

Spectrum Inversion

Peter W. Ross

Introduction

The fundamental idea of spectrum inversion is that the way a particular object looks with respect to colour can vary radically—as radically as the difference between what it’s like to see red and green—between two perceivers in the same viewing conditions (or a single perceiver over time in similar viewing conditions). This idea can occur to people independent of philosophical or scientific discussion of colour and colour perception, often with an interest in whether such differences could be undetectable. The philosophical treatment of the spectrum inversion idea examines its presuppositions and its implications for accounts of colour and colour experience. In what follows, I’ll focus on the current philosophical treatment of the spectrum inversion idea as this idea is expressed in a general form of argument, often called the inverted spectrum hypothesis. (Locke’s use of the spectrum inversion idea is often noted as an important example of a philosophical treatment, but since Locke’s theoretical purposes in using spectrum inversion were so different from current theoretical purposes, I’ll set Locke’s views aside; for a historical examination of Locke’s purposes, see Allen, 2010.)

Characterized as a general form of argument, the inverted spectrum hypothesis has instances which compose a family of objections to certain kinds of account of colour experience. These objections are typically presented in thought experiments which envision a difference in colour experience as being radical and systematic, even while properties relevant to colour experience are the same. A simple illustration of the radical difference in colour experiences that these thought experiments present is this: suppose that two people see a particular ripe strawberry, and one (helpfully named Nonvert) experiences the strawberry as red (that is, as we experience ripe strawberries), while the other (helpfully named Invert) experiences the strawberry as green (that is, as we experience ripe limes). This radical difference in colour experience is systematic in that, for example, as they look at a variety of objects together, Invert experiences objects as

red just in case Nonvert experiences them as green, and Invert experiences objects as green just in case Nonvert experiences them as red, and that this sort of inversion occurs for a wide range of colours. (One might presume that ‘a wide range of colours’ means every colour in the spectrum. The term ‘spectrum inversion’, while standard in the literature, is misleading. What’s typically meant is a shift in the psychological colour space—a representation of qualitative relations among colours with respect to hue, saturation, and lightness—that flips one or both of the red-green and yellow-blue poles.)

As described so far, this instance of the hypothesis provides a challenge for an account of differences in colour experiences in terms of differences in the properties of objects experienced (for example, properties of the ripe strawberry) and viewing conditions (including lighting), since the differences in colour experiences occur while Nonvert and Invert are looking at the same object in the same viewing conditions. But the hypothesis has many other instances.

For example, the hypothesis is commonly presented in a thought experiment elaborated to suppose that relevant functional (or causal) properties of Nonvert’s and Invert’s colour experiences are the same despite their radical and systematic difference in colour experiences. Such functional properties include how perceivers interact with, think about, and communicate about red and green objects. To illustrate this further supposition, consider that Nonvert’s experience caused by a French absinthe causes her to say “What a lovely green”, while Invert’s experience caused by the same absinthe causes him to say “What a lovely green”, despite the radical difference in their colour experiences, and that, more generally, the difference in colour experience isn’t manifested in anything that Nonvert and Invert say or do. This instance of the hypothesis provides a challenge for the standard functionalist account of colour experience, since differences in colour experience occur even while Nonvert’s and Invert’s colour experiences are equivalent in their causal relations to stimuli, other mental states, and behaviour, precisely the factors by which the standard functionalist account characterizes colour experience.

To set up a discussion of the inverted spectrum hypothesis and some of the main differences among its instances, I’ll explain some terminology. By ‘colour experience’ I’ll mean a kind of perceptual state. I’ll assume that these states can be characterized as

representational states, since this is widely assumed in the literature having to do with spectrum inversion. (By a ‘representational state’ I mean a mental state that conveys a content, that is, a way things are, where this content can be accurate or inaccurate.) Adopting useful terminology from Byrne and Hilbert (1997b and 1997c), I’ll call the aspect of the experience often described as what it’s like to be conscious of colour the ‘colour-feeling’ aspect, and I’ll call the aspect of the experience of colour that represents colour as a property of objects the ‘colour-representing’ aspect (Shoemaker, 1982, pp. 647–8 draws the same distinction in terms of the qualitative character and the intentional content of colour experience; the colour-feeling aspect is sometimes called the phenomenal aspect). (Because some theorists who support the inverted spectrum hypothesis, for example, Ned Block, claim that the colour-feeling aspect of experience is ineffable and so cannot be specified in language as, for example, red feeling as opposed to green feeling, I won’t use determinate colour terms—red, green, etc.—to express the colour-feeling aspect.)

The centre of attention for all instances of the inverted spectrum hypothesis is the colour-feeling aspect. All instances strive to show that the colour-feeling aspect cannot be accounted for in terms of some other properties relevant to characterizing colour experience, and all instances strive to show this by means of hypothesizing the separation of the colour-feeling aspect from these other properties.

However, there are two importantly different ways in which the inverted spectrum hypothesis is deployed, either objecting to a direct account of the colour-feeling aspect of colour experience in terms of some candidate non-qualitative property, or objecting to an account of the colour-feeling aspect in terms of the colour-representing aspect. According to the first type of objection, the colour-feeling aspect cannot be explained in terms of non-qualitative properties, in particular, some range of physical (including neurophysiological) or functional properties. In this case, instances of the hypothesis are used to distinguish the colour-feeling aspect from the candidate physical or functional property—as, for example, an instance was just used against the standard functionalist account of colour experience. Used this way, an instance of the hypothesis is a *direct objection* to an attempted account.

According to the other type of proposal, the colour-feeling aspect cannot be explained in terms of the colour-representing aspect (or, in other words, in terms of representational content, since the colour-representing aspect is characterized in terms of content); this type of account of the colour-feeling aspect is often called representationalism. By itself, representationalism does not claim that the colour-feeling aspect can be accounted for in non-qualitative terms. Thus, an objection to representationalism does not directly object to such an account. However, a well-known strategy for explaining the colour-feeling aspect in non-qualitative terms combines representationalism with an account of mental representation in functional terms (in particular, in terms of some specified causal relation that determines content) and an identification of colours included in content with physical properties of objects. (This strategy has been prominent recently, but it has been around at least since the 1960s; see, for example, Armstrong 1968/1993, and in particular pp. xviii–xix, and pp. xxi–xxii for a brief summary.) Instances of the inverted spectrum hypothesis are used to undermine this strategy by distinguishing the colour-feeling aspect from representational content. In this case, the route to an account of colour feeling in non-qualitative terms is blocked. When the inverted spectrum hypothesis is used in this way, it is an *indirect objection* to the attempt at a non-qualitative account.

After explaining the reasoning involved in use of instances of the hypothesis as direct objections in section 1 and as objections to representationalism in section 2, I'll briefly take up the issue of the kind of possibility involved with the hypothesis in section 3 and the methodologies used to assess possibilities in section 4. I'll then describe some general considerations that are commonly used against the inverted spectrum hypothesis in section 5, and in section 6 I'll discuss attempts to support it with findings from colour science. I'll end with an opinionated conclusion.

1 Direct objections to non-qualitative accounts of colour feeling

Many theories of the nature of mind since the second half of the twentieth century attempt to account for mind in physical or functional terms, and so attempt to account for colour experience—a kind of mental state—in these terms. In offering an

explanation of colour experience, each of these attempts has faced its own instance of the inverted spectrum hypothesis. I'll centre my discussion on instances opposing different versions of functionalism.

1.1<en>The inverted spectrum thought experiment

Consideration of spectrum inversion typically involves a thought experiment. Such thought experiments have been depicted in many ways, but the gist is to suppose circumstances which make plausible the claim that while some range of properties relevant to characterizing colour experience are the same, the colour-feeling aspect can vary. When the inverted spectrum hypothesis is used directly against an attempted account of colour feeling in non-qualitative terms, the range of properties is some specified range of physical or functional properties offered to explain the colour-feeling aspect. As I'll explain in section 2, when the hypothesis is used against representationalism, the range of properties is a range of colour-representing properties (characterized in terms of content) offered to account for the colour-feeling aspect.

Ned Block offers a widely known presentation of the inverted spectrum thought experiment (I'll focus on his 2007, pp. 91–100 presentation of the thought experiment, but this presentation is similar to those in his 1990, pp. 681–2, and his 1994, p. 516; also, it is interesting to see the similarity in general outline between Block's presentation and Armstrong's 1968/1993, pp. 259–60). The thought experiment involves putting you, the reader, in the shoes of a subject of an experimental colour inversion surgery, and the story is intended to get you to consider a series of events from the first-person perspective. (Block's 2007 presentation can be used against functionalism, as Block notes on p. 93 and as I'll discuss in this section, but its primary aim is to argue for the existence of ineffable colour-feeling aspects of experience, which Block calls colour qualia (2007, p. 74). In section 2, I'll give additional background for the argument for ineffable colour-feeling aspects.)

At Stage 1 of the thought experiment you are a normal colour perceiver. As a normal colour perceiver, your colour experiences are veridical (or accurate) in normal viewing conditions. (In this context, veridicality has to do with accurately identifying the determinate colour attributed to objects—as red or green, for example. This claim

need not conflict with eliminativist views, which, as Boghossian and Velleman, 1989, pp. 98–101 contend, can give an account of the veridicality of colour attribution.)

Stage 2 occurs a day after (elective) colour inverting surgery (which, as far as Block's description specifies, flips the red-green poles of the psychological colour space). At this point, some things seem to have changed colours. It seems that ripe strawberries have turned green, but your experiences of red and green are not veridical; red things look as green things had before the surgery, and green things looks as red thing had.

Decades later, at Stage 3, red things still look as green things had before the surgery, and you acknowledge this as an odd sort of colour illusion. In the meanwhile, a few years after the surgery, to fit in with your peers' use of colour language, you *say* that red things are red, even though they still look as green things used to look. Thus, you effortfully mimic your pre-surgical use of colour language. Eventually, mimicking becomes effortless, and your beliefs about red things, as well as your experiences of red things in normal viewing conditions, become red representing. But you continue to acknowledge that red things look as green things had prior to the surgery. Thus, even though your experiences of red objects are red representing, you still acknowledge that you have an odd sort of colour illusion.

Finally, yet another decade later at Stage 4, you develop amnesia with respect to the period of time up to Stage 3, and thus you have no memory of the surgery or the way things had looked prior to it with respect to colour. You continue to say that red things are red, and so you continue to effortlessly mimic your pre-surgical behaviour, and your experience continues to be red representing. But, since you no longer remember the surgery or the way things used to look, you no longer acknowledge that red things look the way green things had looked. Consequently, even though you are still colour inverted, there's no difference between your thought and talk about colour and a normal colour perceiver's. You are, Block claims, a normal perceiver again (2007, p. 94).

This thought experiment can be expressed as a general form of argument. Given a range of properties A that's offered to account for the colour-feeling aspect of colour experience, the thought experiment advances the hypothesis that:

- 1 Colour experiences of ripe strawberries are equivalent with respect to A at Stages 1 and 4, and
- 2 colour experiences of ripe strawberries at Stage 4 are inverted relative to colour feeling at Stage 1.

If an instance of this hypothesis objecting to an attempted account of colour feeling is plausible, it provides a powerful counterexample to the account.

1.2<en>Formulation of direct objections to particular accounts of colour feeling

Direct objections to particular accounts of the colour-feeling aspect are formulated by replacing A in the argument form with the range of non-qualitative properties proposed by the particular account. For example, the standard version of functionalism replaces A with causal relations of experience to stimuli, other mental states, and behaviour. Thus, the objection to the standard version of functionalism is that at Stages 1 and 4, colour experiences of ripe strawberries are equivalent in their causal relations to stimuli, other mental states, and behaviour, but inverted with respect to colour feeling.

Of course, for this objection to be convincing it has to be plausible that at Stages 1 and 4, colour experiences are inverted with respect to colour feeling. But, arguably, this is plausible. Block's presentation of the thought experiment differs from the presentation involving Nonvert and Invert in that it has you think through a series of events from the perspective of your experience—that is, *intra*-subjectively—so that the events of the thought experiment can be considered from the first-person perspective. And an inversion of the colour-feeling aspects of your experience seems to be a plausible description of what your experience would be like as a result of the surgery (2007, p. 81; 1990, pp. 681–2). In addition, the first-person perspective seems to be authoritative about the colour-feeling aspect of actual experience, as well as authoritative about what the colour-feeling aspect would be in the supposed circumstances.

Also, for the objection to be convincing the functional equivalence at Stages 1 and 4 has to be plausible. Again, arguably, it is plausible. Since at Stage 4 you mimic the thought and talk of a normal colour perceiver, it seems plausible that causal relations

of your colour experiences to stimuli, other mental states, and behaviour are equivalent at Stages 1 and 4 (Block, 1990, p. 681). (Empirical findings that the human psychological colour space is irregularly shaped have been used to argue that colour-inverted human perceivers would not be functionally equivalent. I'll describe this argument in section 5.)

Crucial to this equivalence in functional properties is the epistemological idea of undetectability. Spectrum inversion is commonly specified as involving undetectable inversion, where undetectability is used as evidence of the equivalence of colour experiences with respect to A, the range of properties that are proposed to account for the colour-feeling aspect. Since the replacement of A differs with different instances of the hypothesis, the relevant undetectability does as well. Against the standard version of functionalism, undetectability is often specified with respect to a range of properties that's detectable in ordinary situations, in particular, behaviour such as verbal communication about coloured objects (Shoemaker, 1982, pp. 648–9). For example, in Block's argument against the standard version of functionalism, undetectability is with respect to such behaviour. In contrast, undetectability is not with respect to neurophysiological properties, since these properties are not detectable in ordinary situations, and Block allows that inversion is neurophysiologically detectable (2007, p. 86; also see Shoemaker, 1982, pp. 648, 651–4 for this position).

But if one is convinced that the objection to the standard version of functionalism succeeds, the hypothesis allows for exploration with respect to alternative replacements for A. In particular, A can be replaced by alternative functionalist characterizations of colour experience.

For example, while Austen Clark accepts that the standard functionalist characterization is vulnerable to the inverted spectrum hypothesis (1993, pp. 200–2), he proposes a different functionalist characterization of colour experience which is both limited to causal relations among states in the head and scientifically informed. Clark claims that long-arm functionalism (called long arm because its characterization of mental states includes stimuli and behaviour; see Block, 1990, p. 680 for this terminology) fails because the same external stimulus can produce radically different colour experiences. He points out, however, that even if the same stimulus can produce

(subtly or radically) different colour experiences among human perceivers (or the same perceiver over time), perceivers share largely the same qualitative similarity relations among colour experiences (such as that an experience of red is qualitatively more like an experience of orange than it is like an experience of green) (1993, pp. 169–70). This intersubjective similarity is the basis for Clark’s short-arm functionalism, where explanations of qualitative similarity relations are to be provided in terms of psychophysics and neurophysiology. Furthermore, Clark contends that such an explanation of qualitative similarity relations provides an explanation of the colour-feeling aspect of experience (1993, pp. 202–9).

Yet it’s not clear that Clark’s short-arm functionalism does explain the colour-feeling aspect of experience. The relations among internal states described in scientific terms might explain qualitative similarity relations, but without capturing the individual (or determinate) colour feelings that are related. Thus it seems that at Stages 1 and 4, colour experiences equivalent in their internal causal relations could be inverted in their colour-feeling aspects. (For criticisms of this sort, see Chalmers, 1996, p. 235; Levine, 2001, pp. 97–8, 100.)

Conceding aspects of the standard functionalist account in a different way, Sydney Shoemaker’s classic article, “The Inverted Spectrum” (1982), precedes Clark in proposing to explain the qualitative similarity relations among colour experiences in terms of functional properties (realized in neurophysiology). Shoemaker’s considerations in favour of explaining qualitative similarity relations are not scientific, but rather considerations about the effects of qualitative similarities and differences on beliefs and behaviour (the sorts of beliefs and behaviour that a science such as psychophysics can employ as evidence in the attempt to develop a scientific account of colour experience). Nevertheless, Shoemaker concedes that an explanation of qualitative similarity relations doesn’t capture the individual (or determinate) colour feelings related, and that an instance of the inverted spectrum hypothesis, where colour experiences are equivalent with respect to qualitative similarity relations but inverted in colour feeling, shows that functionalism fails to account for individual colour feelings (1982, pp. 650–1). However, Shoemaker claims that the individual colour-feeling

aspects of experience are identifiable with neurophysiological properties (1982, pp. 651–2).

An objection to Shoemaker's account is that scientific descriptions of neurophysiological properties don't seem sufficient for *explaining* the colour-feeling aspect any more than do scientific descriptions of internal causal relations. It seems that a description of a neurophysiological property doesn't tell us why one has an experience with one determinate colour feeling rather than another (see Chalmers, 1996, pp. 99–101 for this point).

Furthermore, the inverted spectrum hypothesis can be used against neurophysiological identity. To see this, modify Block's thought experiment as follows: at a post-op examination at Stage 3, your neurosurgeon is astonished to find that your brain's plasticity has managed to reverse the inversion surgery. But, even so, red things continue to look as green things had before the surgery. Consequently, it seems that at Stages 1 and 3, colour experiences that are physically identical could be inverted in colour feeling. (Stage 4 gets dropped, since your testimony claiming colour inversion plus the examination attesting to neurophysiological identity is all that's needed to make the point.) This instance of the inverted spectrum hypothesis pushes us toward the claim that the colour-feeling aspect of experience is a non-physical property.

1.3 Spectrum inversion and the explanatory gap

Nevertheless, many who support use of the inverted spectrum hypothesis against functionalism—Block and Shoemaker, for example—also hold fast to the claim that colour-feeling aspects are identifiable with neurophysiological properties, and so don't consider use of the inverted spectrum hypothesis against neurophysiological identity to be plausible. In order to better understand why, it is helpful to make a connection between the inverted spectrum hypothesis and the so-called problem of the explanatory gap.

As Joseph Levine, the primary formulator of the problem of the explanatory gap, poses this problem: it seems there can be no explanation of the colour-feeling aspect in physical or functional terms. (By 'explanation', Levine has in mind the deduction of what is to be explained from scientific laws. Applied to the colour-feeling aspect of

experience, this would involve a deduction of colour feeling from scientific laws. However, what is involved in explanation is controversial. See Levine, 2001, pp. 70–6 for a brief discussion.)

Levine thinks of the inverted spectrum hypothesis as a manifestation of the problem of the explanatory gap, and so as an *epistemological* problem for materialism about mind, as opposed to a reason to reject materialism altogether (2001, pp. 78–9). According to this way of understanding the inverted spectrum hypothesis, materialism, and in particular neurophysiological identity, is plausible (for example, due to reasons presented by Levine, 2001, chapter 1); nevertheless, the colour-feeling aspect of colour experience is strongly resistant to explanation in neurophysiological terms.

2<en>Objections to representationalism

So far, I've discussed the inverted spectrum hypothesis as a direct objection to theories that attempt to explain the colour-feeling aspect of experience in terms of some range of physical or functional (and so non-qualitative) properties. Against representationalism—which accounts for the colour-feeling aspect of experience in terms of representational content—the inverted spectrum hypothesis is not a direct objection to an explanation of colour feeling in non-qualitative terms. Representationalism by itself does not offer an account of colour feeling in non-qualitative terms, but rather leaves open both whether mental representation and whether colours included in content can be accounted for in physical or functional terms.

One version of representationalism accounts for the colour-feeling aspect in terms of the colour-representing aspect to the extent that a difference in colour feeling requires a difference in the colour-representing aspect. Thus, the idea is that the colour-feeling aspect of experience supervenes on the colour-representing aspect. A more ambitious claim, which is the focus of a great deal of the discussion of representationalism in the literature, is so-called strong representationalism, which claims that the colour-feeling aspect of experience is identified with the colour-representing aspect. (In what follows, what I'll mean by 'representationalism' is the supervenience thesis, unless stated otherwise.)

Those who support representationalism form a motley group. Many supporters of *strong* representationalism, including David Armstrong (1968/1993), Fred Dretske (1995), William Lycan (1996), and Michael Tye (2000), try to explain the colour-feeling aspect of experience in physical or functional (and so non-qualitative) terms by proposing a functional account of mental representation along with an identification of the colours included in content with physical properties of objects (Dretske, 1995, p. 72 and pp. 88–90, gives a brief statement of this strategy).

But not all supporters of representationalism have this aim. For example, Shoemaker claims that colour experience represents not only colours (understood as physical properties of objects) but also phenomenal properties (or appearance properties) which are dispositional properties of objects to cause colour experiences, and Shoemaker holds that the colour-feeling aspect supervenes on phenomenal properties. Thus, he accepts a version of representationalism. Nevertheless, Shoemaker allows for spectrum inversion, by contending that experiences with the same objective-colour-representing aspects can have inverted phenomenal-colour-representing aspects. And, appealing to the explanatory gap, Shoemaker denies that the colour-feeling aspect can be explained in physical or functional terms while holding that it can be identified with neurophysiological properties (2001, pp. 458–9).

In addition, Jeff Speaks (2011) defends representationalism against the inverted spectrum hypothesis, but at the same time offers a strategy for arguing that neither the colour-feeling nor colour-representing aspects can be explained in physical or functional terms. Along with defending representationalism, he considers whether instances of the hypothesis can be used as *direct* objections to the explanation of the colour-feeling aspect of experience in physical or functional terms (2011, p. 357). If a particular direct objection is plausible, then this objection combined with representationalism can be used as an objection to a physical or functional explanation of the colour-*representing* aspect. Against an account of the colour-representing aspect, the objection can apply to its physical or functional account of mental representation (2011, pp. 358–9).

On the other side of the debate, philosophers who use the inverted spectrum hypothesis against representationalism often accept that mental representation can be

explained in physical or functional terms, but claim that the colour-feeling aspect cannot be explained in this way. Therefore, their contention is that the colour-feeling aspect cannot be accounted for in terms of the colour-representing aspect. For these philosophers, the objection to representationalism is motivated by the same concern as that which motivates the direct objection to a functionalist account of colour feeling: the colour-feeling aspect of experience cannot be explained in physical or functional—and so non-qualitative—terms. But since the objection opposes representationalism rather than accounts of colour feeling in physical or functional terms, its opposition to the latter accounts is indirect.

The objection against representationalism can be stated using the same argument form as that used as a direct objection, namely the hypothesis that:

- 1 Colour experiences of ripe strawberries are equivalent with respect to A at Stages 1 and 4, and
- 2 colour experiences of ripe strawberries at Stage 4 are inverted relative to colour feeling at Stage 1.

Against representationalism, A is replaced by some range of colour-representing properties (characterized in terms of content) that is offered to account for the colour-feeling aspect of experience. Plausible instances of this argument provide counterexamples to representationalism. Against even the representationalist supervenience claim, they show that a difference in colour feeling (the inversion) is consistent with sameness of the colour-representing aspect of experience.

To successfully press an instance of the inverted spectrum hypothesis against representationalism, it has to be plausible that at Stages 1 and 4, colour experiences are inverted with respect to colour feeling. And again, from the first-person perspective, the inversion seems plausible.

However, for an instance of the objection to be successful, it also has to be plausible that colour experiences are representationally equivalent (that is, equivalent in content) at Stages 1 and 4. In particular, it has to be plausible that the colour-representing aspect doesn't simply invert along with the colour-feeling inversion. If the colour-representing aspect does invert, then the colour-representing and colour-feeling

aspects co-vary. In this case, the suggestion is that the colour-representing aspect accounts for the colour-feeling aspect, and that representationalism is correct.

If the colour-representing aspect does invert along with the colour-feeling inversion, experience comes to *misrepresent* the colours of things (given the strawberry is red, not green). Thus, use of the inverted spectrum hypothesis against representationalism involves giving reasons that your experience *doesn't* misrepresent colours at Stage 4 relative to Stage 1, supporting the idea that the colour-representing *hasn't* inverted. Consequently, the inverted spectrum hypothesis against representationalism is often put in terms of colour inversion without misrepresentation. (In this section, I'll focus on general considerations about representational equivalence without taking up exploration of alternative replacements for A. I'll take up that dimension of variation in connection with the Inverted Earth thought experiment in section 2.1.)

But support for the claim of colour inversion without misrepresentation is controversial. Going back to Block's description of the inverted spectrum thought experiment, if an instance of the hypothesis is used against representationalism, it is crucial that at Stage 4 (after amnesia has struck) your experience of red things isn't illusory. Block tries to establish that your experience of red things isn't illusory at Stage 4 by arguing that at this stage you are a normal colour perceiver again.

According to Block, being a normal colour perceiver cannot be characterized in terms of colour feeling—which he claims is ineffable—but instead in terms of colour representing (2007, p. 82). Normal colour perceivers are perceivers who acquire colour terms in the normal way (2007, p. 80). In his (2007) presentation of the inverted spectrum thought experiment, Block appeals to what he calls the Principle of Normality. This principle states that normal perceivers in normal viewing conditions perceive veridically (2007, p. 94). But from Block's standpoint that is just to say that the standard for accurate application of colour terms is set by people who have acquired colour terms in the normal way. Abnormal perceivers, by contrast, are perceivers for whom “color terms have to be used relative to normality” (2007, p. 94). An example of an abnormal perceiver is a person who, as a result of colour inversion surgery, says ‘red things look green’. This does not indicate that red things produce green-feeling experiences in the

colour-inverted perceiver—‘green’ doesn’t express the green-feeling aspect of experience. Instead, it indicates that for the colour-inverted perceiver, red things produce the feeling that green things used to produce prior to the colour inversion surgery. Assuming that the colour-inverted perceiver had been a normal colour perceiver prior to the surgery, the colour-inverted perceiver—if aware of the colour-inversion—uses colour terms relative to normality. At Stage 4, amnesia dispenses with your awareness of colour inversion. Thus, you no longer use colour terms relative to normality. You are a normal colour perceiver.

However, Block’s Principle of Normality won’t be acceptable to many representationalists (Block, 2007, p. 84, notes it would be acceptable to Shoemaker). In particular, representationalists need not think that colour illusion is judged relative to normality. Thus, Armstrong (1968/1993, p. 258) argues that even if the population of colour perceivers was evenly split between two radical and systematic differences in colour experience, one of the groups would be misrepresenting colour, even though in this situation considerations about normality wouldn’t help determine which group (1968/1993, p. 258). According to Armstrong, what determines which group is misrepresenting is the colour of objects, which is a mind-independent matter (1968/1993, p. 260). But whether, and in what sense, colour is a mind-independent property is controversial.

In the context of a wide-ranging defence of representationalism against the inverted spectrum hypothesis, David R. Hilbert and Mark Kalderon (2000, section 4) argue that there are no arguments which succeed in showing that an inversion in colour-feeling aspects of experience wouldn’t be accompanied by an inversion in colour-representing aspects. Consequently, they claim that there is no reason to accept that there is colour inversion without misrepresentation.

At the same time, it’s difficult to *support* the claim that misrepresentation accompanies colour inversion. To make a claim of misrepresentation compelling, a representationalist requires independent justification in terms of a theory of mental representation or a theory of colour, or both, and these sorts of theory are (as just noted with respect to Armstrong’s theory of colour) controversial.

2.1<en>The Inverted Earth thought experiment

Block has sought to bring more clarity to the debate with a related thought experiment which he calls the Inverted Earth thought experiment. To aid understanding of this elaborate thought experiment, I'll start by describing its aim in contrast with the aim of the inverted spectrum thought experiment (as it is used against representationalism). The aim of the inverted spectrum is to make plausible the idea that colour experiences could be the same in their colour-representing aspects but inverted in their colour-feeling aspects. The aim of the Inverted Earth thought experiment is to make plausible the converse: that colour experiences could be the same in their colour-feeling aspects but inverted in their colour-representing aspects.

The Inverted Earth thought experiment is tailored to the latter aim. Inverted Earth is a place where everything *has* inverted colours—ripe strawberries are green (and unripe ones are red), the sky is yellow, and so on. Also, on Inverted Earth, colour language is systematically switched so that red is referred to by the word 'green' and yellow is referred to by the word 'blue', and so on. The thought experiment proceeds as follows: asleep one night, you are abducted by Inverted Earthlings and transported to Inverted Earth. While unconscious during the trip, you have been given 'inverting lenses'. When you awake, you have no awareness of the trip or the lenses, and you have been fitted into an environment that (apart from colours) matches your home environment. As far as you are aware, you had an ordinary night's sleep (perhaps with some odd dreams). Most pertinently, due to the combination of inverted colours and inverting lenses, as well as the switched colour language, everything about colours seems normal (Block, 1990, pp. 682–3).

In your early days on Inverted Earth, when you look at a ripe strawberry, you see it as red, and say and think 'what a bright red'. But you are misrepresenting its colour, which is in fact green. According to Block, it is plausible (given his assumed theory of mental representation, which I'll describe below) that the colour-representing aspect of your experience, as well as your representation of colour in thought and speech, will eventually shift to be in line with your environment. After perhaps a decade, even though your inverting lenses continue to invert the colour-feeling aspects of experience, when you see ripe strawberries, your representation of their colour by experience,

thought, and speech will match that of your Inverted Earth companions. When this occurs, the thought experiment advances the Inverted Earth hypothesis that:

- 1 Colour experiences of ripe strawberries are the same with respect to colour-feeling aspects on Earth and Inverted Earth, and
- 2 colour experiences of ripe strawberries are inverted with respect to A on Earth and Inverted Earth.

(Note that instances of this form are counterexamples to the idea that a difference in the colour-representing aspect of experience requires a difference in colour feeling. This is the converse of the representationalist supervenience claim stated earlier. However, such counterexamples still count against strong representationalism. Also, it's easy to formulate a counterexample to the representationalist supervenience claim with Inverted Earth resources: the colour-representing aspect of your experience of ripe strawberries on Earth is equivalent to that of your experience of ripe limes on Inverted Earth (where, of course, limes are red), but these experiences are inverted in colour feeling.)

For this new objection to be convincing, it has to be plausible that colour experiences are inverted with respect to representational content. As Block presents the thought experiment, he replaces A—the range of colour-representing properties characterized in terms of content—with the normal causes in your environment of colour experience. Thus, Block assumes a normal cause theory of mental representation (where the normal cause of mental states determines content; in Block's presentation, deference to your linguistic community on Inverted Earth also plays a role in determining content) (1990, p. 683). But A need not be replaced this way.

While it's true that Block's normal cause theory of mental representation would have it that the colour-representing aspect of your experience would eventually conform to the environment and linguistic community of Inverted Earth, alternative theories of mental representation would not. Thus, exploration can commence with respect to A's alternative replacements. According to Dretske's (1995) theory, contents are not determined by normal causes of colour experience, but by causes which colour experience has an evolutionarily determined biological function to represent. This

content does not change with your long stay on Inverted Earth, since the evolutionarily determined biological function doesn't change, and your experiences' colour-representing aspects will not invert. However, there are objections to Dretske's theory of content. Furthermore, as Fiona Macpherson (2005) argues, any theory of content determination for experience will have to mesh with a theory of content determination for belief. If one were to accept a theory of content determination of experience that gets around the Inverted Earth thought experiment by disallowing an inversion in content on Inverted Earth, but also hold a theory of content determination for *belief* that allows an inversion in belief contents on Inverted Earth, then it seems that when beliefs invert and so come to correctly attribute colours to objects, one's reports of one's current colour experiences (which haven't inverted) become false. For example, when one's beliefs eventually come to correctly attribute green to ripe strawberries (which are green on Inverted Earth), and one is asked the colour of ripe strawberries, one will say—expressing an introspective belief—that they look red (which means green on Inverted Earth). But then this report of one's experience is false—beliefs attribute green while the colour experience hasn't inverted in colour-feeling or colour-representing aspects. Yet it seems implausible that introspective beliefs could be systematically wrong about current colour experience (Macpherson, 2005, p. 138; but see Hilbert and Kalderon, 2000, section 4(b) for a response to this sort of worry).

For the Inverted Earth hypothesis to be convincing, it also has to be plausible that colour experiences are the same with respect to colour-feeling aspects on Earth and Inverted Earth. The events of the thought experiment are to be considered intra-subjectively, and from the first-person perspective, the sameness of colour feeling—that you wouldn't notice any change in the colour feeling on Inverted Earth—seems plausible.

2.2 Some strengths of the Inverted Earth hypothesis compared to the inverted spectrum hypothesis

What clarity does the Inverted Earth thought experiment bring to the debate? Block claims that a major advantage of Inverted Earth over the inverted spectrum thought experiment is that in addition to your first-person testimony of sameness in colour

feeling, we can also suppose that you are *physically* the same in relevant ways on Earth and Inverted Earth (1990, p. 684). Here, Block appeals to a supervenience claim called phenomenal internalism, which claims that colour feeling supervenes on internal physical properties. Since this claim implies that perceivers who are the same with respect to internal physical properties must be the same with respect to the colour-feeling aspects of their experiences, it supports (1) of the Inverted Earth hypothesis. Thus, the Inverted Earth thought experiment brings some clarity to the extent that phenomenal internalism is plausible.

Also, this supervenience claim can be used to support the claim that there is a plausible *inter*-subjective version of the Inverted Earth hypothesis. If Nonvert (on Earth) and Invert (on Inverted Earth) are physically the same, phenomenal internalism holds that they have the same colour feeling (1990, p. 686). Since a comparison in colour feeling between perceivers cannot be made on the basis of introspection, this significantly strengthens the case for (1) of an inter-subjective version of the hypothesis—again, to the extent that phenomenal internalism is plausible.

3<en>What kind of possibility is involved?

Because the thought experiment has us consider a hypothetical, it has us consider a possibility rather than (what's known to be) an actuality. Because attempts to account for the colour-feeling aspect of experience are metaphysical—they offer a proposal about the nature of colour experience—the kind of possibility that's focused on in the literature is typically metaphysical possibility. (Metaphysical possibility is often characterized by contrast with logical possibility and possibility according to scientific laws, called nomological possibility. Accordingly, metaphysical possibility includes all nomological possibilities, but excludes some logical possibilities due to the nature of things.) The idea is that a proposal about the nature of colour experience rules out certain situations as metaphysically impossible. If what the proposal rules out is plausibly found to be metaphysically possible, then that indicates that the proposal is mistaken.

Some discussions of the hypothesis suggest that consideration of metaphysical possibility is merely an indulgence in ignorant speculation. C. L. Hardin (1997,

pp. 299–300) suggests this attitude. But if it is his attitude, it is too dismissive toward the role of considering metaphysical possibilities in philosophy. Metaphysical theories are, in fact, distinguished from science in part by the depth of our ignorance of the subject matter. But with respect to issues such as the nature of the colour-feeling aspect of experience, we face a combination of deep ignorance and compulsion to attempt a better understanding. Metaphysical theories help to advance thinking about problems which, due to our ignorance, are scientifically intractable, so that they might eventually become scientifically tractable (see Ross and Turner, 2013, pp. 4247–50 for general characterization of the distinction between philosophical and scientific existence problems). Since we aren't at a point where the colour-feeling aspect of experience is scientifically tractable, it is important to consider whether certain metaphysical possibilities are plausible.

It might be that Hardin's point isn't that we shouldn't *consider* metaphysical possibilities, but that proposed possibilities need to be constrained by findings from colour science. If that is his point, it is one about methodology, which I'll take up in the next section.

Block asserts the stronger claim that spectrum inversion is nomologically possible. He contends that spectrum inversion can be achieved by switching the pigments of the M and L cones, and, he points out, colour science indicates that this switching of pigments is nomologically possible. Thus, he claims that there is scientific support for the inverted spectrum hypothesis (2007, p. 86, pp. 97–9). I'll say more about this in section 6.

4<en>What kind of methodology is involved in affirming a possibility as being plausible?

When should we consider the claim that a situation is metaphysically possible to be plausible? One methodological approach characteristic of philosophical theorizing is use of armchair methods. A common armchair method is the use of conceptual analysis in addressing problems, and this method can be conspicuous when thought experiments are used to set the stage for conceptual analysis. In philosophy of mind, another armchair method involves use of introspection as an authoritative source of information

about the nature of mind. Over the past number of decades, philosophy of mind, and philosophy of colour and colour perception in particular, has largely moved away from addressing problems solely through armchair methods. In the philosophical literature on colour and colour perception, C. L. Hardin (and especially his 1988/1993) has been a leader in this shift away from exclusive use of armchair methods by incorporating scientific findings from psychophysics and neuroscience into his philosophical work. Thus, current standard methodology includes use of scientific findings mixed with use of armchair methods.

However, there are important disagreements about methodology, a prominent one being with respect to the authority of introspection. The use of introspection is standard, and presumably ineliminable in addressing questions about the nature of the mind. But the question remains whether introspection is authoritative about the nature of the mind—and, in particular, about the nature of the colour-feeling aspect of experience—and has an authority that trumps science. This question is important with respect to the inverted spectrum hypothesis because from the standpoint of introspection, it seems quite plausible that colour-feeling aspect of an experience can be varied while its physical or functional properties remain constant. If introspection is considered authoritative about the nature of the colour-feeling aspect, the plausibility of the inverted spectrum hypothesis might be taken to mark an insuperable limit on science with respect to the mind. The visual scientist Stephen E. Palmer provides a clear statement of the view, which is held by many philosophers, that introspection is authoritative with respect to colour feeling (1999a, pp. 627–8), and he argues that this authority does set a potentially insuperable limit on science, which he calls the subjectivity barrier (1999a, pp. 656–63; also see Palmer, 1999b for a more complete presentation of Palmer’s views, and see the peer commentary and Palmer’s responses that follow this article for a useful discussion).

But many philosophers consider introspection to often be misleading about the nature of the mind, and so judge it to not be authoritative about the nature of the colour-feeling aspect of experience. These philosophers are sceptical that introspection of the colour-feeling aspect of experience can establish a potentially insuperable limit on science, and treat the plausibility of the inverted spectrum hypothesis as an indicator of

how misleading introspection can be about the nature of the mind when it has not yet been understood scientifically (Rosenthal, 1999, pp. 149–52 states this scepticism about the authority of introspection). Given that one's attitude toward the authority of introspection provides a basis for one's judgments about the plausibility of the inverted spectrum hypothesis, the basis for these judgments is disputed.

5<en>Common considerations against the inverted spectrum hypothesis

A common general objection to the inverted spectrum hypothesis is an epistemological worry about undetectability (this objection is general because it applies to the hypothesis used either as a direct objection or as an objection to representationalism). As Shoemaker (1982, p. 648) explains, the relevant undetectability in the context of the instance of the hypothesis used against the standard version of functionalism is behavioural undetectability, not neurophysiological undetectability. Even so, if there are behaviourally undetectable inversions in colour feeling among people, then it seems that the problem of other minds—the problem of knowing if and when you have mental states of the same types as others—is a serious problem. As Shoemaker admits, behavioural differences are the ordinary ways in which we detect others' mental states (1982, p. 648). If brain science is needed to know other minds, we don't have the knowledge of other minds we think we have. And if a lack of knowledge of other minds seems implausible, this provides a serious objection to the inverted spectrum hypothesis.

Shoemaker's response is that the epistemological problem does not apply to aspects of mental states that are functionally characterized and so (on the standard version of functionalism) are characterized in part by behaviour. Thus, beliefs, desires, the colour-representing aspect of experience, and even (for Shoemaker) qualitative similarity relations among colour experiences, are behaviourally detectable. The only aspect of mind to which behavioural undetectability applies, and thus the only place where the problem of other minds gets a grip, is with respect to the colour-feeling aspect of experience. Shoemaker (1982, p. 656) admits the problem but emphasizes that this is a limited problem of other minds.

Another common general objection to the hypothesis contends that according to colour science any inversion would in fact be detectable. Since the undetectability of inversion is used as evidence for either the functional or representational equivalence required for the hypothesis to be plausible, detectability indicates the hypothesis is implausible.

As noted in the Introduction, what's called spectrum inversion is typically taken to be a shift in the psychological colour space where either the red-green poles are flipped, the yellow-blue poles are flipped, or both. However, Hardin (1997) explains that according to colour science, the human psychological colour space is irregularly shaped (also see Hilbert and Kalderon, 2000, section 6.1 for this explanation). For example, the yellow and blue regions of the colour space are not symmetrical. A saturated yellow is much lighter than a saturated blue (Hardin, 1997, pp. 296–7; Palmer, 1999a, p. 626). Thus, Invert's inversion of saturated yellow and saturated blue would be detectable—for Nonvert a saturated yellow of a lemon is lighter than a saturated blue of a blueberry, but for Invert, the blueberry would be lighter than the lemon.

However, Palmer (1999a, p. 626) claims that this asymmetry could be corrected by inverting black and white along with yellow and blue, and that in any case, a red-green inversion would work better since saturated red and green are not grossly different in lightness. Justin Broackes (2007) argues to the contrary that saturated red and green are different enough in lightness to make an inversion detectable, and thus that a correction on the white-black axis would also have to accompany red-green inversion (p. 173). But, Broackes argues, any inversion of white and black would be detectable. (Palmer, 1999a, p. 626, note 2, seems to dismiss detectability of white-black inversion, but says very little to support this point.) The upshot, according to Broackes, is that the science of colour and colour perception indicates that any colour inversion very likely would be detectable.

One response to this objection is that the inverted spectrum hypothesis provides a tool to get at the nature of the colour-feeling aspect of experience. Our actual visual systems have various contingent characteristics that might mislead us about the nature of colour feeling. Thus, considerations about the nature of colour feeling should not be

limited to considerations about our actual visual systems (Shoemaker, 1982, pp. 648–9; Block, 1990, pp. 683–4).

Another general objection to the inverted spectrum hypothesis, as well as an objection to the Inverted Earth hypothesis, targets the assumption of phenomenal internalism (that is, the claim that the colour-feeling aspect of experience supervenes on perceivers' internal physical properties). Phenomenal internalism is denied by phenomenal externalism, which holds that the supervenience base of the colour-feeling aspect encompasses both external and internal physical properties. Phenomenal externalism, held by many strong representationalists including Dretske (1995), Lycan (1996), and Tye (2000), claims that it is possible for perceivers with the same internal physical properties to have experiences with different colour-feeling aspects, due to being related to different external physical properties of objects, such as reflectance properties of their surfaces. If this is the case, it might be that perceivers with systematically switched neurophysiological properties (as is supposed with colour-inverting surgery) do not undergo an inversion in colour feeling at all. Instead, switched neurophysiological properties provide different physical realizations of colour experiences, the colour-feeling aspects of which are determined at least in part by physical properties of objects in perceivers' surroundings (Byrne and Hilbert, 1997c, p. 271 note this problem for the inverted spectrum hypothesis). Interestingly, if this objection is right, my description of Nonvert and Invert in the second paragraph of the Introduction was already misguided, for it indicated that the physical properties of strawberries play no role in determining colour feeling. I'll discuss the debate between phenomenal internalism and phenomenal externalism further in relation to the use of colour science to support the inverted spectrum hypothesis.

6<en>The use of colour science to support the inverted spectrum hypothesis

Palmer (1999a, p. 626) claims that a behaviourally undetectable red-green inversion is plausible from the standpoint of colour science. In support of this, he points out that the psychological colour space is not grossly asymmetrical with respect to flipping the red-green poles. In addition, he claims that an important factor in the scientific plausibility

of red-green inversion is that “a good biological argument can be made that there should be some very small number of seemingly normal trichromats who should be red-green reversed” (Palmer, 1999a, p. 626). According to Palmer, a biological case can be made for what’s called pseudonormal vision as well as for spectrum inversion.

A widely accepted neurophysiological explanation of red-green blindness is that genetic abnormalities result in the M and L cones containing the same photopigment, rendering red and green indiscriminable. As it turns out, M and L cones contain the same photopigment sometimes because the photopigment normally contained in the M cones is also contained in the L cones, and sometimes because, the photopigment contained in the L cones is also contained in the M cones. With the right combination of genetic abnormalities, the photopigments in the M and L cones could switch. The condition of this switch is called pseudonormal vision (Boynton, 1979, p. 356; Nida-Rümelin, 1996, pp. 99–100; Palmer, 1999a, pp. 626–7). This condition has not been detected (Palmer, 1999a, p. 627), but its possibility is supported by widely accepted science. This science indicates that pseudonormal vision is nomological possible, and, as Palmer indicates, that it is likely actual.

Nevertheless, pseudonormal vision by itself does not imply that this science indicates that *spectrum inversion* is likely actual. Instead, as Palmer makes admirably clear, phenomenal internalism is also needed to conclude that pseudonormal vision results in red-green inversion (1999a, p. 662; also see Nida-Rümelin, 1999, p. 571). But how do we decide the debate between phenomenal internalism and phenomenal externalism? Martine Nida-Rümelin claims that phenomenal internalism is fundamental to colour science, and so the success of colour science provides substantial support for it (1999). But this isn’t so. Phenomenal internalism is a claim about the nature of the colour-feeling aspect (or other qualitative-feeling aspect) of experience. While colour scientists such as Palmer make claims about colour feeling, their claims are not grounded in science; as I stated in section 4, Palmer’s claims assume controversial philosophical views about the authority of introspection. We don’t know enough about the nature of colour feeling for it to be scientifically tractable.

Palmer's biological argument is plausible for pseudonormal vision. But the argument for red-green inversion is not a biological argument (see Ross, 1999a and 1999b for more discussion of this point).

An opinionated conclusion

Many supporters of the inverted spectrum hypothesis, for example, Block and Shoemaker, use the hypothesis to argue (directly, indirectly, or both) that the colour-feeling aspect of experience cannot be explained in non-qualitative terms. Nevertheless, by relying on independent support for materialism, they claim that colour feeling is a neurophysiological property. Spectrum inversion is, for them, a manifestation of the problem of the explanatory gap understood as an epistemological problem rather than a reason to deny a materialist theory of mind. Many theorists find this combination of a materialist metaphysics and the explanatory gap attractive.

However, independent support for materialism is controversial, making identification of colour feeling with a neurophysiological property vulnerable to the inverted spectrum. For example, Block (1994, p. 517) appeals to phenomenal internalism as independent support for materialism, but phenomenal internalism isn't an adequate defence of materialism for property dualists such as Chalmers. Indeed, Chalmers uses the inverted spectrum hypothesis to argue that materialism is false.

Alternatively, materialists can object to phenomenal internalism from the standpoint of phenomenal externalism. I'll conclude with some remarks from the standpoint of phenomenal externalism. From this standpoint, the problem of the explanatory gap, at least in its standard formulation, is mistakenly framed. In its standard formulation, the problem of the explanatory gap concerns how the colour-feeling aspect of experience can be explained in *internal* physical or functional terms, that is, it assumes phenomenal internalism. However, according to phenomenal externalism, the physical properties of external objects are part of what makes a visual experience red-feeling as opposed to green-feeling. If external properties are left out, the problem is mistakenly framed.

If physical properties of external objects are part of what makes a visual experience red-feeling as opposed to green-feeling, then phenomenal externalism must

explain how external physical properties are involved in making that difference. Whether an explanation is possible has yet to be seen. From the standpoint of phenomenal internalists who assume that introspection is authoritative about the nature of the colour-feeling aspect of experience, phenomenal externalism will seem like a non-starter. Since introspection isn't authoritative about the nature of external physical properties, phenomenal externalism might even seem perverse from this standpoint. But the view that introspection is authoritative about the nature of colour-feeling is controversial, and questioning its authority might be necessary for explaining colour feeling in non-qualitative terms. If this turns out to be the right direction, then the inverted spectrum will serve as a reminder of how misleading introspection can be about the mind.

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References

- Allen, Keith (2010). "Locke and the Nature of Ideas", *Archiv für Geschichte der Philosophie*, Volume 92, Issue 3 (January 2010): 236–55.
- Armstrong, D. M. (1968). *A Materialist Theory of the Mind*. Revised Edition 1993. London: Routledge.
- Block, Ned (1990). "Inverted Earth", *Philosophical Perspectives, 4: Action Theory and Philosophy of Mind*, edited by James E. Tomberlin. Atascadero, Cal.: Ridgeview Publishing Company, 53–79. Reprinted in Block, Flanagan, and Güzeldere, 1997, 677–93. Page numbers refer to reprint.
- Block, Ned (1994). "Qualia", in *A Companion to the Philosophy of Mind*, edited by Samuel Guttenplan. Oxford: Blackwell Publishers, 514–20.
- Block, Ned (2007). "Wittgenstein and Qualia", *Philosophical Perspectives*, Volume 21, Issue 1 (December 2007): 73–115.
- Block, Ned, Owen Flanagan, and Güven Güzeldere (Editors) (1997). *The Nature of Consciousness: Philosophical Debates*. Cambridge, Mass.: The MIT Press.

- Boghossian, Paul A. and J. David Velleman (1989). "Colour as a Secondary Quality", *Mind*, Volume 98, Number 389 (January 1989): 81–103. Reprinted in Byrne and Hilbert, 1997a, 81–103.
- Boynton, Robert M. (1979). *Human Color Vision*. New York: Holt, Rinehart and Winston.
- Broackes, Justin (2007). "Black and White and the Inverted Spectrum", *The Philosophical Quarterly*, Volume 57, Number 227 (April 2007): 161–75.
- Byrne, Alex and David R. Hilbert (Editors) (1997a). *Readings on Color, Volume 1, The Philosophy of Color*. Cambridge, Mass.: The MIT Press.
- Byrne, Alex and David R. Hilbert (1997b). "Introduction", in Byrne and Hilbert (1997a), xi–xxviii.
- Byrne, Alex and David R. Hilbert (1997c). "Colors and Reflectances", in Byrne and Hilbert (1997a), 263–88.
- Chalmers, David J. (1996). *The Conscious Mind: In Search of a Fundamental Theory*. New York: Oxford University Press.
- Chalmers, David J. (Editor) (2002). *Philosophy of Mind: Classical and Contemporary Readings*. New York: Oxford University Press.
- Clark, Austen (1993). *Sensory Qualities*. Oxford: Clarendon Press.
- Dretske, Fred (1995). *Naturalizing the Mind*. Cambridge, Mass.: The MIT Press.
- Hardin, C. L. (1988). *Color for Philosophers: Unweaving the Rainbow*. Revised Edition 1993. Indianapolis: Hackett Publishing.
- Hardin, C. L. (1997). "Reinverting the Spectrum", in Byrne and Hilbert (1997a), 289–301.
- Hilbert, David R. and Mark Eli Kalderon (2000). "Color and the Inverted Spectrum", in *Color Perception: Philosophical, Psychological, Artistic and Computational Perspectives*, edited by Steven Davis. Oxford: Oxford University Press, 187–214.
- Levine, Joseph (2001). *Purple Haze: The Puzzle of Consciousness*. Oxford: Oxford University Press.
- Lycan, William G. (1996). *Consciousness and Experience*. Cambridge, Mass.: The MIT Press.
- Macpherson, Fiona (2005). "Colour Inversion Problems for Representationalism", *Philosophy and Phenomenological Research*, Volume LXX, Number 1 (January 2005): 127–52.
- Nida-Rümelin, Martine (1996). "Pseudonormal Vision: An Actual Case of Qualia Inversion?" *Philosophical Studies*, Volume 82, Number 2 (May 1996): 145–57. Reprinted in Chalmers, 2002, 99–105. Page numbers refer to reprint.

- Nida-Rümelin, Martine (1999). “Intrinsic Phenomenal Properties in Color Vision Science: A Reply to Peter Ross”, *Consciousness and Cognition*, Volume 8, Number 4 (December 1999): 571–4.
- Palmer, Stephen E. (1999a). *Vision Science: Photons to Phenomenology*. Cambridge, Mass.: The MIT Press.
- Palmer, Stephen E. (1999b). “Color, Consciousness, and the Isomorphism Constraint”, *Behavioral and Brain Sciences*, Volume 22, Number 6 (December 1999): 923–43.
- Rosenthal, David M. (1999). “Sensory Quality and the Relocation Story”, *Philosophical Topics*, Volume 26, Numbers 1 and 2 (Spring and Fall 1999): 321–50. Reprinted in his *Consciousness and Mind*, 1995, Oxford: Oxford University Press, 149–74. Page numbers refer to reprint.
- Ross, Peter W. (1999a). “Color Science and Spectrum Inversion: Further Thoughts”, *Consciousness and Cognition*, Volume 8, Number 4 (December 1999): 566–70.
- Ross, Peter W. (1999b). “Color Science and Spectrum Inversion: A Reply to Nida-Rümelin”, *Consciousness and Cognition*, Volume 8, Number 4 (December 1999): 575–6.
- Ross, Peter W. and Dale Turner (2013). “Existence Problems in Philosophy and Science”, *Synthese*, Volume 190, Issue 18 (December 2013): 4239–59.
- Shoemaker, Sydney (1982). “The Inverted Spectrum”, *Journal of Philosophy*, Volume 79, Number 7 (August 1982): 357–81. Reprinted in Block, Flanagan, and Güzeldere, 1997, 643–62. Page numbers refer to reprint.
- Shoemaker, Sydney (2001). “Introspection and Phenomenal Character”, *Philosophical Topics*, Volume 28, Issue 2 (Fall 2000): 247–273. Excerpt reprinted in Chalmers, 2002, 457–72. Page numbers refer to reprint.
- Speaks, Jeff (2011). “Spectrum Inversion without a Difference in Representation Is Impossible”, *Philosophical Studies*, Volume 156, Issue 3 (December 2011): 339–61.
- Tye, Michael. (2000). *Consciousness, Color, and Content*. Cambridge, Mass.: The MIT Press.