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TINTS AND THEIR VALUE*

BY

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THE subject of tints has become rather a prominent one of recent days. A great deal has been written—some reasonably, some unreasonably—about ultra-violet rays and their destructive effects on human eyes. Mainly, I think, owing to the energy with which the optical trade has run excursions and alarums, the general public has become to a large extent imbued with a haunting fear of daylight, and the wearing of lenses which eliminate the ultra-violet rays has become the fashion. Like all fashions, the reasonableness has been largely lost in unreasonableness; the desirability of protection for some has become merged in a totally undesirable wish for protection by a large body of the healthy public, a desire fostered by ignorance, and maintained, to a large extent, by advertisements calculated to bring monetary profit to those who advertise. Further, a great deal of confusion seems to have arisen with regard to tints themselves. They seem to me, in a very large number of cases, to be prescribed in a kind of indiscriminate and indefinite way, without any special reference to anything in particular. Especially, I suppose, it is due to the

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bugbear of ultra-violet rays, which seems to have induced, in some minds, an uncontrollable desire to order Crookes' glass for all sorts and varieties of patient, whether healthy or unhealthy, and no matter what the condition of their eyes may be; and simply because the tint is said to produce a feeling of comfort and refreshment.

For these reasons I think this is a good opportunity to make an attempt to clear up the matter of the value attaching to the wearing of tinted glasses.

I fear that the subject, as I shall present it, may give rise to a certain amount of controversy, but at any rate I am, like you, a seeker after truth, and if my version of this estimable virtue as regards the use of tinted glasses leads to a clearer outlook, that is as much as I can or do expect.

What is the real truth about the human eye and its susceptibility to ultra-violet rays? To examine this point, I must traverse, briefly, some well-known ground. Assuming the acceptance of the wave theory of light, it is known that the visible spectrum extends, roughly, from waves of light of $700\mu\mu$ wave-length at the red end, to $400\mu\mu$ wave-length at the violet end, or, in some people, to $380\mu\mu$. Beyond the visible spectrum are the infra-red (or heat) rays, which produce a rise in temperature, whilst beyond the violet end extend the ultra-violet rays, which cause harmful chemical action. Now, whilst there is no direct protection from the luminous and infra-red rays, which pass almost unimpeded to the retina, there is, on the other hand, a great deal of direct protection given by Nature against the ultra-violet rays. It has been found by experiment that this protection is furnished by the cornea and by the crystalline lens, and especially by the latter. The cornea absorbs all waves of shorter wave-length than about $290\mu\mu$, whilst the lens is impervious to ultra-violet rays of a shorter wave-length than $350\mu\mu$. Thus only ultra-violet rays of wave-lengths between $400\mu\mu$ and $350\mu\mu$ normally reach the retina. Now, in various ways the ultra-violet radiation has been traced, in the laboratory, to waves of about $20\mu\mu$ wave-length, so it is obvious that only a very small proportion of possible ultra-violet radiation can reach the retina under normal conditions. Ordinary sunlight, that is, the sunlight of the lower altitudes, is, as a matter of fact, rather poor in ultra-violet rays, and contains few of shorter wave-length than $350\mu\mu$. All the ultra-violet waves of shorter wave-length than these are stopped by vapour and the density of the atmosphere. Thus the eye is constructed so as to allow the ultra-violet rays of ordinary sunlight to pass unimpeded to the retina, whereas all excess of ultra-violet radiation beyond what is present in ordinary sunlight, is excluded by the natural protective qualities of the eye. So again, protection from the

heat radiation proceeding from the red end of the spectrum is to some extent afforded by the absorptive properties of the pigment lining the back of the iris and choroid and by the contracting power of the pupil. Hence the dark eyes of the Southern and Negroid races, who are subjected to sunlight containing excess of heat radiation.

Now, it must be conceded that in all human races the eye is self-adapted to endure, without harm, the daylight common to the part of the world from which any particular race springs: the point is sufficiently obvious and need not be laboured. And it therefore follows, as a necessary corollary, that ultra-violet radiation of wave-lengths between $400\mu\mu$ the end of the visible violet spectrum, and $350\mu\mu$ are also perfectly harmless. Consequently again, therefore, there is no need to protect healthy eyes from the ultra-violet radiation of ordinary daylight for which the eye is self-adapted under ordinary circumstances.

The same applies to the luminous rays of the visible spectrum and to the infra-red radiation. The eye is normally adapted to endure them without harm.

Practically, however, there are several possible subsidiary factors which complicate the situation and make it less straightforward than it appears at first sight. The most important of these factors are: (1) The intensity of the light; (2) the duration of the exposure; (3) the presence of glare; (4) occupation or trade.

(1) *Intensity of light.* The intensity of the light may react on the eye in one or both of two ways. Intense degrees of sunlight imply an atmosphere abnormally charged with ultra-violet and infra-red radiations, and this is well illustrated in the sunlight of mountains such as the Alps, where, on account of the rarefaction of the atmosphere and the comparative absence of vapour, the spectrum is extended at both ends. And again, extreme degrees of sunlight imply an actual increase of dosage, apart from the consideration of the wave-lengths of the penetrating light. If the light in a room is suddenly doubled, the respective wave-lengths of the spectrum are not altered, but only the total amount of light is changed. It is obvious that the effects of increasing the intensity of the light must be cumulative in the eye, but these cumulative results do not seem to react equally in every direction. They are almost certainly much more concerned with the luminous and infra-red portions of the spectrum than with the ultra-violet. As the light is increased, the luminous and heat rays are increased in proportion, and also our consciousness of them, because they all pass through the pupil unimpeded. The ultra-violet radiation must also be increased in quantity, but the eye is not so conscious of it, because of the natural protection afforded by the cornea and lens. Although by increasing the light there is a cumulative

effect with regard to those ultra-violet rays which can pass to the retina, any actual increase in the ultra-violet radiation is nullified to a very large extent by the construction of the eye. The natural protection from the luminous and infra-red radiations does not appear to be nearly so efficient; so that any danger arising

FIG. 1.

from submitting an eye to intense sunlight would seem to be chiefly with regard to the red end of the spectrum, and not with regard to the violet end.

(2) *The duration of the exposure to high light.* Here again the question of cumulative effect must very much modify our conception of the self-protectiveness of the eye. Under certain conditions of health, prolonged exposure to even moderate degrees of light may be harmful, because the natural resistance may be lowered. We see, of course, the same thing throughout the whole

range of disease in the sense that a general lowering in the power of function is a natural sequence when the nutrition is lowered, from whatever cause. Consequently when we begin to talk about what, if any, protection from light is needed in any particular instance, the question has not only to be considered from the

FIG. 2.

narrow point of the intensity of the light, but also from the broader standpoint of the length of time the eyes are to be exposed, and the individual's own capacity to endure the light without harm.

(3) *Glare*. The presence of glare may complicate the matter very considerably. Glare is an expression which denotes the unpleasant effect produced on the eyes by an excessive amount of reflection from below. It generally proceeds from snow, desert sand, rock, water or chalk; and it owes its disagreeable effects

to two causes. Firstly and chiefly, because we are accustomed to proceed with our eyes directed straight before us or slightly lowered, and the reflected light or glare strikes the eye in an unusual and unaccustomed manner, which distresses us on that account: and, secondly, because glare is something over and beyond what we normally experience, and which must be added, as it were, to the effects of sunlight. Thus it is estimated that snow reflects about 70 per cent. of the existing sunlight, and it is possible, therefore, in situations where there is much glare, to experience the effects of intense light even though the direct sunlight may be of quite a moderate intensity. For the reasons just stated, the effects of glare would seem to be exerted rather in the luminous and infra-red directions than the ultra-violet, and on this account one is led to the conclusion that snow-blindness is not nearly so much due to excess of the ultra-violet radiation as to excess of exposure to the luminous and infra-red radiations. The distressing conjunctivitis that accompanies snow-blindness is, according to this point of view, due to direct scorching of the conjunctiva similar to that which occurs in the retina in cases of eclipse blindness.

(4) *Occupation.* Some trades involve long and dangerous exposure to particularized forms of light. Thus, on the one hand, acetylene welding exposes the worker to an intense ultra-violet radiation, whilst glass-blowers and workers in foundries are subjected to much heat radiation. Trades of these kinds are abnormal conditions of life, which must receive special consideration over and beyond that accorded to those not so occupied.

Considerations as to the relative value of various Tints

In order to present the matter as accurately as possible I asked for help from Messrs. Hamblin, who most kindly took the greatest interest in the matter and arranged for the necessary examinations. To them and to Dr. Judd Lewis, who undertook the experiments, and whose name is a sufficient warranty for the accuracy of the work, I tender my most hearty thanks.

For the purpose in hand I selected London Smoke No. II and IV, Amber Nos. I, II, and III. Fieuzal Nos. I, II, III, IV and V. Crookes' A, A2, B and B2, and Peacock Blue. Dr. Judd Lewis was asked to produce spectrum photographs of each of these tints in two grades of thickness, one of 0.5 mm. and the other of 2 mm. thickness. These photographs are incorporated in Figs. 1 and 2. Comparison between these two series of photographs will at once emphasize the enormous difference the thickness of the glass makes to the spectroscopic value. In order to illustrate the matter more completely Dr. Judd Lewis undertook to demonstrate the spectrum photographs of the 2 mm.

tints in a series of absorption curves. The majority of these curves have been incorporated by Messrs. Hamblin in a chart (Plate) in which each tint is represented by a separate colour. For the sake of clearness some of the shades have been omitted, those included being sufficient to emphasize certain points which I wish to demonstrate to you this evening. I did not think that it was worth while to examine the spectrum photographs of the 0.5 mm. tints because the photographs were sufficient to bring out the point on which I desire to lay stress, that surgeons should realize how much the value of any prescribed tint is affected by the thickness of the glass supplied by the optician. To this point I shall refer yet once again a little later on.

If you look at the chart of absorption curves you will note that each tint starts steeply at zero at the violet end of the spectrum where visible light ceases and then trends away in various degrees of curvature to the red end where it passes away into the little known infra-red portion. At the extreme limit of the red end all the tints are still allowing a certain amount of light transmission with the exception of the Peacock Blue which absorbs all light of wave-length longer than $570\ \mu\mu$.

Looking at the violet end of the spectrum the deeper Fieuzal tints have the greatest absorption value, being slightly more powerful than Peacock Blue and considerably more so than Crookes' glass.

One is further struck by the fact that only in the case of Crookes' glass is there any sort of uniformity in the position of the zero point at the violet end. All the various shades of Crookes' glass have practically the same protective power with regard to the ultra-violet radiation, whereas all the other kinds of glass submitted for examination show an extraordinary variation in this respect, the ultra-violet protection seeming to depend very largely on the depth of the tint, being less marked in the lighter shade and becoming progressively deeper as the shade is deepened. This can, I think, be only explained by the composition of the glass employed. In Crookes' tints the glass is absolutely standardized and the tints, as it were, superimposed, whereas in all the other tints the various shades are the main factor, and their effect is influenced by being incorporated in a glass which is not standardized. In other words the ultra-violet protective value of Crookes' glass is not much affected by the density of the tint, whereas the value of all the other tints is very much so influenced.

It would seem, therefore, that although Crookes' glass is not the most powerful agent we possess for shutting off the blue end of the spectrum as well as the ultra-violet rays, it nevertheless has this most valuable property, viz., that we know exactly what we

are getting when we prescribe it, and if protection from ultra-violet radiation was the only point to be considered Crookes' A would be just as valuable as Crookes' B2.

However, as I have already attempted to point out, protection from excess of ultra-violet radiation is only one factor in the situation. In the majority of cases when a tint is ordered it is chiefly from the point of view of general shade effect, whilst in others, protection from red and infra-red radiation is at least as important as protection from ultra-violet, and sometimes more so. If we look upon the tint simply as a means of obtaining shade, all the various types of glass in common use are approximately of the same value, the main factor to be borne in mind being the amount of shade desired, which is regulated by the density of the tint and by the thickness of the glass.

There is, moreover, a second subsidiary factor to be remembered, which is the effect of the tint on the patient's comfort. Some tints exercise a more depressing effect than others and some interfere more than others with the general colour scheme. Thus the shades of London Smoke and Crookes' B and B2 are less pleasant in these respects than Amber or Fieuzal tints; but if you refer to the absorption curves reproduced on the chart, you will see that to produce a given shade effect a somewhat deeper shade of Fieuzal and Amber is needed than if London Smoke or Crookes' glass is employed.

With regard to the particular protection from the red and infra-red radiation Peacock Blue is obviously far and away the best tint to employ. However, it cuts out such a tremendous lot of colour that the effect on the patient is extremely unpleasant and depressing and its uses are, therefore, very much restricted. There is not a great deal to choose between the other tints. The deeper shades of Crookes and London Smoke produce curves which are very similar and exclude rather more than the corresponding shades of Fieuzal. All the Amber spectrum photographs were so inefficient as regards all the points just considered, when compared with the other tints, that I have only reproduced one Amber curve on the chart. The example shown of a medium Amber shade curve sufficiently proves the inferiority of this tint to all the others in general use.

After these remarks on tints in general I will pass to a short analysis of the absorption curves shown on the chart. To prevent the confusion necessarily arising from a great many intersecting lines only a certain number, which were calculated to bring out the special points just mentioned, have been included.

The most interesting curve of all the tints is the Peacock Blue, which absolutely excludes all rays shorter than $400\mu\mu$ or longer than $570\mu\mu$, which means that all the ultra-violet and some of

THE ABOVE ABSORPTION CURVES SUPPLIED BY
THEODORE HAMBLIN LTD
DETERMINED SPECTROPHOTOMETRICALLY BY MEANS OF A JUDD LEWIS SECTOR PHOTOMETER AND A QUARTZ SPECTROGRAPH

the violet rays are excluded at the one end and all the yellow, orange and red rays at the other. It thus affords an infinitely larger range of protection than any other tint.

All the tints compounded with Crookes' glass shut off the ultra-violet rays of a shorter wave-length than $350\ \mu\mu$, which means that they give good ultra-violet protection, but they are not nearly so efficient with regard to the blue and violet end of the visible spectrum as the corresponding shades of Fieuzal. The charts show quite conclusively the point, which I do not think has been generally noted before, that the deeper shades of Fieuzal Nos. 3, 4, and 5 effect the most powerful protection of all known tints with regard to the violet end of the spectrum, much more so even than Peacock Blue. It will be seen that Fieuzal 5 shuts off nearly all the blue and every ray of shorter wave-length than $490\ \mu\mu$.

London Smoke IV (dark medium) which is of a little lighter hue than Crookes' B2 produces an interesting curve. It affords very nearly as much protection from the ultra-violet radiation as does the Crookes' B2, but it allows a good deal more of violet and blue radiation than does the Crookes' B. On the other hand it shuts off a good deal more of the orange and red radiation than Crookes' B2.

With regard to the protection from red radiation, Crookes' B and B2 and London Smoke IV are better than any of the Fieuzal shades, but both are markedly inferior to Peacock Blue.

As an efficient shade from high lights without general reference to ultra-violet and infra-red radiation, London Smoke of medium tint in the form of Crookes' B is very satisfactory. Crookes' B2 and London Smoke IV exhibit very similar curves and are both excellent when deep shade is required, Crookes' B2 being preferable because of its superior protection from ultra-violet radiation. The Fieuzal tints are all rather disappointing in this respect.

Crookes' A2 is a remarkable glass in that it affords substantial protection from ultra-violet radiation without seriously impeding the luminous rays. It is in this respect infinitely superior to a light shade of London Smoke and much better than Amber. In this way is explained the refreshing qualities in conditions of mild glare such as exist in theatres and cinemas.

The most uniform curve is obtained from Crookes' B. This glass gives good protection throughout the whole length of the spectrum transmitting at one point no more than about 35 per cent. of the radiation. It is on these grounds the most satisfactory of all the tints examined and seems to be the best for general use.

Finally, two more points arise from the consideration of these tints. Both have been previously mentioned; but I should like

to draw a little more detailed attention to the desirability of obtaining a greater uniformity of shade and spectroscopic effect than that which obtains at the present time. It is quite obvious, I think, that nobody does or can know what is really provided when a tint is ordered, unless Crookes' glass is selected.

Take, for instance, the three shades of Fieuzal given. The three pieces of glasses from which the spectrum photographs and the illustrating curves were made were precisely similar in thickness and only apparently differed in shade. Yet you at once see that the composition of the glass must be very different because they give such extremely varying effects spectroscopically, and, most curious point of all, Fieuzal 3, which is a darker shade than Fieuzal 2, allows more transmission of the red, orange and yellow rays than does Fieuzal 2. This question of standardizing the glass is the first point, the second being the thickness of the glass employed to which I have already alluded. I do not suppose that any ophthalmic surgeon has ever interfered with what may be regarded as purely opticians' work, to the extent of suggesting the thickness of the glass to be used when ordering a tint; but yet it is often a matter of the greatest importance, and especially so, perhaps, when prescribing a tint to be overlaid on a minus lens.

As a result of this lack of standardization in the quality and thickness of the glass employed, the whole supply of tinted glass with the exception of Crookes' glass is in a most unsatisfactory state. Nobody can write a prescription for the supply of a tint and have the slightest idea of the true value of what will be supplied to his patient unless he has some private arrangement with a firm of opticians, and has a special box of tints of uniform thickness which correspond exactly with what the optician supplies. Even then, neither he nor the optician has any control over the manufacture of the glass and as I have pointed out both may be utterly deceived in consequence.

Perhaps these considerations are of the greatest importance when it is a question of supplying special protection in dangerous trades, or for those undertaking journeys or exploration in countries where they will be exposed for long continuous periods to great glare, as for example in the recent expeditions to explore Mount Everest. I hope that this question of standardizing different tints will now receive the consideration which is its due, and I think it is a question which might with great advantage be brought before the Council of British Ophthalmologists.

My personal belief is that if Crookes' glass were combined with Fieuzal shades as well as with London Smoke, we should then possess with Peacock Blue a series of highly standardized tints which would meet all and every requirement. It should

further be made clear that the glass, unless there is a special indication to the contrary, is always provided of a certain standard thickness, and that variations from this standard must be compensated for by ordering a lighter or darker shade, as the case may be.

The Wearing of Tints in Health and Disease

1. *The wearing of tints for healthy eyes.* As harmful ultra-violet radiation does not exist under ordinary circumstances of daylight, protection by special ultra-violet glasses is quite unnecessary. When extraordinary circumstances are apt to be encountered, the main factors to be considered are the luminous and the heat radiations, rather than the ultra-violet. As already explained, these circumstances are present when the eyes are exposed for prolonged periods to the effect of high sunlight and glare, especially when these factors are present in rarified atmospheres of the higher altitudes, such as the Alps on the one hand, or to the sun of the plains in the Tropics, on the other hand. Although the effect of the Fieuzal tints seems rather to diminish towards the red end of the spectrum, I believe that these would, if the glass were properly standardized, prove to be, on the whole, much the best shades to employ in high glares, with the exception of Peacock Blue, which is the most protective of all.

One often hears of Crookes' glass A or A2 being ordered for reading and work. Very often, I think, it is because the prescriber has the idea that artificial light is stronger in ultra-violet radiation than is sunlight, which is an entirely erroneous view. Dr. Leonard Hill, in his recent work on sunlight and fresh air, states that in the case of an oil lamp 97 per cent. of the energy is in the infra-red region, and of electrical incandescent lamps, 95 per cent.; so that if it is considered desirable to protect the eyes by some tint in artificial light, Crookes' glass possesses no special advantage from a medical point of view. Crookes' A or A2 glass has, however, this superiority, namely, that it affords a general shade without materially disfiguring the appearance or altering colour values, and, as a matter of practice, it is, on these accounts, very useful and often very much appreciated by sensitive patients.

Then we must consider a large class of cases consisting of patients who have perfectly healthy eyes but who are physically or mentally abnormal. In physical disease and in neurasthenia the general function of the eyes is very commonly impaired. Thus we note that the physical invalid prefers, as a rule, that the blinds should be, to some extent, drawn; and, similarly, mental invalids suffer to some extent from photophobia. Whilst, therefore, undue protection is to be deprecated in health, we are bound to give help in cases of lowered health, from whatever

cause, and whether for the purpose we prescribe yellow, smoked, or Crookes' glass, is immaterial. The choice of tint rather depends upon the effect that the tint has on the individual. Smoked glass is to-day as valuable as it ever was, but it has the disadvantage of being somewhat depressing in its general effect, and Fieuzal, which is as effective without interfering so much with the colour scheme, is often preferred. Crookes' glass is excellent too, especially that variety which combines a smoke tint, and is known as Crookes' B, or Crookes' B2. In any case, however, we should disapprove of too much protection in this way, and should not only advise the gradual discontinuance of the tint as the general health improves, but should, in nearly all cases strongly discountenance what has become a very common and pernicious habit, viz., that of wearing some sort of tint continuously, whatever the light and whatever the occupation.

We should always remember that the habitual wearing of shades is apt, like all other habits, to become fixed, and to produce not only a dislike of conditions of light which are perfectly harmless, but a positive inability to endure them unaided. When such a condition is reached, the person suffers a great deal of inconvenience, besides, of course, detracting very much from her or his personal appearance.

2. *The wearing of tints for diseased eyes, or as a prophylactic measure against disease.* It has been shown quite definitely, I think, that cataract due to glass-blowing and allied trades is due more to harmful infra-red radiation than to ultra-violet rays. Tints such as Fieuzal 4 or Fieuzal 5 or Peacock Blue afford the best prophylactic. In all cases of cataract, from whatever cause, tinted glasses to wear in bright sunlight or in glare should be ordered. I have no doubt in my own mind that there is nothing more harmful in the early stages of cataract than exposure to bright lights of any kind, and I am most careful to order efficient protection to all my patients with that condition. Glare by artificial light should be shunned as much as glare in daylight. I think, in this variety of cases, where a habitual tint is indicated, there is nothing more pleasant or comforting to the patient than Crookes' glass, though other tints are just as effective. I often make a point of ordering two degrees of shade, one for moderate, and one for extreme degrees of light. Reading glasses of Crookes' A are quite efficient, and have the advantage of not cutting off so much of the luminous rays as to interfere with the patient's comfort. After the extraction of cataract, the eye is deprived of its most powerful protector against undue ultra-violet radiation. Further, the high plus lens usually necessary to correct the refraction acts to some extent as a burning-glass. Consequently aphakic eyes need special protection, a point which, it seems to me,

is not insisted upon as much as should be the case. There are practical difficulties in the way in the case of hospital patients, who are usually supplied with large bi-convex lenses, on account of their extreme thickness, and also, to a slight extent, on account of the increased expense involved in making the glasses out of a tint. In the more modern and expensive "luxe" type of cataract lens the matter is easier. Crookes' A glass or the lightest shade of London Smoke or Fieuzal are the most suitable tints to employ, and personally I much prefer the Crookes' A, as being the less disfiguring and the most suitable for the purpose. I feel strongly that all aphakic patients should have some protection outdoors, except on dark and cloudy days, and if the lenses are made out of Crookes' A, the same glasses will do for indoors as well as outdoors, without materially interfering with the patient's comfort. Reading lenses may be similarly constructed, and should indeed be so made if the patient is wearing lenses made out of Crookes' A glass at all other times.

In active inflammatory disease of the retina and choroid, I much prefer, and always order, Peacock Blue. By it all ultra-violet and infra-red radiations are entirely shut off, and a very large proportion of the luminous rays as well. It has a peculiarly soothing effect on the patient, and forms a most valuable kind of treatment. There is, to my mind, no other tint comparable with it.

A NOTE ON THE LATERAL OCULAR MUSCLE BALANCE IN SCHOOL CHILDREN, WITH SPECIAL REFERENCE TO SQUINT IN MYOPIA*

BY

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STIRLING

MUCH study has been given to heterophoria and a great deal has been written about it, yet it is doubtful whether statistics of tests of the muscle balance in any considerable number of children have been published. For that reason alone the present figures, although only covering some 500 cases, may be of interest. Yet statistics as such, and without a direct purpose, are not the primary interest of this article.

In the July, 1919, number of this journal the writer published

*This article was written several years ago. It is now published in order to supplement the writer's opening paper at the Oxford Congress, 1924, on the "Treatment of Convergent Concomitant Strabismus." It is much to be regretted that an error crept into the MS. of Table II, as sent to the printer (*Trans. Ophthal. Soc. of the U.K.*, 1924, p. 241) where the figures for the 4th group are wrongly given. The correct figures for the 24 Emmetropic cases are: Orthophoria, 1; exophoria, 5; esophoria, 18; the ratio exophoria to esophoria being 1 to 3.6.