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SOME MISUNDERSTANDINGS ABOUT COLOR PERCEPTION, COLOR MIXTURE AND COLOR MEASUREMENT

Dorothea Jameson*

Alan Lee’s criticisms of Josef Albers’ concepts of color [1] give me an opportunity to try to clarify some basic matters concerning color perception, color mixture, color interaction and color measurement. I have long been convinced that a major culprit responsible for the many confusions, misunderstandings, and incorrect statements about color is our use of the language. When we say that something looks blue or yellow, red or green, white or black, light or dark, we are using these color terms to describe what we see. If we have grown up in a normative language system, and if we have normal color vision, then we know what we are talking about when we use color terms in this way. We are categorizing a perceptual experience, and an audience who shares our language and a comparable color vision mechanism understands our statements. On the other hand, when we say that we mix yellow and blue to get green, or alternatively that we mix yellow and blue to get white, our readers or listeners usually do not know what we are talking about in the same way. The reason for this is that we have not said what we are mixing or how we are producing the mixture.

We might be placing two pigments on top of each other on a palette and using a palette knife to blend them into a homogeneous mixture before applying this mixture to a canvas or other material substrate. We might be placing two pigments on a canvas next to each other in an array of tiny dots that cannot be resolved as individual dots when we step back from the canvas, but will rather look like a uniform area of some color. The first procedure is subtractive color mixture, and the second, pointillist technique, is an example of spatial color mixture. The mixture results will differ in the two cases, but we will not be able to say what the result is in either case until we know something more about the pigments that are used.

More often than not, the names blue and yellow are just that: they are category names or labels that include a wide gamut of appearances. The appearance of the pigment labelled blue, when looked at alone, might be more precisely described as reddish-blue or greenish-blue or a blue that appears to have no trace of either reddish or greenish hue in addition to its blueness. The same is true for the pigment labelled yellow. Consequently, when Josef Albers, who puts practice before theory, and who makes it very clear that trial and error is part of the painter’s craft, says that he puts blue and yellow dots in a pointillist array and gets green from their spatial mixture, he is certainly misleading the reader, but he might well be telling the truth. This is because his trial and error procedure would certainly have led him, if he wanted to get green from spatial mixture, to use a yellow pigment that by itself in larger areas appeared greenish-yellow and a blue pigment that appeared greenish-blue. If one were to do this, then the spatial mixture would have a greenish hue.

There is a third thing that we might be doing with the pigments that we have labelled yellow and blue. We might be using each of them to paint a different sector of a paper disc, and then we might be mixing the colours by placing the paper disc on a so-called color wheel and spinning it at a rate fast enough so that we see the disc as a uniform color. This is temporal color mixture, and it is the technique that was used by Ogden Rood, to whose work Lee referred in his critique. In spatial mixture we exceed the spatial resolution of the eye by controlling the dimensions of the individual pigment dots and their separations, in temporal mixture we exceed the temporal resolution of the visual system by controlling the rate of succession of the individually pigmented areas of the disc in each part of the visual field. Rood was interested in art as well as in optics, and he actually published some results using particular pigments in particular proportions on his color wheel and stated their equivalents for palette mixtures of the same pigments. An important generalization from Rood’s comparisons was that some black pigment must always be included in an additional sector on the spinning disc to make the mixed color equivalent to the otherwise darker color produced by the subtractive pigment mixture on the palette. Rood’s results were useful to the extent that he was comparing identical pigments used for the two mixture techniques; they would have had little significance for practice had he simply used category names like yellow and blue to restrict his choice of pigments to be compared in the different mixture situations, and had he reported his findings in these same terms.

There does, indeed, seem to be documentary evidence that the results of Rood’s experiments were known to the French painters of the time after the French translation of his work appeared. Among these painters we think particularly of Seurat. The transposition of the temporal mixture results to spatial mixture was probably an approximately valid one. Although Lee chastises Albers for his misleading description of these kinds of mixtures, we can also question Lee’s own assertion that temporal color mixture is strictly a case of additive mixture. In fact, when light reflected from two different pigments is seen as uniform in colour because of failure of either spatial or temporal visual resolution, the process and the result can be described more accurately as averaging than as addition. Strictly speaking, additive mixture occurs only when one light is actually added to another light making it perfectly coincident in both space and time. Both the process and the results are additive. What is the result of a truly additive mixture of yellow and blue lights? The answer here is just as uncertain as the answer to the spatial or temporal mixture that starts with yellow and blue pigments. If we are simply using category names as labels for the lights, then we cannot say what the mixture result will be. If the labels blue and yellow are applied to lights that when seen alone appear to be greenish-blue and greenish-yellow, then their additive mixture will be greenish. If the lights with the same labels are seen when viewed alone as reddish-blue and reddish-yellow, then their additive mixture will be reddish. If the lights when seen alone are, respectively, a blue with no trace of either

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green or red, and a yellow with no trace of either green or red, then their mixture will contain no trace of either green or red. Depending on the relative proportions of the two lights used in the mixture, the result will be either bluish or yellowish or, when the proportions are just right, neither blue nor yellow nor red nor green, but white or grey.

With respect to the whole question of the results of different methods of color mixture, the message seems obvious. The use of color names is both ubiquitous and ambiguous. With artists the problems arise more often than not in their discussions of mixtures of 'yellow' and 'blue'. With visual scientists, who typically talk about additive light mixtures, there is an equivalent problem with respect to red and green. The issue is precisely the same. More often than not, in a scientific discussion of color mixture, one will read that red and green mix to produce yellow. This is very easy to demonstrate. But in such a demonstration, if you ask to see the red light alone you will see that it looks yellow-red, and if you ask to see the green light alone you will see that it looks yellow-green. Indeed, when they are superimposed, the mixture of such lights does look yellow. If you wish, you can also demonstrate with equal ease that red and green lights when mixed additively produce blue. In this case, if you asked to see the red light alone it would look bluish-red and the green light alone would look bluish-green. Only if you have taken great pains to assure that the green light is a green that looks neither bluish nor yellowish and the red light is a red that looks neither bluish nor yellowish can you determine the result of a mixture of red and green lights in additive combination. It is not yellow but either pinkish or greenish or, in appropriate mixture proportions, a grey or a white.

But this is only part of the story. There has never been any doubt that the perceived color in a given part of the visual field is influenced by the context as well as by the light characteristics in that part of the visual field. And by context I mean here the light in surrounding parts of the image on the retina and also whatever light preceded this one in its same position. That color depends on context is always true, but it is not always noticed. This interaction of color is, of course, the main point of Albers' book and a fundamental aspect of much of his art. Lee objects to Albers' description of this interaction process and of its result as 'deception' about the color 'as it really is'. I, too, object, but my objection doesn't cause me to devalue Albers' art.

What information, reliable or otherwise, does color convey? Certainly, we cannot deduce from color identity an identity in wavelengths and energies of lights. The many color matches that can be made between additive mixtures of very different lights makes this clear enough. The quantitative data and procedures of colorimetry, or color measurement, have been standardized to enable precise specification of the different physical light distributions that are visually identical. So if color perception is used for information about the physical characteristics of the physical world, this is the prime deception. But this kind of deception is hardly Albers' concern.

The color of the concrete terrace just outside my study window is a sometime thing, as is the color of Monet's Rouen Cathedral in its many versions. And yet, and I think this is the source of the problem, I have no difficulty picking up the green notepad on my desk and not the blue one whether I do it in the daytime or at night with the study light on, or whether the blue and green notepads are resting on the bare surface of the desk, or one is on top of the orange journal, or the pile of papers that I have not yet filed. The color seems to inhere in the object, to be an intrinsic part of its physical self. But of course, here I again am using the color terms, blue and green, as category labels, and it would be foolish not to do so. The fact that we can use category hue labels to identify objects tells us two things. The first is that the visual system is designed to compensate in large part for changes in the quality and the quantity of light falling on the object and reflected from it into our eyes. The compensatory changes in the visual system account for what we call approximate color and lightness constancy. The departures from constancy are not, for many strongly colored objects, of sufficient magnitude to move the object color from one hue category to another. And this is also true of the color changes brought about by context, including both simultaneous and successive contrast effects. It is not that the blue color of the notebook is not at all changed by placing it in different contexts or under different illuminants. It is that the label is sufficiently inclusive to cover the gamut of somewhat different appearances that the blue notebook takes on. The different appearances that do occur do not interfere with our identification and consequently we do not notice them. We say the notebook has a 'real color', and in so saying we are deceived.

When colors become more difficult to categorize by hue names, or by black or white, these subtle colors are more appropriate for demonstrating changes due to spatial interaction effects, as Albers does, or illumination effects, as Monet does with his cathedrals and haystacks. I share Lee's dissatisfactions with many of Albers' explanations, and I also share his admiration for most of Albers' visual demonstrations. It is the illustrations, I believe, and not the words, that are the important didactic instrument for Albers' and other students, and also the important background documents for appreciation of his paintings.

Lee suggests that Edwin Land's Retinex theory is a better source for understanding the matters that Albers deals with in his book. It is certainly true that Land has many powerful demonstrations showing that we cannot use the colors we see to deduce the physical characteristics of the lights in different parts of an image. Unfortunately, however, both Land's descriptions of his demonstrations and the models that he develops to account for them imply that the colors we see are much more constant than our experience shows them to be. Thus, when Land says, and his models require, that the light can be changed in any of a number of various ways and the perceived colors do not change, he is correct only in the sense that the category names appropriate to describe the perceived colors do not change. If Lee is using the demonstrations and implications of Retinex theory in teaching his students, then I trust that he, like Albers, also emphasizes practice before theory.

Reference