CLASSICAL ARTICLES IN COLOR

Lichtenberg's Letter to Goethe on "Färbige Schatten"

G. C. Lichtenberg

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Received 17 January 2001; accepted 17 September 2001

The age of enlightenment saw the emergence of many central ideas in visual science. Georg-Christof Lichtenberg (1742–1799) was among the leading figures in 18th-century physics and had wide-ranging interests in vision. He taught in Göttingen, with Thomas Young one of his students and acquaintances. When Johann Wolfgang von Goethe (1749–1832) proposed an anti-Newtonian color theory, Lichtenberg wrote a response in 1793 that chronicled an early disagreement with Goethe's theory and contained a surprisingly modern point of view.

Lichtenberg was born in 1742. Members of his family were associated with the church or public service, but he pursued an academic career. He became professor of physics at Göttingen's Georga Augusta University in 1775 and continued in this position until his death in 1799. Although his scientific contributions were significant, in his lifetime he was best known for his lecture courses in physics, which were famous throughout Europe. Today he is best known for his essays and aphorisms on both scientific and popular subjects, much of which remained unpublished in his lifetime. A more extensive biographical sketch, a description of his relationship with Goethe, and his role in the development of theories of vision and color are given elsewhere.[1,2]

Goethe was seven years younger than Lichtenberg. In 1791–92 he published the first sections of the Beiträge zur Optik. *These contained the elements of the* Farbenlehre *of 1809, although the anti-Newtonian polemic was more restrained. The third part was published in 1793, and it contains a section on "Färbige Schatten" (colored shadows). On August 11, 1793, Goethe sent a draft of this section to Lichtenberg for his comments. Goethe hoped to enlist Lichtenberg's support for his color theories. However, Lichtenberg was firmly committed to Newtonian physics; his first scientific task in Göttingen had been to carry out astronomical measurements in Lower Saxony for cartographic purposes, and the framework for such measurements depended on Newtonian mechanics. He also had strong connections with the English scientific establishment and owed his position in Göttingen to the intervention of English King George III (who was also Elector of Lower Saxony).*

In his letter Goethe described a series of experiments in which induced colors could be generated, usually using one or two artificial light sources (usually candles) in combination with a daylight source. He interpreted these effects in terms of his Farbenlehre, *and his conclusion was that induced colors were in some way associated with the relative*

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energies of the two sources ("daß es hier nicht auf die Farbe des Lichts, sondern auf Energie desselben ankomme"; "der Schatten, den das stärkere Licht werft,…blau ist,… (Beitrage zur Wissenschaft III, pp. 70–71). However, Goethe soon abandoned a physical interpretation of induced colors and accepted that they were "physiologische Farben" (physiological colors).

Although Lichtenberg did not publish extensively on scientific subjects in his lifetime, his scientific journals and transcriptions of his physics lectures[3] *reveal a thoroughly empirical approach that would not be out of place today. In particular, his writing lacks the polemical style and rhetoric often present in writings of that period, which is well exemplified by his letter to Goethe; he took pains to cite earlier works, and his arguments and rejection of Goethe's thesis were concise and restrained. However, he took care to address Goethe with the appropriate respect. Goethe was of noble birth and occupied a ministerial position at the court in Weimar, whereas Lichtenberg was of bourgeois origin.*

It is interesting to read this letter in light of contemporary ideas on color appearance and constancy. A number of issues and observations were introduced by Lichtenberg with a sophistication unsurpassed by modern works. The notion that a "white" paper is identified as the one that would appear white in sunlight but of a possibly different color in a different light, has a number of interesting aspects. First, it clearly separates the invariant spectral reflectance of the material (explicitly stated to be uniform in this case) from the variations in "sensed" color and relates it to the invariance of "concluded" color. He is able to do this by invoking a "standard" illuminant, that is, sunlight. It is worth noting that the light reflected from every material under an equal-energy illuminant has the same spectral distribution as its spectral reflectance, and hence the color of the material under such an illuminant can also be considered an invariant (termed essential color *by Zaidi*[4]*). It is interesting that unlike most recent authors, Lichtenberg wrote of the judged constancy of the essential color, which is consistent with his experience, not of the constancy of sensed color.*

Another contemporary fashion is to model visual processes as Bayesian with prior probabilities related to frequency of occurrence. Lichtenberg's example that a white paper is almost never present under a neutral light and so almost never appears really white makes it clear that in models of color appearance, Bayesian priors should probably not be based on frequentist considerations of appearance. The emphasis on the significant role of interreflected light on the apparent colors of objects is also one that deserves serious consideration in models of color appearance in natural scenes. Lichtenberg explained colored shadows primarily in physical terms of different spectral compositions but added a role for induced color contrast. Colored shadows are easily found in U.S. cities that have both mercury and sodium streetlamps. Together the lamps provide a fairly neutral illumination on the ground, against which discrete objects form three shadows depending on the angles among the lamps, object, ground, and observer: brownish where the mercury lamp alone is blocked, bluish where the sodium lamp is blocked, and dark where both lamps are blocked. The hues and darkness of the shadow colors seem to be enhanced by simultaneous contrast. It is interesting, though, that whereas Lichtenberg was willing to concede a physiological locus for colored afterimages, he did not seem willing to do so for simultaneous color induction, instead implying a judgment that was influenced by context.

1. Joost U. "Da ich…Den bunten Schatten nachlaufe, wie ehmals als Knabe den Schmetterlingen"—Lichtenberg, Goethe, and the coloured shadows. Color Res Appl 2001;26:S28–S31.
2. Lee BB. Color science in Göttingen in the 18th century. Color Res Appl 2001;26;S25–S27.
3. Lichtenberg GC. Lichtenberg über Luft und Licht. Vienna and Trieste: Geistinger's Buchhandlung; 1811.
4. Zaidi Q. Identification of illuminant and object colors: Heuristic-based algorithms. J Opt Soc Am A 1998;15:1767–1776.

GEORG CHRISTOF LICHTENBERG TO JOHANN WOLFGANG VON GOETHE (7/10/1793; BW NR. 2303)

Noble Sir,
Esteemed Minister,

All that I have undertaken in the last few years seems to have proceeded very slowly, and even worse, without the advantage, which, following the old proverb, should accrue from such a course; I mean with a less sure outcome. I still suffer a great deal from nerves, and I doubt it will improve until my nerves cease functioning once and for all. I thus very much depend on your noble Excellency's good opinion toward me to excuse my delayed reply. Your Excellency could not easily have given me greater pleasure than through the generous communication of your excellent paper. Through it you made me aware of an area in the theory of light with which I had until now neglected. Some of the commoner phenomena of colored shadows were indeed known to me, but, to tell the truth, I had not thought that there still would be so much new, as to make a further elaboration so necessary. The issue is very interesting and should occupy me not a little, if my strength allows.

Before I describe to your Excellency some of my own thoughts on the matter, I must before anything else draw your attention to a publication on this subject by Dr. Gehler in his phys. Wörterbuch (physical Dictionary) article: *Schatten* (*blaue*) Volume III[,] p. 826 is important, because it contains not only a large number of experiments (92 in number), some very elegant, but also because the intelligent author arrives in the end to an explanation of the phenomena, which comes very close to yours. The complete title is: *Observations sur les ombres colorées, contenant une suite d'Expériences sur les différentes Observations sur les ombres colorées, et sur les causes de la différence de leurs couleurs. Par H.F.T.* à *Paris 1782,* in 12mo. That this person's theory is not so different from that of your Excellency, you will be able to gather from what that Dr. Gehler

says about the subject (presumably after Brisson). Since I have the book in my hands, so I will recount a short result from his experiments in the author's own words: ["]*Tout ceci prouve bien,["]* he says on p. 197, ["]*qu'une certaine proportion de clarité entre les Lumieres est non-seulement nécessaire pour colorer les ombres, mais encore que leurs* différentes couleurs dépendent aussi de la proportion d'intensité; entre les mêmes lumieres[."] I very much wish that your Excellency can one day look into this book, and would therefore offer, in the case, as I suspect, that it is not to be found in your region, to send the copy from the local library, if you so desire. It does not appear to have aroused the interest which it deserves. The author has very many nice experiments; among others, he has by means of two gratings, whose shadows cross one another, and by the light of two tallow candles and an open fire, seen *red, violet, yellow, blue and green* shadows *at the same time*. If the observations are not somewhat modified by imagination to suit the author's purposes—which, without the intention of the observer, in this area of physics, can happen more easily than in any other, of which I shall have more to say later. Despite the striking experiments, with which your Excellency supports your theory, and so much they appear to support the observations of your Excellency, following some of my own observations, I cannot yet commit myself to accept them without reservation. In particular, I reckon in the whole shadow-affair with very much uncertainty concerning the expressions *white, white paper,* etc. People certainly know what color it is that they call white, but how many have ever been confronted with a pure, white colour? In ordinary life we call white, not what looks white, but what would look white if it was set out in pure sunlight, or in a light whose quality did not differ much from sunlight. It is more the potential to be white and become white, in all its gradations, that we call white in some object, rather that the pure white colour itself. I take this sheet of paper, for example, to be white in the deepest twilight, even at night in the weakest starlight, by tallow, wax or lamp light, in the brightest sunshine, in the red of evening, by snow and rain, in the woods or in a decorated room, etc., for I am convinced that in the clearest sunshine, taken from an alpine peak where the blue sky's reflection is missing, it *is* nothing less than white. We certainly are not aware of this, because, in all our judgments based on visual sensations, judgment and sensation have so grown together, that after a certain age it is scarcely possible to separate them; we believe at every moment that we *sense* something which we really only *conclude*. It is on this basis, that a bad portraitist paints faces over and over with flesh tints; they cannot imagine that in the human face blue, green, yellow and brown colored shadows can be present, and with their collars they proceed so carefully, that one can only guess from the position and shape, that the spot of chalk, which they have dabbed in, should portray a collar. Opposite my window there stands a white chimney, of which both the sides visible seldom have identical illumination. Sometimes when one side seems to me to be yellow or bluish, I ask persons of otherwise normal judgment about the colour of the chimney. The usual answer is that it is as white on one side as on the other, but on one side the sun is shining and that makes the difference. In the camera obscura, judgments are made more correctly; because of this coloration is more easily studied in the works of the great masters, because one has there the colour already judged and analyzed on the canvas, and can examine it like any other coloured patch, in all types of light at all possible angles; but then sensation must be separated from judgment, which is not possible for everyone. In a few words: we call white the *disposition* of a surface of a body to reflect all types of coloured lights equally in all directions, and such a body only appears really white, if all those coloured rays, in correct proportions, properties and intensities, fall upon it, in all other cases not. It is a wager of almost infinity to one, that a body, for example a sheet of white paper, which has the *capacity* for white in the highest degree, never really appears white and never has to be portrayed as white in a painting. For example, I am writing now opposite a window that faces north, the sky is fairly bright and several roofs, which face south and west, are getting some sunlight; my room is decorated in sky blue, its white ceiling is noticeably illuminated from the opposite houses; what a varied light falls upon my sheet of paper? However, that all the colours from these external objects fall on the paper does not, I feel, need any proof. For, if I were to make the room completely dark, and at random here or there were to poke a hole in the wall, so invariably there would appear on the paper the colour of the object in that position which is directly in line with the hole. So as I thus, after I have drilled holes perhaps here, perhaps there, can generate blue, red, yellow, etc., spots on my paper, so arise coloured shadows on so-called white paper, when some obstruction blocks some of the incident light, which would be necessary to bring out the so-called white (which it is not). That blue shadows do not arise from the *blue sky* has been irrefutably demonstrated by your Excellency; only I believe that also in an overcast sky either blue can be dominant, or at least gray surroundings can appear blue through a yellow context. I experienced this in a manner which left me with no doubt. I own a plane mirror with almost orange-yellow glass. With it I sat by the wall farthest removed from the window. It was a very dull day. As I viewed the window with its dark bars, so I saw some of them three times, once black, once orange yellow and once sky blue. I explained to myself this appearance as follows; I do not believe I am mistaken. The mirror produced two images, one from the surface as with any other reflecting object, and the other from the coating. The image of the bar from the coating was black when it overlapped with the image from the surface; orange coloured, when the surface image had the bright sky's image from the coating *under* it, and sky blue, when the image from the coating had the bright sky's image from the surface *over* it. It appeared splendid. As soon as I put a yellow, unsilvered mirror next to it, from the comparison I saw, that what I held to be sky blue in the narrow bands between the many splendid yellows, was nothing other than the gray sky which I saw on the glass plate, and finally I no longer saw my sky blue

stripes as blue. Although I cannot thus directly explain some aspects of your Excellency's experiments, this might well be possible, if the local conditions, which seem to be extremely important, were known to me. I have also experienced the following. About 10 days ago, as the sun shone into my corridor at 12 o'clock, I held a key against a white wall, which was only illuminated by reflection, and found the shadow pale lilac. Today at 12 o'clock, since the conditions apart from the different declination of the sun were subjectively identical, I held the key on the same wall and the shadow was a dirty yellow. Has your Excellency perhaps also seen the splendid lilac shadows? As I have pursued coloured shadows like a small boy chasing butterflies since the arrival of your letter, so recently I found in one of my rooms a splendid sight. There reigns in this room, where I keep books, a special, diffuse, magical light, which one could tell was the result of overlapping reflections from objects lying opposite and illuminated by the sun, of which the entrance was partially obscured by a half-drawn white curtain. I immediately placed farthest from the window a sheet of paper, and when I held my hand opposite it the shadow was lilac, and when held nearby the shadow was black with a lilac surround, and alongside there were 2 to 3 pale green shadows. A thick pencil held horizontally gave only lilac shadows, vertically lilac and pale green next to one another. Without having to explain myself further, your Excellency will see what I wish to conclude, so I will leave the detailed application here. But I do not wish to say that there is nothing left in this issue which still has to be explained. It is for example obvious, that when one looks for a long time through a red glass and removes it suddenly from before the eyes, so objects appear for a moment green; if one looks on the other hand through a green glass, so they then appear reddish. This is connected to Büffon's *couleurs accidentelles,* which one notices in one's eyes. In summary, I believe the subject is very important and I expect much more from your Excellency's endeavors after this splendid beginning. I will certainly work on this topic as much as circumstances allow and not miss the opportunity of informing you of my results. Gehler cites 2 further publications, one from Beguelin and one from Opoix, that are probably of lesser significance. I request your forgiveness for my hasty note, which I have the honour to present with the utmost esteem and deepest respect[.]

Your excellency's
obedient servant
Göttingen 7 Oct 1793
GCLichtenberg

Published online in Wiley InterScience (www.interscience.wiley.com).
DOI 10.1002/col.10069