

## Color Science and Spectrum Inversion: A Reply to Nida-Rümelin

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Martine Nida-Rümelin (1996) argues that color science indicates that behaviorally undetectable spectrum inversion is possible and raises this possibility as an objection to functionalist accounts of visual states of color. I show that her argument does not rest solely on color science, but also on a philosophically controversial assumption, namely, that visual states of color supervene on physiological states. However, this assumption, on the part of philosophers or vision scientists, has the effect of simply ruling out certain versions of functionalism. While Nida-Rümelin is quite right to search for empirical tests for claims about the nature of visual states, philosophical issues remain pivotal in determining the correctness of these claims. © 1999 Academic Press

Martine Nida-Rümelin (1996) argues that a well-established theory of color vision along with a widely accepted scientific explanation of red–green blindness in human beings indicates that behaviorally undetectable spectrum inversion<sup>1</sup> is possible. She claims that scientific support for the possibility of spectrum inversion provides an objection to a variety of functionalist accounts of visual states of color which deny its possibility.

I will briefly give some background on the opponent-process theory of color vision and describe the scientific explanation of red–green blindness. I will then examine Nida-Rümelin's claim that visual science supports the possibility of spectrum inversion and conclude with an objection to her claim.

### *The Opponent-Process Theory of Color Vision*

The human retina contains three types of wavelength-sensitive cells called *cones*. Cone types are differentiated by the photopigments they normally contain, there being three types of photopigment which are in turn distinguished by their differential sensitivity to light. The sensitivity of a photopigment is described in terms of the part of the spectrum where it is most likely to absorb light. Normal human perceivers have

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<sup>1</sup>Although the expression “spectrum inversion” is standard in the literature, it is somewhat misleading. What is usually meant by this expression, and what Nida-Rümelin has in mind, is an inversion in hues as they are represented in the *psychological color space*. The color space, which represents qualitative relations among colors with respect to hue, saturation, and lightness, is a three-dimensional structure with red–green, yellow–blue, and black–white poles. The expression “spectrum inversion” usually refers to inversions of hues with respect to the red–green and yellow–blue poles.

cones with photopigments sensitive to the shortwave region of the spectrum (S cones), the middlewave region (M cones), and the longwave region (L cones).

When cones absorb light, they produce outputs which are logarithmically related to their absorptions. According to the *opponent-process theory of color vision*, these outputs are gauged by other processes of the human visual system, in particular two opponent chromatic processes or channels, namely, the red–green and yellow–blue channels, and one opponent achromatic channel, namely, the black–white channel.

Perceived hue correlates with specific ratios of absorptions of the three types of cones. Because the outputs of the cones are logarithmically related to their absorptions (and since subtracting the logarithms of two numbers is equivalent to finding their ratio), the chromatic channels can encode these ratios, and thus encode perceived hue, by gauging the differences in outputs of the three types of cones.

For example, the red–green channel gauges the difference in the output of the M cones from that of the L cones. If the output of the L cones is greater than that of the M cones so that this difference is positive, the red–green channel is excited and encodes red. If the output of the L cones is lesser than that of the M cones so that this difference is negative, the channel is inhibited and encodes green.

A physical object is seen as red if it affects the visual system such that the red–green channel is excited and the yellow–blue channel is in equilibrium. Likewise, a physical object is seen as green if it affects the visual system so that the red–green channel is inhibited and the yellow–blue channel is in equilibrium. When neither of the chromatic channels are in equilibrium, perceived colors are discernibly mixtures of a hue encoded by the red–green channel and one encoded by the yellow–blue channel. [For further description of the opponent-process theory, see Leo M. Hurvich (1981, pp. 128–135), Robert M. Boynton (1979, pp. 207–250), or C. L. Hardin (1993, pp. 26–40).]

### *Pseudonormal Vision*

According to the widely accepted neurophysiological explanation of red–green blindness which Nida-Rümelin cites, individuals with this disorder have M and L cones containing the same photopigment. Consequently, their M and L cones have identical outputs. Since the visual system encodes red and green by gauging the difference in the output of the M cones from that of the L cones, the result is that red and green are indiscriminable.

This explanation holds that in some red–green blind individuals the M and L cones contain the same photopigment because L cones contain the photopigment normally contained in M cones. But in other red–green blind individuals the M and L cones contain the same photopigment for the opposite reason, namely, because M cones contain the photopigment normally contained in L cones.

A theory of the genetic basis of color blindness explains how M and L cones can contain the same photopigments. Furthermore, the genetic theory which provides the explanation of this sort of abnormality also indicates that it is possible that the photopigments normally contained in M and L cones switch (Nida-Rümelin, 1996, pp. 147–148). (All references will be to Nida-Rümelin (1996), unless otherwise noted.)

Although it is not known whether anyone actually has switched photopigments, visual science indicates that it is a condition someone could have. The condition of having switched photopigments is called *pseudonormal vision* (Boynton, 1979, p. 356).

### *The Empirical Argument for the Possibility of Spectrum Inversion*

Nida-Rümelin argues that the possibility of pseudonormal vision along with the opponent-process theory indicates the possibility of behaviorally undetectable spectrum inversion. She points out that a switch in photopigments between M cones and L cones would have the following result. Physical objects that affect these cones such that the difference in output of the M cones from that of the L cones is *positive* in someone with normal vision would affect them such that this difference would be *negative* in someone with pseudonormal vision. She maintains that since positive values encode red and negative values encode green, the perceived reds and greens of physical objects would be inverted between these types of people (p. 148).<sup>2</sup> Thus, she holds that the possibility of red–green inversion can be formulated in the terms of visual science.

Moreover, she cites (p. 145 and p. 155, n. 3) visual scientist Robert M. Boynton (1979, pp. 356–358) as referring to the same theories and arriving at the same conclusion with regard to the possibility of behaviorally undetectable red–green inversion. He claims: “[a pseudonormal] observer would be expected to have normal color vision except that the sensations of red and green would be reversed—something that would be difficult, if not impossible, to prove” (1979, p. 358).

Since visual scientists formulate and consider the possibility of red–green inversion, Nida-Rümelin holds that functionalists are at least *prima facie* wrong to reject this possibility. Her objection to functionalism is that it conflicts with a claim she holds to be a plausible *prima facie* constraint: “No hypotheses accepted or seriously considered in colour vision science should be regarded according to a philosophical theory to be either incoherent or unstatable or false” (p. 145).

### *A Reply*

Without disputing the possibility of pseudonormal vision, the claim that switched photopigments produces red–green inversion is objectionable. Nida-Rümelin holds that positive values resulting from the difference in the output of M cones from that of L cones encode red *regardless* of the physical properties of objects seen. Thus, she assumes that whether a physical object is experienced as red or green is not determined at all by physical properties of objects.

At least some functionalist accounts will reject this assumption and claim that perceived red is a physical property of physical objects which can be encoded by either positive or negative values. In normal visual systems, perceived red is encoded by a positive value resulting from the difference in output of M cones from that of

<sup>2</sup> Nida-Rümelin points out that pseudonormal vision would leave perception of yellow and blue unaffected. Thus, the purported inversion in perceived colors which comes with pseudonormal vision may be better described as red–green inversion.

L cones. However, in visual systems where the photopigments contained in M cones and L cones are switched, perceived red is encoded by a negative value resulting from such a difference. In this case, since perceived red and green can be encoded by the same physiological state in different people, visual states of color do not supervene on physiological states.

Nida-Rümelin does consider this objection. But she holds that in a case where “. . . the *very same* physiological state [would] lead to a red-sensation in the [normal] case and to a green-sensation in the [pseudonormal case]” (p. 153), it would be mysterious how these states would be differentiated by color. For “. . . the only difference between the two cases lies in the way the physiological state is *caused* (by different patterns of light stimuli) and . . . the brain does not have any access to this information” (p. 153). Furthermore, she contends, the possibility that red is encoded by either positive or negative values is simply ruled out by visual science. This possibility “. . . is in conflict with the way the case [of pseudonormal vision] is described in color vision science” (p. 156, n. 8).

However, Nida-Rümelin’s objections indicate that she simply assumes that visual states of color supervene on physiological states and that the opponent-process theory must incorporate this supervenience claim.

Certainly if this supervenience claim, called *phenomenal internalism*, is correct, then a switch in physiological states would be sufficient for an inversion of perceived colors. But at least some functionalist accounts take an alternative view, called *phenomenal externalism*, which proposes that visual states of color supervene on *relations* between *physical properties* of objects and their effects on perceivers’ visual systems [Fred Dretske (1995, chap. 5), for example, proposes phenomenal externalism]. On this alternative view, perceived red is a physical property of objects, and a switch in physiological states would not be sufficient for an inversion of perceived colors. Rather, this physical property would be encoded by negative values rather than positive. By claiming that the brain does not have access to the physical stimuli of visual states of color, Nida-Rümelin’s claim excludes this alternative without argument.<sup>3</sup>

Moreover, phenomenal externalism is motivated because it fits naturally with *color physicalism*, the view that perceived colors are physical properties of physical objects, a position which has recently gained a large number of adherents in the philosophical literature [in addition to Dretske, see, for example, Michael Tye (1995), Gilbert Harman (1996), and William G. Lycan (1996)]. Some philosophers [see, for example, C. L. Hardin (1993)] and many psychophysicists and neurophysiologists maintain phenomenal internalism because they claim that perceived colors just are neural processes of our visual systems. However, this neurophysiological subjectivism faces serious difficulties in explaining color perception. The basic problem is the following: if perceived colors are neural processes, and thus physical objects are colorless, how

<sup>3</sup> By contrast, other functionalist accounts of visual states of color allow that these visual states supervene on physiological states and hold that while spectrum inversion is possible, it would be behaviorally detectible. Hardin (1993) holds such a functionalist account. Because functionalist accounts that propose phenomenal externalism deny that visual states of color supervene on physiological states, these accounts reject the possibility of spectrum inversion altogether.

do we explain our perception of colors as located on the surfaces of physical objects? [See my “Location Problem for Color Subjectivism” (in press b) for an extended argument against neurophysiological subjectivism on the basis of its problem in explaining color perception; also see my “The Relativity of Color” (in press c) for a defense of color physicalism against subjectivist arguments.]

Clearly, the possibility of pseudonormal vision is an empirical issue. But the interesting question is whether a switch in photopigments produces an inversion in perceived colors. The claim that visual states of color supervene on physiological states indicates that it does, but then we need an argument, either philosophical or scientific, to support this supervenience claim. The *assumption* of this claim on the part of philosophers or visual scientists has the result of begging the question with regard to phenomenal externalism. [Stephen E. Palmer (in press) appeals to Nida-Rümelin’s argument in support of functionally indistinguishable red–green inversion. In my “An Externalist Approach to Understanding Color Experience” (in press a), I point out that Palmer, like Nida-Rümelin, simply assumes that visual states of color supervene on physiological states.]

Thus Nida-Rümelin’s constraint is too strong. She is, I think, quite right to search for empirical ways of testing claims about the nature of visual perception of color, and philosophers should take scientists’ hypotheses seriously. But if these hypotheses incorporate philosophically contentious assumptions we should not hold them as being above philosophical criticism. For in this case it is quite possible that there are philosophical reasons to consider them false.

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