COMPARISON BETWEEN VISUAL GRADING AND REFLECTANCE MEASUREMENTS OF ERYTHEMA PRODUCED BY SUNLIGHT*

FARRINGTON DANIELS, JR., M.D. AND J. DONALD IMBRIE, B.S.

The scientific study of the skin and its responses requires consideration of methodology of observation of skin color. The quantitative determination and expression of skin color is of dermatological interest for a variety of reasons. Such measurements can be used (a) to quantify the erythema and pigmentation following exposure to ultraviolet light and ionizing radiation; (b) for matching of skin grafts, cosmetics and prostheses to background skin color expressed in standard terms such as those used in the paint industry; (c) for quantitative confirmation or refutation of clinical impressions of correlations between skin color and tendencies to various disease processes such as actinic keratoses, skin carcinomas, and malignant melanomas.

The human eye and its associated central nervous system circuitry is the principal diagnostic tool of the dermatologist. Its remarkable capacities and deficiences are of concern in dermatologic diagnosis. The eye and its circuitry have high resolving power. The central nervous system contributes to the visual apparatus modifications and corrections which permit vision to surpass the optical qualities of the eye itself. As a device for discriminating color, the eye is said to be able to discriminate at least 10 million different colors, shades and hues (1). Difficulties in research or in the clinic do not arise from deficiencies of sensitivity or discriminatory capacities of the visual apparatus, but from other causes. The physics, psychophysics and psychology of color have been reviewed extensively by Judd (1, 2).

Among the factors which can produce error in color identification and description are the spectral color of the viewing light, color of the surrounding objects and background, and colors previously seen. The effects of light, background and expectation can be considered as corrections, provided by the brain, which are generally useful in daily living. The visual apparatus corrects so that we do not "see" the pink and red glow which turns up in our Kodachromes taken in the late afternoon. A patient with jaundice seen under yellow light may be incorrectly diagnosed. Yet we do not make the mistake of considering every white skinned person seen under yellowish light to have liver disease. Judd (1) describes many virtues of the eye, but remarks that "the chief trouble with it is that it is connected not to a well-behaved amplifier but to a brain". Wired to a brain with clinical training, the eye of the dermatologist may become a truly formidable analytical device. The recognition of a common skin disorder in a fraction of a second indicates circuitry of a remarkable nature.

Why then should we consider instrumental methods which cannot approach the eye in sensitivity and which substitute tedious arithmetic for the flash of insight followed by a familiar word such as violaceous, ham-colored, salmon-colored, heliotrope, and so on? The reasons are the same as for the use of any scientific instrumentation. These include: 1) instruments provide extension beyond the range of human senses, for example into the infrared and ultraviolet ranges of the electromagnetic spectrum; 2) instruments can provide sets of numbers which can be studied by appropriate mathematical means; 3) with instruments it is possible to compare against standard units, for example, breaking color down into percentage reflectance compared to magnesium oxide at specified wavelengths permits comparison of results obtained in Africa, Japan and the United States; 4) by use of a less sensitive system than the human senses we filter out superfluous information which may be confusing; 5) by using apparatus we can eliminate artifacts of the human mind and psyche from the measuring system.

In studying the effects of 8-methoxypsoralen on the skin's erythema and tanning response to ultraviolet light we have been concerned with quantitative expression of the effects and are presenting here not only our results but also

* From the Division of Dermatology, University of Oregon Medical School, Portland, Oregon.

Presented in part at the Eighteenth Annual Meeting of The Society for Investigative Dermatology, Inc., New York, N. Y., June 2, 1957.

This study was supported by Public Health Service, Grant No. C-2837 PET.

some of the rationale in our choice of measuring system. Types of measuring system applicable to skin color include the following:

1. VERBAL DESCRIPTIONS

We cannot have ten or twenty million different words to describe the seeable colors. Simplified verbal systems, based on the Munsell color standards are discussed by Appel (3) and by Judd (1).

Appel (3) in his paper "Decadent Descriptions in Dermatology" called attention to the inadequacies of many of the color terms in dermatology. He pointed out, for example, that the color of a salmon varies from head to tail and that the term apple jelly color may be completely obscure to a foreign dermatologist.

2. RATING SCALES

In studies of the effects of ultraviolet and other radiation, most of the interpretations have been based on a 1+ erythema or in some cases a 2+ erythema. The use of a 1+ or 2+ criterion of response implies some features of an ordinal scale because less than 1+ is separated in rank order from more than 1+. There are several drawbacks to the use of such rating scales. These include the ever-present hazard that linearity will be assumed where none exists or where none has been established. In practical use of such scales it is also difficult to force borderline ratings into the fixed categories even when the investigator has devised the scale himself. There is a tendency for some of the data records to show in addition to the scheduled 1, 2, 3 and 4 plus ratings, such ratings as ±, 2½+ and so on. These reflect the pressure of the experiment on the investigator but are not useful in the mathematical treatment of the data and force a delayed decision of some type. In an experiment with many observations there is less strain to reading a dial than to categorizing in an arbitrary scale. As in any system of measurement where human decisions are involved, the rater must be kept independent of the rest of the experiment or at least ignorant of the role of the individual measurement in the overall hypothesis being tested. The values and limitations of various types of rating scales have been thoroughly studied by Stevens (4).

3. COMPARISON WITH COLOR STANDARDS

Comparison of the skin color with standards such as the Munsell standards, or matching skin color by adjusting the components of a color wheel, theoretically, is a much sounder system than the single or multiple category arbitrary rating scale. Many errors in color perception can be obviated by using the eye as a null system as is done in chemical and other forms of colorimetry. We have not made comparative studies of this general method, but at least two drawbacks are immediately evident. The first is that the painted standards such as the Munsell Book of Color do not have the general appearance of skin. They lack the details of hairs, surface texture, translucency and various patterns which are conspicuous on visual examination. Munsell numbers are distributed approximately in terms of psychological color space, but the numbers produced by this system are not easily incorporated into routine arithmetical procedures and as with the visual rating scales the standards are much better for establishing equality than they are for quantifying differences.

4. RECORDING SPECTROPHOTOMETERS

The definitive method for measuring skin color is the recording spectrophotometer adapted for reflectance readings. This type of apparatus has been used by the investigators who have discovered which pigments determine skin color (5, 6, 7, 8). Color is, of course, what the eye and brain "see" and the spectrophotometer measures the component wavelengths of light, not the color itself. This apparatus scans through all wavelengths of visible light (and variable distances into the ultraviolet and infrared regions) and compares reflectance of the sample with that of a white standard at all wavelengths. While this remains the definitive instrument, it has drawbacks for general clinical and field use. The apparatus is expensive, not portable, and for the purposes of the current experiments would provide an excess of information giving reflectance data at all wavelengths rather than a critical few.

5. PHOTOELECTRIC COLORIMETERS

Photoelectric colorimeters measure diffuse reflectance by use of a light bulb, a glass filter, and two photocells. One photocell measures light intensity passing through the filter on the way to the skin, and the other filter measures the intensity reflected from the skin surface and measured at a 45° angle to the incident 90° beam. As in the case of the recording spectro-

photometer, the reflectance through the different filters is measured in comparison to standard surfaces which consist either of freshly prepared magnesium oxide or of standards referred to the reflectance of freshly prepared magnesium oxide. The apparatus which we have used is the Photovolt Photoelectric Meter Model 610-T, which provides controls and a galvanometer in a portable box. The reflection head is readily moved about on its cable, which plugs into the galvanometer and control box. This model has provision in a revolving turret for four different filters. This type of instrument has been used in a number of anthropological and clinical studies (9, 10, 11).

The most commonly used filters with photoelectric reflection meters are the Hunter tristimulus filter (1), which in combination with the incandescent tungsten lamp and photocells estimate the X (red) primary, the Y (green) primary, and the Z (blue) primary of the CIE system (International Commission of Illumination) (1). Tristimulus colorimetry therefore provides a means for approximate numerical specification of colors in a manner related to visual perception of these colors. The readings obtained with the tristimulus photoelectric reflection meter provide useful two or three digit numbers representing spectral regions. These can be handled by standard methods or converted to the three tristimulus values which can be incorporated into more complicated analyses in three-dimensional color space.

The terms reflection and reflectance often are used more or less interchangeably. Strictly defined, however, spectral reflectance is a special case of the general phenomenon, reflection. Reflectance is the ratio of reflected to incident radiant flux of narrow wavelength range.

The photoelectric colorimeter can also be used to perform abridged spectrophotometry. It is this use which we have found most suitable to date for use in studies of the erythema and pigmentation responses of the skin to ultraviolet light. The rationale for this approach is evident from the spectral reflection curves of human skin given in Figure 1. The information in this figure was redrawn from the publications of Edwards and Duntley (5), Kuppenheim and Heer (6), and Jacquez (7). The pigment factors in normal skin color are melanin, melanoid, oxyhemoglobin, reduced hemoglobin and carotene. There is some absorption near the far end of the visible spectrum which is attributed to water. With the exception of specific absorption bands attributed to other components, the reflectance curves and the skin color are primarily determined by melanin. It can be seen in Figure 1 that in the red portion of the visible spectrum the reflectance curves are approximately parallel in a light skinned person and in the dark negro. The curves are also approximately parallel in the blue portion

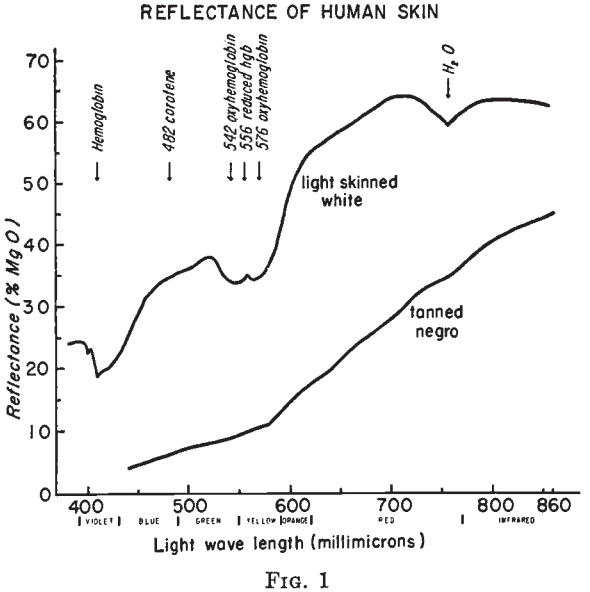

FIG. 1

of the visible spectrum. Measurements of correlation of reflectance at different wavelengths between the different portions have not been published, but inspection of the published curves suggests that the correlations are high in areas dependent upon melanin as the principal determiner of color.

In our approach to the measurement of skin color by the use of abridged spectrophotometry we are interested in obtaining a small number of filters which are most representative indicators of the factors in skin color, not necessarily those which give the closest approximation to visual impression.

The transmittance of the blue, green and amber tristimulus filters and the red filter supplied for use with the Photovolt reflection meter are indicated in Figure 2. The tristimulus filters have considerable overlap in the areas of absorption due to oxyhemoglobin and reduced hemoglobin. They are therefore not ideally suited to discrimination between absorption due to hemoglobin as

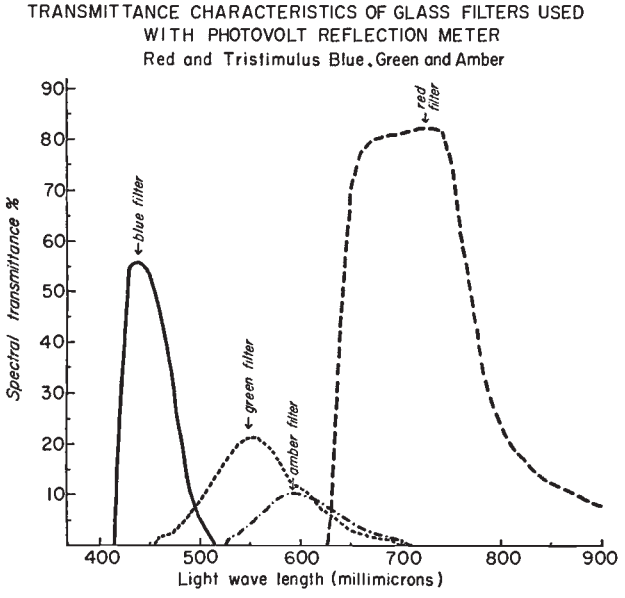

FIG. 2

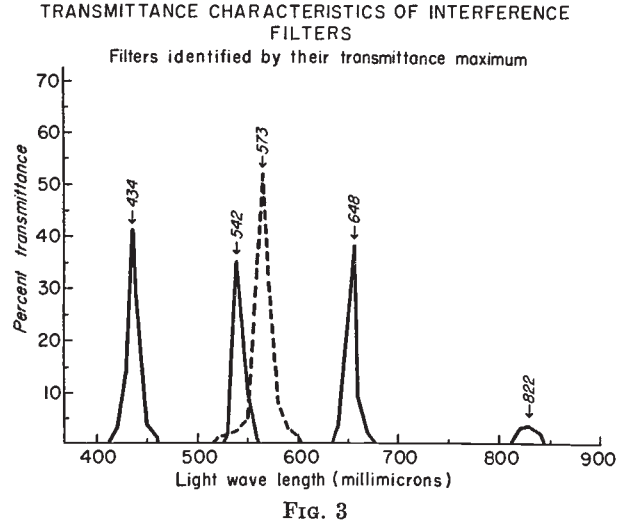

FIG. 3

contrasted to that of melanin, although the characteristics of the photocell and incandescent tungsten lamp weight the results so that the reflectance readings at different wavelengths are not determined solely by the transmittance characteristics of the filters.

The relatively recent commercial availability of optical interference filters* with narrow transmittance bands simplifies abridged spectrophotometry (12). In these filters the separation of transmitted and reflected wavelengths is quite literally done with mirrors. The most common type consists of a transparent dielectric material between two thin films of silver. Greenland (13) has discussed some of the characteristics of interference filters. The transmittances of the different filters used in our studies are given in Figure 3. These were measured with a Cary recording spectrophotometer. The portions of the graph which indicate 0 transmittance actually represent a transmittance of less than 1%. The filters are identified by their peak transmittance wavelength in millimicrons (1 millimicron = 10 Angstroms). To distinguish hemoglobin from melanin, filters were selected to have a maximum effect from hemoglobin or to avoid it as much as possible.

MATERIALS AND METHODS

The subjects in these experiments were 30 white men studied at the Arizona State Prison in April, 1956, and 45 white males at the Idaho State Prison in July and August of 1956. Volunteers were not accepted for the study if the skin of the back had been exposed to sunlight during the preceding 6 months. More numerous observations were made on the Idaho group and most of the conclusions in this paper are based on the Idaho observations.

The men were exposed to sunlight within one hour of solar noon on clear days. Single or multiple exposures of the back to sunshine were made for periods ranging from 10 to 120 minutes. The subjects received placebo capsules or various doses of 8-methoxypsoralen. (The dosage and effects of 8-methoxypsoralen are not a concern of this paper which deals only with the methods of color measurement.)

* The filters used in the study are the Balzers filters manufactured in Lichtenstein and purchased through Robert M. Lynn, Arcadia, California. Other sources of interference filters in this country include Bausch and Lomb, Axler Associates and Baird-Atomic.

Erythema and melanin pigmentation (tan) were graded visually on a scale of 0 to 5+ (14). Verbal equivalents were set up for guidance purposes. They were as follows: erythema 0 = none visible, 1+ = barely perceptible erythema, 2+ = pink, 3+ = red, 4+ = fiery red, and 5+ = furious red. The descriptive terms for the pigment classifications were 0 = no increase over surrounding skin, 1+ = barely perceptible, 2+ = light tan, 3+ = medium tan, 4+ = dark tan, and 5+ = chocolate brown. Spot checks between observers indicated good agreement. The observations at the Idaho State Prison were all made by one observer (J. D. I.).

In performing the visual grading the observer estimated erythema in the presence of pigmentation by blanching the skin with thumb traction. The ratings were made indoors with diffused daylight illumination.

The Photovolt model 610-T reflection meter was used for parallel measurement of skin color. The blue, green and amber tristimulus filters and a red filter (Corning #2403) were used. The transmittance characteristics of these filters are given in Figure 2. The reflection meter was operated from 110 volt line current.

The reflectance meter was standardized against a white enamel working standard which was calibrated against a freshly shaved block of magnesium carbonate. Reflectance values are expressed as percent of magnesium oxide using published values for the conversion between magnesium oxide and magnesium carbonate.

Because of the large number of measurements made on the field trials the following procedure was adopted. After warm up, the reflection meter was adjusted so that reflectance through the red filter read 100 on the white enamel standard. Readings through other filters were taken without resetting. Each number was subsequently multiplied by an appropriate correction factor. The reflection meter was calibrated on the white enamel standard immediately before the readings on each subject or more frequently if current fluctuation were conspicuous. The white enamel working standard, which had a reflectance through the red filter of 70%, proved very useful under these conditions in that all skins studied were encompassed in the range used. The lightest skins studied had reflectances through the red filter of 96 to 98 per cent of the working standard.

J. Hardy (15) has found that the scatter of

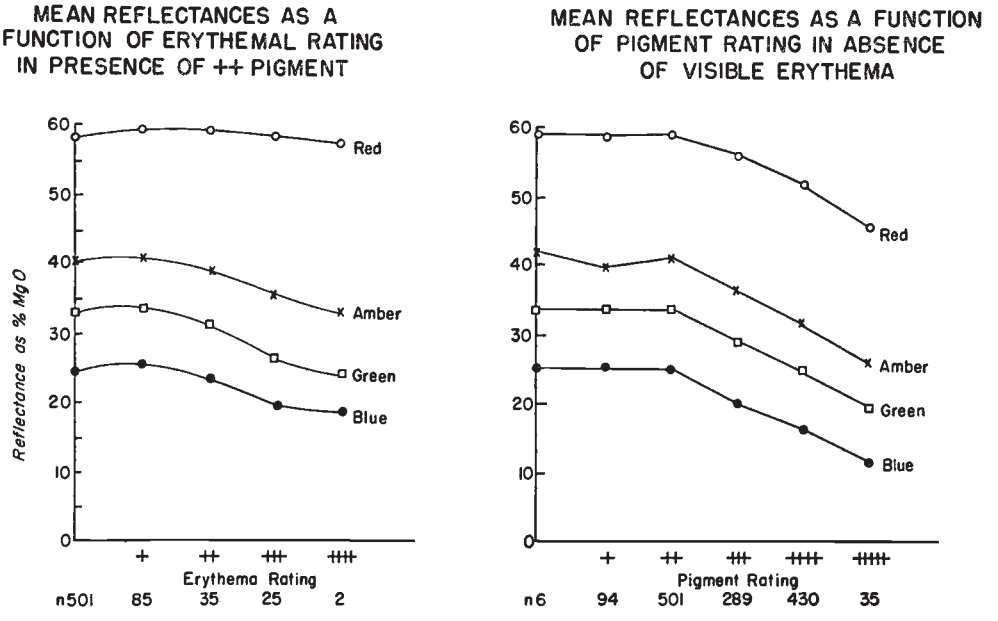
MEAN REFLECTANCES AS A FUNCTION OF ERYTHEMAL RATING IN PRESENCE OF ++ PIGMENT
Reflectance as % MgO
60
50
40
30
20
10
0
Red
Amber
Green
Blue
+
++
+++
++++
Erythema Rating
n501 85 35 25 2
MEAN REFLECTANCES AS A FUNCTION OF PIGMENT RATING IN ABSENCE OF VISIBLE ERYTHEMA
Red
Amber
Green
Blue
+
++
+++
++++
+++++
Pigment Rating
n6 94 501 289 430 35
Idaho 1956

FIG. 4

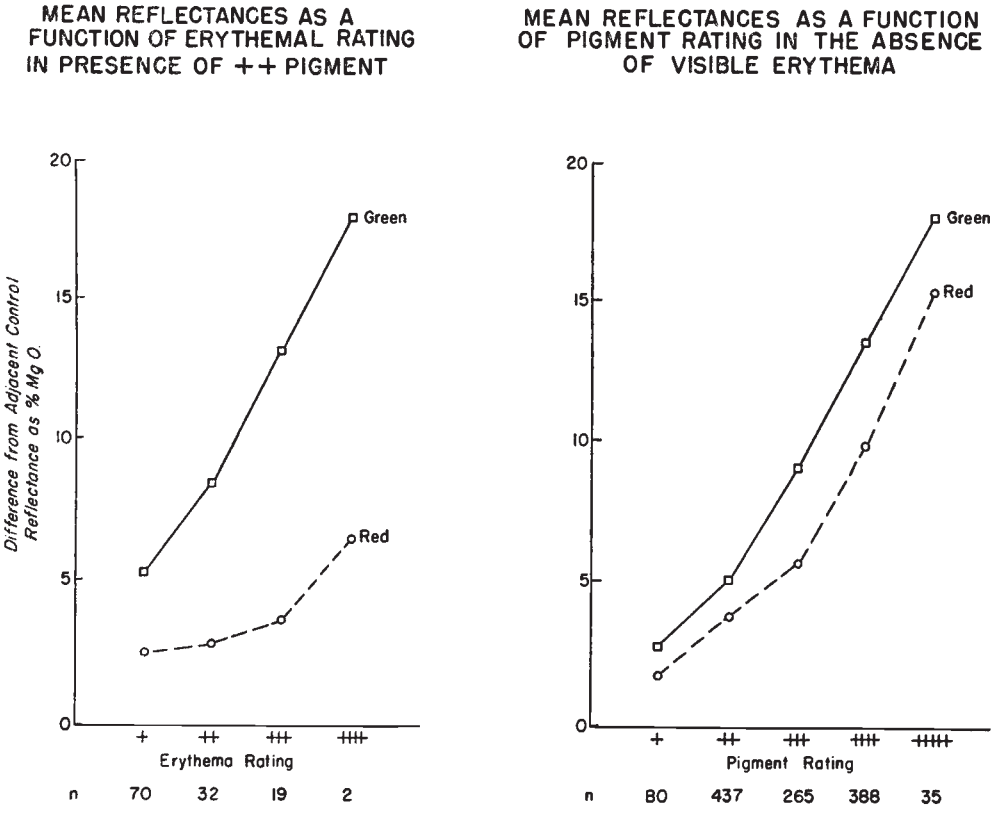
MEAN REFLECTANCES AS A FUNCTION OF ERYTHEMAL RATING IN PRESENCE OF ++ PIGMENT
Difference from Adjacent Control Reflectance as % Mg O
20
15
10
5
0
Green
Red
+
++
+++
++++
Erythema Rating
n 70 32 19 2
MEAN REFLECTANCES AS A FUNCTION OF PIGMENT RATING IN THE ABSENCE OF VISIBLE ERYTHEMA
Green
Red
+
++
+++
++++
+++++
Pigment Rating
n 80 437 265 388 35
Idaho 1956

FIG. 5

visible light from the skin surface follows Lambert's law and that the measurement of skin reflectance with integrating spheres or by comparison with standard diffusely reflecting surfaces will produce dependable data. In the present study it was assumed that in the absence of vesicles, hairs, or scales, the reflectance readings obtained were primarily dependent upon skin and intravascular pigments rather than on differences in scatter or other optical properties of the skin.

RESULTS

In the studies at the Idaho State Prison, 1865 sets of observations were made. These observations included the visual grading and reflectance measurements through the red and the blue, green and amber tristimulus filters. Comparison between the two types of observations is shown in Figure 4. In Figure 4 the reflectance through the four different filters is depicted as a function of the erythema visual grading. Mean reflectance values for each grade are given. The sample size (n) is given beneath each graph. It is evident that with constant visual grading of 2+ pigment (melanin) the mean values for the amber, green and blue produce approximately parallel curves through the different grades of erythema. The green filter is more sensitive to the effects of reythema than the amber and blue. Reflectance through the red filter is only slightly sensitive to the erythema.

In the other half of figure 4, the mean reflectances through the four filters are given for different grades of pigment where erythema was graded 0. The curves for the four filters are approximately parallel, as expected, since they are all measuring principally the effect of melanin in the skin.

From the measurements made on subjects at the Arizona State Prison correlation coefficients (r) were calculated in 127 sets of readings. The correlations among the three tristimulus filters were blue and amber, .92; blue and green, .92; green and amber, .93. Correlations were lower with the red filter than among the tristimulus filters. The correlations were red and amber, .83; red and green, .41; red and blue, .83. This analysis confirms the expectation that the blue, green and amber tristimulus filters measure approximately the same thing.

In Figure 5, the results from the observation at the Idaho State Prison study are expressed as differences from the adjacent control readings for the green and red filters. This analysis demonstrates that the red filter readings are relatively unresponsive to erythema without pigmentation and that in the absence of erythema the green and red filter readings are approximately parallel. This figure also indicates that from 2 plus to 5 plus grades an approximately equal interval scale for the mean reflectance values has been achieved. It therefore appears safe in large samples to average and perform other manipulations on the rating scale values.

The high correlations among the standard tristimulus filter readings confirmed the similarity expected from the spectral characteristics of skin and the filters as given in figures 1 and 2. The narrow band interference filters were therefore studied as a means of performing abridged spectrophotometry. This method was expected to provide: a) more specific information on pigments, b) greater sensitivity to absorption peaks, c) less susceptibility to discrepancies between the spectral composition of the source light and the spectral sensitivity of the photocell. The four glass filters were compared to interference filters having transmission peaks at 434 millimicrons, 573 and 648 millimicrons. The 573 filter was chosen to be near the oxyhemoglobin absorption maxima at 542 and 576 millimicrons. On each of 20 patients and normal subjects at the University of Oregon Medical School, a forehead and upper arm measurement was made with the filters indicated in Table I. The people ranged from albino to negro and included a patient with phenylketonuria, one asiatic and variously tanned caucasians. These measurements were of basic skin color without erythema.

In Table I the relationships between the different filters for the forty measurements are given as the coefficient of determination. This value is the square of the correlation coefficient (r^2), and indicates the percent of total variation in the

TABLE I

Relationships between reflectances through different filters expressed as coefficients of determination (r^2) ($n = 40$)

	Red	Amber	Green	Blue	648	573
Amber	.90					
Green	.89	.96				
Blue	.77	.85	.88			
648	.94	.89	.88	.80		
573	.77	.81	.83	.76	.73	
434	.76	.84	.80	.84	.80	.74

readings through one filter which can be predicted from readings obtained through another filter. In the absence of acute erythema the red filter shows a higher correlation with the three tristimulus filters than in the solar exposure experiments. In general, reflectance measurements made through interference filters have lower correlations with each other and with the colored glass filters than the colored glass filters have among one another.

DISCUSSION

The suggestion of Lasker (10) and of Barnicot (17) that a red filter be used to measure melanin independently of erythema has been supported by our measurements. The high correlation between the interference filter in the red region of the spectrum and the red glass suggests that the cheaper red glass filter may be adequate for this purpose.

Two general types of use of the reflectance meter in evaluating skin color are evident. The first of these is expression of color as tristimulus coordinates for purposes of specifying skin color in terms which can be compared to ointments, cosmetics, prostheses, and perhaps matching of recipient and donor sites in skin grafting. The other general approach is to measure melanin and and hemoglobin independently and thus quantify pigmentation in the presence of erythema or evaluate the degree of erythema in patients with different basic skin color. For this purpose our studies to date would suggest that an interference filter with a transmission maximum at approximately 542 or 576 millimicrons should be used to provide a system maximally responsive to erythema. To measure melanin independently of erythema either the red glass filter or an interference filter with transmittance maximum between 600 and 670 millimicrons appears suitable, but not perfect (16, 17).

Goldman (18) has reported that there is no reflectance change on diascopy at 620 millimicrons. We have not tried a 620 millimicron filter, but it would appear desirable as the melanin sample because of this property, if the transmittance "tail" of the filter avoids the hemoglobin absorption areas.

CONCLUSION

In developing methods of skin color measurement to substitute for verbal descriptions or rating scales we can set as our goal the development of methods which provide parallel columns of 2 or 3 digit numbers for evaluation by standard statistical methods. The photoelectric reflectance meter with appropriate filters and standards appears to meet this desideratum.

In this report we have presented our rationale, and correlation studies on skin reflectance readings and parallel visual grading of skin made erythematous or tanned by sunlight exposure.

On the basis of this experience our current recommendation for filters for analyzing skin color is as follows. A sample of the blue region of the visible spectrum should be obtained by an interference filter; a transmittance maximum of about 460 millimicrons would appear desirable. An interference filter with a transmittance maximum at 542 or 576 millimicrons should be used for maximum response to oxyhemoglobin. Either an interference filter with transmittance maximum between 620 and 660 millimicrons or a red glass filter (such as Corning glass #2403) should be used to sample the region in the red end of the visible which depends primarily upon melanin, although some effect from oxyhemoglobin and reduced hemoglobin cannot be avoided (16, 17).

ACKNOWLEDGMENTS

The studies in Florence, Arizona, could not have been carried out without the cooperation of Warden Eyman, Dr. Otis Miller and Dr. Elmer Heep, and in Boise, Idaho, of Warden Clapp and Dr. Frank Crowe. Prisoners in the Arizona and Idaho State prisons were cooperative volunteer subjects for the experiments. At Oregon, Mr. Edward Peterson performed the spectrophotometric analyses of the filters used in this study. Calculating equipment was provided by a contribution from Hoffman La-Roche, Inc. We are also grateful to Dr. T. B. Fitzpatrick and Dr. Carl Hopkins for advice and help in carrying out these experiments.

REFERENCES

1. Judd, D. B.: Color in Business, Science and Industry. New York, John Wiley and Sons, 1952.
2. Judd, D. B.: Basic correlates of the visual stimulus. Chapt. 22 in Stevens, S. S. (ed.), Handbook of Experimental Psychology. New York, John Wiley and Sons, 1951.
3. Appel, B.: Decadent descriptions in dermatology. Arch. Dermat. & Syph., **62:** 370, 1950.

4. Stevens, S. S.: Mathematics, measurement, and psychophysics. Chapt. I in Stevens, S. S. (ed.), Handbook of Experimental Psychology. New York, John Wiley and Sons, 1951.
5. Edwards, E. A. and Duntley, S. Q.: The pigments and color of living human skin. Am. J. Anat., **65:** 1, 1939.
6. Kuppenheim, H. F. and Heer, R. R., Jr.: Spectral reflectance of the white and negro skin between 440 and 1000 mu. Army Medical Research Laboratory Report No. 54, 1 May, 1951.
7. Jacquez, J. A., Randall, J. T., Goodman, M., McKeehan, W., Dimitroff, J. M. and Kuppenheim, H. F.: The spectral reflectance of human skin in the region 235–1000 mu. Army Medical Research Laboratory, Report No. 159, 1 Dec., 1954.
8. Jacquez, J. A., Kuppenheim, H. F., Dimitroff, J. M., McKeehan, W. and Hues, J.: Spectral Reflectance of human skin in the region 235–700 mu. J. Applied Physiol., **8:** 212, 1955.
9. Lasker, G. W.: Photoelectric measurement of skin color in a Mexican Mestizo population. Am. J. Phys. Anthropol., **12:** 115, 1954.
10. Lasker, G. W.: Seasonal changes in skin color. Am. J. Phys. Anthropol., **12:** 553, 1954.
11. DeKleine, E. H.: Photoelectric determination of skin color. Plastic and Reconstructive Surgery, **15:** 176, 1955.
12. Letzer, E. K. and Powers, S. A.: Interference filters for photographic densitometry. J. Optic. Soc. America, **44:** 879, 1954.
13. Greenland, K. M.: Interference filters in optics. Endeavor, **11:** 143, 1952.
14. Fitzpatrick, T. B., Hopkins, C. E., Blickenstaff, D. D. and Swift, S.: Preliminary and Short report. Augmented pigmentation and other responses of normal human skin to solar radiation following oral administration of 8-methoxypsoralem. J. Invest. Dermat., **25:** 187, 1955.
15. Hardy, J. D., Hammel, H. T. and Murgatroyd, D.: Spectral transmittance and reflectance of excised human skin. J. Appl. Physiol., **9:** 257, 1956.
16. Barnicot, N. A.: Human pigmentation. Man, **57:** 114, 1957.
17. Tronnier, H.: Uber die U. V.-Reaction an der menschlichen Haut. Zeit. fur Haut und Geschlechts-Krankheiten., **21:** 13, 1956.
18. Goldman, L., Plotnick, H. and Balinkin, I.: Investigative and clinical studies with diascopy in dermatology. Arch. Dermat. & Syph., **75:** 699, 1957.

DISCUSSION

Dr. Victor H. Witten (New York, N. Y.): This is a most important subject because of the numerous studies being done today that utilize erythema as a means of judging the biologic effects produced by various substances and agents on skin.

Like Dr. Daniels, we too do not own such an instrument although we considered purchasing one on several occasions. We considered the General Electric apparatus but because of its high cost we stuck to the "eye attached to the brain", as Dr. Daniels puts it.

I wonder if any correlation exists between the instrument readings and those made with the naked eye according to classifications or criteria mentioned. For our own studies we set up a descriptive classification for differentiating degrees of erythema and the two or three of us working together found that when taking independent readings we came within one plus of each other's readings in almost every instance. We feel that because of the many variable factors which contribute to the color of human skin, e.g. pigmentation, hair and so on, the eye may still be the best means of judging local erythema as it automatically adjusts for the differences in pigmentation, hair color, etc.

Dr. Farrington Daniels (in closing): Dr. Witten has asked why we believe reflectance colorimetry offers any advantages over the

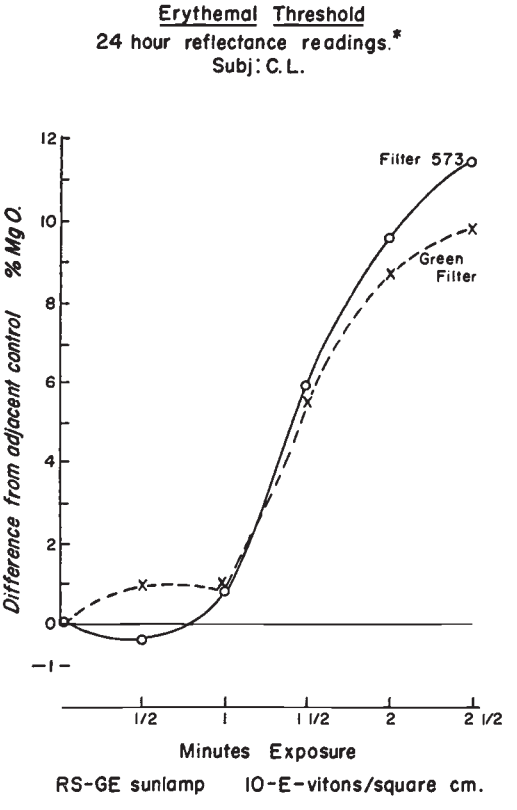

Fig. 6

minimal perceptible erythema response which has been used for many years in evaluating skin responses to ultraviolet and ionizing radiation. This can best be explained by showing an additional slide (Figure 6).

On one patient the erythema response to graded doses of ultraviolet light to untanned areas on the back from an R.S. G.E. 275 watt sunlamp was determined. Using the General Electric sunlamp tester, exposures were made at an intensity of 10 E-vitons per square centimeter. The relationship between exposure time and erythema response is given in Figure 6. Each point of the depicted curve is the mean of three separate exposures except for the 30-second exposures, which is the mean of 2 determinations. The straight line portion of this response curve can be seen to extend from about 2% to 6% of reflectance difference from the adjacent control skin. It is obvious that the preparation of such a curve permits interpolation between readings so that a more exact correspondence between exposure time and a standard erythema response can be measured, and that this method is more precise than the clinical rating of one plus erythema. While the findings presented indicate general linearity of the visual grading scale the numerical values provided by reflectance readings have the advantage of greater precision and of greater versatility in analysis.