The Perspectival Nature of Scientific Observation

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Abstract

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Scientific observation, I claim, is *perspectival*. My paradigm for perspectivism is human color vision. Rejecting both claims that colors are objective and claims that they are subjective, I argue that colors are perspectival. They are part of the perspective from which humans view the world. Using examples from astronomy, I then point out that scientific observation is perspectival in roughly the same way as human color vision. Although perspectivism is often dismissed as just another form of relativism, I argue that it is a form of realism, and that this is a perfectly reasonable conclusion from fairly obvious scientific facts.

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1. Introduction. For several generations, philosophers of science have embraced the doctrine that scientific observations are "theory laden." In the now canonical texts of Kuhn (1962) and Feyerabend (1962), this was primarily a *semantic* thesis about the *meaning* of terms used to report the results of observation in science. Such terms, according to this doctrine, derive at least some of their *meaning* from their connections with a theory. That the most prominent thesis about observation in science was a thesis about the *meaning of terms* reflected the then dominant preoccupation of philosophy with questions of semantics and the predominance of the philosophy of language within philosophy generally.

Nevertheless, the doctrine of the theory ladenness of observation had a point that transcends questions of meaning. This point was that scientific observation is not objective in any absolute sense. There are no unconditioned observational facts. Rather, observation is relative. In this case the relativization was to a theory. I now want to point out an altogether different way that observation is relative, a way that has nothing in particular to do with the meaning of terms. I say "point out" deliberately, because I will be appealing only to uncontroversial scientific knowledge. But I will be suggesting that some things we already know full well should be given a much richer significance than they are now accorded. I want to point out a way in which all scientific observation is *perspectival*.

Perspectivism has a long history which includes such disparate philosophical figures as Leibniz and Nietzsche. In contemporary disputes about the nature of science, particularly skirmishes in the so−called "science wars," perspectivism is often dismissed as just another form of relativism.[1] My scientific perspectivism, on the contrary, is arguably a form of realism. The claim that realism can be perspectival is, I will argue, not a contradiction, but a perfectly reasonable conclusion from fairly obvious scientific facts.

2. Color vision. In order to illustrate the nature of scientific perspectivism, I begin with an example that is both extremely familiar and scientifically accessible —human color vision. Most humans perceive the world as containing objects exhibiting different colors. Interestingly, there are currently three recognized philosophical accounts of color vision: objectivism, subjectivism, and interactionism.

Objectivists regarding color argue that colors are properties of the surfaces of objects and are, therefore, located on or at these surfaces. This accords with the common sense realist view that objects have colors. Roses are red, violets are blue, grass is green, and the sky is blue too. But no one thinks that colors are *autonomous* properties of objects. Rather, colors are assumed to be a function of other physical properties of surfaces. The most sophisticated view I know identifies colors with the *surface spectral reflectances* of objects (Hilbert, 1987).

Imagine shining a light of constant intensity through the whole visible spectrum onto a surface and simultaneously measuring the intensity of the light reflected from that illuminated surface as a function of wave length. The resulting function would be its surface spectral reflectance. Figure 1 shows surface spectral reflectances for several common surfaces.

Figure 1

It is very difficult to reconcile this objectivist notion of color with current scientific knowledge of the nature of color vision. Consider the phenomenon of *metamerism*, that is, the production of the *same* color experience of a given surface by light with *different* spectral characteristics. For example, a pure yellow is experienced when a monochromatic light with wave length 580 nm is projected on a neutral screen (Figure 2a).

Figure 2

However, as shown in Figure 2b, the same perception can be produced with appropriate intensities of monochromatic light with the two wave lengths, 540 nm (a greenish yellow) and 670 (a reddish yellow). Many other pairs of wavelengths would have the same effect. More generally, many surfaces can be made to appear *any color whatsoever* to any normal viewer by using monochromatic light from just *three* different sources at appropriate intensities. So just which color is to be assigned to any particular surface? Just what sort of surface is objectively yellow? A temptation here is to relativize to the experiences of a standard viewer under standard conditions. So any surface has the property of being yellow if and only if it would produce the experience of yellow in a standard viewer under standard conditions. But if an account of color vision must be relativized to standard observers, is it still an *objectivist* account of color vision?[2]

Well, then, how about subjectivism regarding color? For the subjectivist, colors are features of perceptual processes going on in the perceptual systems of individual perceivers. The physiology of color vision provides plausibility to a subjectivist stance.

Humans are trichromats, which is to say, their retinas contain *three* different types of receptors with three different pigments sensitive to three different ranges of the visible spectrum. Figure 3 shows the sensitivity spectra for the three pigments arbitrarily scaled with their maxims at one.

Figure 3

The three peaks are at roughly 450 nm, 530 nm, and 560 nm. These are conventionally labeled S(hort), M(edium), and L(ong) respectively. What gets transmitted to the brain for color vision is *differences* in the activation of the three types of pigments, and these differences stimulate two opponent systems, a red−green system and a yellow−blue system, which together produce the experience of all color hues. Figure 4 provides a schematic rendering of the neural code, where L, M, and S now represent the respective activation levels of the three types of pigments.

$$\mathbf{(L - M) > 0 \Rightarrow Red} \qquad \mathbf{[(L + M) - S] > 0 \Rightarrow Yellow}$$

$$\mathbf{(L - M) < 0 \Rightarrow Green} \qquad \mathbf{[(L + M) - S] < 0 \Rightarrow Blue}$$

Figure 4

This scheme provides a scientific explanation of the fact that no surface can appear to be a uniform reddish green. Because of the nature of this code, the experience must be either of red, or of green, or of neither, but never of both. Similarly for yellow and blue. These are not *a priori* truths, as some philosophers have argued, but experiences for which there is a solid *scientific* explanation. The fact that downstream color processing works with *differences* in activation also explains the phenomenon of *color constancy*, that is the fact that the perception of colors is relatively invariant with respect to the absolute intensity of light over a wide range of intensities. Relative color differences, for example, appear roughly the same in the shadows as in bright sunlight.

It is possible to determine experimentally the relative sensitivity of the human color vision system to each of the four unitary colors (red, green, blue, yellow) as a function of wavelength. Figure 5 shows the experimentally determined *chromatic response function* for a typical observer.

Figure 5

This figure shows again why one cannot simultaneously experience the same surface as uniformly red and uniformly green. There is no frequency that produces both a red and green response and, similarly, no frequency that produces both yellow and blue response.

Furthermore, if we look at the frequency for which the red−green response is zero, about 475 nm, we see that the resulting color experience is that of a pure blue, one with no mixture of either red or green. Similarly, at 500 nm, where the blue−yellow response is zero, the resulting color experience is of a pure green. Finally, at 580 nm the red−green response is again zero, with the resulting color experience of a pure yellow. Interestingly, since the blue−yellow response function crosses the horizontal axis only once, and that in the green region, there is no absolutely pure red. All reds have some component of either blue or yellow, which contradicts the common view that red is the paradigm of a pure color.

These and many other empirical findings seem to provide strong support for a subjectivist view of color vision. There are, nevertheless, good reasons for not being fully satisfied with subjectivism regarding color. One empirical reason comes from the *comparative* study of color vision. Humans are *trichromats*, but there are other species, including our domestic dogs and cats, that are *dichromatic*, that is, possessing only *two* different color sensitive visual receptors. So dichromatic color vision would be something like the color vision of a human suffering from red−green or blue−yellow colorblindness.

Somewhat more surprising, there are other species, including some birds, which are *tetrachromats*, possessing *four* different color sensitive visual receptors, the fourth typically being in the near ultraviolet region of the spectrum. The existence of chromatic systems with dimensions *higher* than three is particularly significant, since such systems must possess chromatic states not present in any form in trichromats. Tetrachromats would experience *six* unitary colors rather than only four. They would presumably experience not only binary hues (mixtures of two unitary colors), but tertiary hues as well. It is difficult for us poor trichromats even to imagine what chromatic experience would be like if we were tetrachromats.

Subjectivist accounts of color vision end up *defining* the various color hues in terms of human experience. Thus, strictly speaking, these accounts make it impossible to speak meaningfully of *color* vision in other species. The idea of a comparative study of color vision is thus ruled out by definition. Humans experience colors; birds experience something else.[3]

There are also conceptual difficulties. If we embrace subjectivism, we shall have to say that there really are no colored objects in the world itself. The world apart from perceivers contains light with various optical spectra, but no colored objects, and no colored lights either! The belief that anything apart from experience is colored is a total illusion. It follows that there is no meaningful distinction between the color of an object and the chromatic visual experience that comes with looking at that object. We cannot say, in some particular circumstance, that an object *appears* to be a different color than it really is, because there is no color that it really is. Part of the motivation for constructing an objectivist account of color is, of course, to preserve just this sort of distinction. But, having rejected objectivism regarding colors, are we not forced to embrace subjectivism? No. There are other alternatives.

Both objectivism and subjectivism share the tacit assumption that colors must be *monadic*, or intrinsic, properties of something or other. The objectivist says the something is spectral reflectances of physical surfaces; the subjectivist says it is chromatic states of a perceiving subject. Since most authors assume that these are the only alternatives, arguments against one view are automatically taken to be arguments for the other. But once one realizes that both views presume that colors must be intrinsic properties of something, the apparent restriction to just these two alternative is removed. An obvious alternative is to hold that colors are *relational* properties involving *both* objective things in the world *and* subjective chromatic states. Colors, I would say, are features of subjective perceptual states of some organisms, typically (but not necessarily) induced by the visual perception of physical objects reflecting, transmitting, or emitting light with particular spectral characteristics. This statement is *not* intended as a *definition* of colors, but merely as an *empirical characterization* of a particular kind of relational property.

This sort of characterization of color vision has been called *interactionism* (Thompson 1995). I prefer to call it *perspectivism* because this term preserves a clear distinction between observer and observed. It allows us to say that color vision provides humans with a particular *perspective* on the world. The world does not have a perspective on humans in any but a metaphorical sense. This emphasis on a human perspective also distinguishes a perspectival account of color vision from a *dispositional* account according to which the color of an object is identified with its disposition to produce the experience of that color in a standard observer.

A dispositional account, like a purely objectivist account, suffers from the fact that the resulting set of similarly colored objects turns out to be a highly heterogeneous grouping from the standpoint of physical and optical theory. Indeed, it is doubly so since the relationship between physical surfaces and surface spectral reflectances is many−one, and the relationship between spectral reflectances and color experiences is again many−one. A perspectival account, which focuses on the experiences of perceivers, does not require that the objects producing color experiences be identified as anything other than objects having this power. Which objects have this power, and why, is an empirical matter.

3. The Perspectival Nature of Scientific Observation. Now I want to suggest that all observation in science is perspectival in roughly the same way as human color vision is perspectival. I offer no philosophical arguments for this view. Rather, I will just remind you of the sorts of things with which you are already familiar and suggest you think of them in a somewhat new way. Here I take my examples from astronomy and astrophysics, although almost any contemporary science would do.

Consider standard black and white photographs of some familiar celestial object, such as the Milky Way, produced with ordinary optical telescopes. Such photographs, I would say, provide us with a *visible* light perspective on the milky way. But many other perspectives are possible. For several years, the Infrared Space Observatory, a satellite based facility, produced infrared images of many celestial objects, including the Milky Way. Infrared light provides a very different perspective on the universe, one not directly accessible to humans. The colors one sees in infrared images are *false* colors produced by computer manipulation of the original data.

Infrared light is of particular interest to astronomers for several reasons. Because it has the shortest wavelengths that are not mostly absorbed by intergalactic dust, infrared images provide the greatest possible resolution for very distant objects which are typically obscured by intergalactic dust. Additionally, of course, since very distant objects will be much red−shifted, many can best be seen in the infrared.

Moving to the other side of the visible spectrum, one can find gamma ray views of the Milky Way produced by another satellite−based facility, the Compton Gamma Ray Observatory. False color images produced by gamma ray detectors aboard this satellite reveal an apparent gamma ray halo above and below the plane of the galaxy. What produces this halo is currently unknown. Finally, moving to still higher energies, the Oriented Scintillation Spectrometer aboard the Compton Observatory has revealed a plume extending out perpendicularly from the center of the Milky Way. The measured energy of the radiation coming from the plume suggests that the high flux of gamma−rays is being produced by the mutual annihilation of electron−positron pairs. Just what might be producing a tremendous jet of positrons is, at this writing, a matter of much speculation.[4]

Earlier I noted the possibility of a comparative study of color vision in which color vision in humans is compared with color vision in other animals. Here I suggest that there could also be a comparative study of radiation detection. It would compare features of the human ability to detect visible light with the ability of various instruments to detect light both in the visible and in other regions of the electro−magnetic spectrum. I suggested that the comparative study of color vision supports a perspectival account of color perception. Here I suggest that the comparative study of electro−magnetic detectors supports a perspectival understanding of radiation detection and, by implication, of scientific observation more generally. Every instrument interacts with the world only from its own particular perspective.

4. Transforming Perspectives. The above examples reveal an aspect of observation in modern science that is so common it is hardly ever noticed. Observations obtained within one perspective can be transformed so as to be accessible from another perspective. In the typical case, observations from the perspective of an instrument are transformed into a form accessible to humans. Humans cannot detect infrared or ultraviolet radiation. But photographic film and electronic sensors can, and the information thereby obtained is transformed into a form accessible from a human perspective. These forms include black and white photographic images, but also contemporary digital graphics, complete with false color renderings of salient features. Computer generated images of the gamma ray halo surrounding the Milky Way, for example, show the body of the galaxy as being a reddish orange and the halo as a bright blue. These are, of course, false colors, introduced at the data processing stage to make the information accessible from the perspective of a human equipped with little more than its natural sensory organs. [5]

5. Perspectivism vs. Objectivism. The doctrine of the theory ladenness of observation relativizes the meaning of terms used to report observations to the meaning of terms occurring in some theory. It denies that there could be any such thing as a description of something observed whose meaning was independent of all theories. The doctrine that observation is *perspectival* relativizes observations themselves to the perspective of the relevant instrument. It denies that there is any such thing as an observation that is *perfectly objective* in the sense of being independent of any perspective whatsoever. The character of such an observation would be in no way limited or influenced by the nature of the instrument of observation. That seems to be impossible. Even if it were physically possible to build an instrument sensitive to the whole electro−magnetic spectrum emitted by a distant galaxy, it would be blind to things such as neutrinos which, we presume, are also emitted. There is no universal instrument that could record every aspect of any natural object or process.

Suppose it is granted that no instrument is sensitive to more than a very few aspects of any object. Could not observations then be objective within that perspective? Could there not be a kind of objectivism that is relativized to a perspective, a “relativized objectivism”? Not quite. Not only are all instruments limited to recording only a few aspects of the world, they do so with only limited accuracy. There is no such thing as a perfectly accurate instrument. They are all subject to margins of error. So part of the perspective of any instrument is determined by its built in margin of error. There is no observation that does not reflect the perspective of the relevant instrument of observation.

Well then, could there not be a kind of objectivism that is relativized to particular aspects of the world and to a given degree of accuracy, both of which are determined by the relevant measuring instrument? Yes there could. That kind of objectivism is just what I am calling perspectivism. Within a perspectivist framework, it is legitimate to claim, for example, that the Milky Way sports a gamma ray halo, though, of course, our knowledge of the extent of the halo and the energy of the gamma rays is limited by the characteristics of the instruments aboard the Compton Gamma Ray Observatory. And it is always possible that this observation is a fluke, an unknown artifact of the instrument itself, or of the method of data transmission, or of the program that produces the final images, or of who knows what.

6. Perspectival Realism. It is because I regard as legitimate perspectival claims about things like gamma ray halos that I take perspectivism to be a form of *realism*. It is surely not a form of social constructivism or any other more radical relativism. But neither is it a pure objectivism. Rather, it simply takes seriously the obvious fact that there are no unmediated observations.

I suspect that most of the arguments against scientific realism are really arguments against a purely objectivist realism. They do not apply to a perspectival realism. It is of course impossible for me here to review all such arguments to support this suspicion. But

I can say a few words about the powerful Kantian form of argument that a purely objectivist reality would be conceptually inaccessible to us. This is because the concepts we use to describe the world are always *our* concepts. We cannot get at the world in its unconceptualized form. From all that I have said above, this argument works as well for physical instruments as it does for humans.

Perspectivism, however, avoids this problem. It is based on the fact that our interactions with the world are always mediated. We and our instruments can only observe the world from our various perspectives. The crucial point is that they are *our* perspectives. We need not claim that our concepts exactly match any structures in the unconceptualized world in itself. We need only claim that they capture enough of the world's own structure to make the world intelligible *to us*.

Finally, it might be thought that my presentation above nevertheless presupposes a pure objectivism. This is because I have appealed to *theories*, for example, the theory of human color perception, to explain why color vision is perspectival. And, it might be thought, theories can be regarded as realistic only in an objectivist sense. I deny that this is so, but cannot defend this position at any length here.

Theorizing, I would claim, is every bit as perspectival as observing. No theory claims to represent more than limited aspects of the world. Mechanics deals only with mechanical aspects of the world. Astrophysics deals only with gravitational, nuclear, electromagnetic, and related aspects. In this respect, theories are just as perspectival as observations. One interesting difference, however, is that theories tend to be perfectly definite. There are seldom built in uncertainties. Even in quantum theory, the intrinsic probabilities are perfectly definite. Whatever parts of the world in itself might be like, they could hardly be exactly as our theories represent them. There are surely interactions between the aspects of the world we attempt to represent and those we leave out. So we are unlikely ever to achieve isomorphism between our theoretical representations and the world itself. We must remain content with limited perspectives.[6]

Notes

1 See, for example (Gross and Levitt 1994).

2 I realize that here more could be said and perhaps even needs to be said. For discussion of the difficulties raised by introducing the notion of a standard viewer, see Hardin (1986).

3 Evan Thompson (1995) emphasizes the importance of making room for the comparative study of color vision.

4 Information about these satellite facilities, as well as dramatic color images that cannot be reproduced here, is available on the NASA website.

5 The qualification covers such things as eyeglasses which, strictly speaking, change the visual perspective of individual humans, but this transformation plays virtually no role in scientific practice.

6 I realize this comment implies that physicists' dreams of a final theory (Weinberg, 1992) are just dreams. I believe this is so, but cannot further argue the point here.

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