has been identified to me as Adam Pautz, who provided an incredibly rich, detailed, and constructive set of comments that resulted in substantial changes and improvements to the paper.

References

Armstrong, D. (1978). *Universals and scientific realism: A theory of universals* (Vol. II). Cambridge: Cambridge University Press.

Bajorath, J. (2002). Integration of virtual and high-throughput screening. *Nature Reviews Drug Discovery, 1*, 882–894.

Barsalou, L. W. (1982). Context-independent and context-dependent information in concepts. *Memory and Cognition, 10*(1), 82–93.

Block, N. (2007). Max Black's objection to mind–body identity. In T. Alter & S. Walter (Eds.), *Phenomenal concepts and phenomenal knowledge: New essays on consciousness and physicalism* (pp. 249–306). Oxford: Oxford University Press.

Boghossian, P. A., & Velleman, D. J. (1991). Physicalist theories of colour. In A. Byrne & D. Hilbert (Eds.). (1997). Readings on colour. Vol. 1: The philosophy of colour (pp. 105–136). Cambridge, MA: MIT Press.

Braddon-Mitchell, D., & Jackson, F. (1996). *The philosophy of mind and cognition*. Oxford: Blackwell.

Byrne, A. (2003). Colour and similarity. *Philosophy and Phenomenological Research, 66*(3), 641–665.

Byrne, A., & Hilbert, D. (Eds.). (1997). Readings on colour. Vol. 1: The philosophy of colour. Cambridge, MA: MIT Press.
Byrne, A., & Hilbert, D. (2003). Colour realism and colour science. *Behavioural and Brain Sciences, 26*, 3–64.
Byrne, A., & Hilbert, D. (2008). Basic sensible qualities and the structure of appearance. *Philosophical Issues, 18*, 385–405.
Carbó-Dorca, R., & Mezey, P. G. (1996). *Advances in molecular similarity* (Vol. 1). Greenwich, CT: JAI Press.
Chalmers, D. (2002). Consciousness and its place in nature. In D. Chalmers (Ed.), *Philosophy of mind: Classical and contemporary readings*. Oxford: Oxford University Press.
Chalmers, D. (2012). *Constructing the world*. Oxford: Oxford University Press.
Clark, A. (1996). True theories, false colours. *Philosophy of Science, 63*(Supplement Issue), S143–S150.
Cohen, J. (2003). On the structural properties of the colours. *Australasian Journal of Philosophy, 81*, 78–95.
Cohen, J. (2009). *The red and the real: An essay on colour ontology*. Oxford: Oxford University Press.
Goodman, N. (1970). Seven strictures on similarity. In L. Foster & J. Swanson (Eds.), *Experience and theory*. Boston: University of Massachusetts Press.
Hardin, C. L. (1988). *Colour for philosophers: Unweaving the rainbow*. Indianapolis, MA: Hackett.
Hering, E. (1920/1964). Grundzüge der Lehre vom Lichtsinn. Translated as Outlines of a theory of the light sense (L. M. Hurvich & D. Jameson, Trans.). Cambridge, MA: Harvard University Press.
Hilbert, D. R. (1987). Colour and colour perception: A study in anthropocentric realism. Stanford: Center for the Study of Language and Information.
Jackson, F. C. (1986). What Mary didn't know. *Journal of Philosophy, 83*, 291–295.
Jackson, F. C. (1998). *From metaphysics to ethics: A defence of conceptual analysis*. Oxford: Oxford University Press.
Johnston, M. (1992). How to speak of the colours. *Philosophical Studies, 68*, 221–264.
Johnston, M. (1996). A mind–body problem at the surface of objects. *Philosophical Issues, 7*, 219–229.
Kalderon, M. (2007). Colour pluralism. *Philosophical Review, 116*(4), 563–602.
Kennedy, C. (2007). Vagueness and grammar: The semantics of relative and absolute gradable adjectives. *Linguistics and Philosophy, 30*, 1–45.
Kubinyi, H. (1998). Similarity and dissimilarity: A medicinal chemist's view. *Perspectives in Drug Discovery and Design, 9–11*, 225–252.
Kubinyi, H. (2002). Chemical similarity and biological activities. *Journal of Brazilian Chemical Society, 13*(6), 717–726.
Lewis, D. (1986). *On the plurality of worlds*. Oxford: Blackwell.
Lewis, D. (1988). What experience teaches. *Proceedings of the Russellian Society, 13*, 29–57.
Lewis, D. (1997). Naming the colours. *Australasian Journal of Philosophy, 75*, 325–342.
Loar, B. (1997). Phenomenal states. In N. Block, O. Flanagan, & G. Güzeldere (Eds.), *The nature of consciousness: Philosophical debates*. Cambridge, MA: MIT Press.
Maund, B. (1995). *Colours: Their nature and representation*. New York: Cambridge University Press.
McLaughlin, B. (2000). Colours and colour spaces. In R. Cubb-Stevens (Ed.), Proceedings of the twentieth world congress of philosophy (Vol. 5). Philosophy Documentation Centre.
McLaughlin, B. (2003). Colour, consciousness, and colour consciousness. In Q. Smith & A. Jokic (Eds.), Consciousness: New philosophical perspectives (pp. 97–154). New York: Oxford University Press.
Medin, D. L., Goldstone, R. L., & Gentner, D. (1993). Respects for similarity. *Psychological Review, 100*(2), 254–278.
Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological Review, 92*(3), 289–316.
Nikolova, N., & Jaworska, J. (2003). Approaches to measure chemical similarity—A review. *QSAR & Combinatorial Science, 22*(9–10), 1006–1026.
Patterson, D. E., Cramer, R. D., Ferguson, A. M., Clark, R. D., & Weinberger, L. E. (1996). Neighbourhood behaviour: A useful concept for validation of "molecular diversity" descriptors. *Journal of Medicinal Chemistry, 39*, 3049–3059.
Pautz, A. (2006). Can the physicalist explain colour structure in terms of colour experience? *Australasian Journal of Philosophy, 84*(4), 535–564.
Quine, W. V. O. (1969/1999). Natural kinds. In J. Kim & E. Sosa (Eds.), Metaphysics: An anthology (pp. 223–242). Oxford: Blackwell, 1999.
Shoemaker, S. (1991). Qualia and consciousness. *Mind, 100*, 507–524.

Shoemaker, S. (2003). Content, character, and colour. *Philosophical Issues, 13*(1), 253–278.

Smart, J. J. C. (1975). On some criticisms of a physicalist theory of colours. In A. Byrne & D. Hilbert (Eds.). (1997). Readings on colour. Vol. 1: The philosophy of colour. Cambridge, MA: MIT Press.

Thompson, E. (1995). *Colour vision: A study in cognitive science and the philosophy of perception*. London: Routledge.

Tversky, A. (1977). Features of similarity. *Psychological Review, 84*(4), 327–352.

White, S. L. (2007). Property dualism, phenomenal concepts, and the semantic premise. In T. Alter & S. Walter (Eds.), *Phenomenal concepts and phenomenal knowledge: New essays on consciousness and physicalism* (pp. 210–248). Oxford: Oxford University Press.

Williamson, T. (1990). *Identity and discrimination*. Oxford: Basil Blackwell.