Summary The eye, refractive errors and their significance and correction, accommodation and presbyopia, and the use of different types of multifocal lenses are first discussed. The functioning of the binocular visual system is considered, particularly in relation to efficient visual performance. Convergence fatigue is of special importance, as is the common association of binocular instability and discomfort with photophobia. Possible reasons for complaints of discomfort with lighting using fluorescent lamps are considered, and the need for closer cooperation between those concerned with different aspects of vision is indicated. Some typical case histories are described in an appendix.

The eye, vision, and visual discomfort

C. H. BEDWELL, FBOA(HD), FSMC, MIllumES

1 Introduction

The lighting engineer is concerned very largely with providing, in as pleasing a form as possible, lighting schemes which give adequate quantity and quality of light for efficient and comfortable vision. As a result of his efforts very considerable improvements in lighting technology have taken place during the last twenty years. Sometimes, however, after much careful effort on his part, the hoped-for improvement in visual comfort and performance is not realized, and he then may have difficulty in deciding on the possible cause and management of these problems.

The purpose of this paper is to discuss in a practical manner the factors likely to be related to the attainment of visual comfort and good visual performance, and to indicate how visual problems can be investigated and managed from the ophthalmic point of view.

2 Visual performance and anomalies in visual mechanics

2.1 Refractive errors

Three refractive errors of the eye can be of significance. The first two are hyperopia, or long-sight (Fig. 1a), in which the eye's optical power is insufficient to allow a sharp image to be formed on the retina for this particular length of eye, and myopia, or short-sight (Fig. 1b), in which the eye's optical system is too powerful in relation to the length of the eye. In the case of hyperopia, if accommodation is adequate, it is possible to produce a sharply focused image, though this action might well cause discomfort, particularly for prolonged near vision. In the case of myopia, distance vision will be blurred, but objects within the far point of clear vision for the eye's optical system can be seen clearly. Accommodation, in a myope, would make images of objects beyond the far point more blurred.

The author is with the Dept. of Ophthalmic Optics, The City University, London. This paper was first received on October 14, 1971. It was presented at a meeting of the Society on February 9, 1972.

In the other common refractive error—astigmatism (Fig. 1c)—there is a difference of optical power between two visually different meridians of the eye, usually because of a difference of curvature over the cornea. Fortunately these two corneal regions

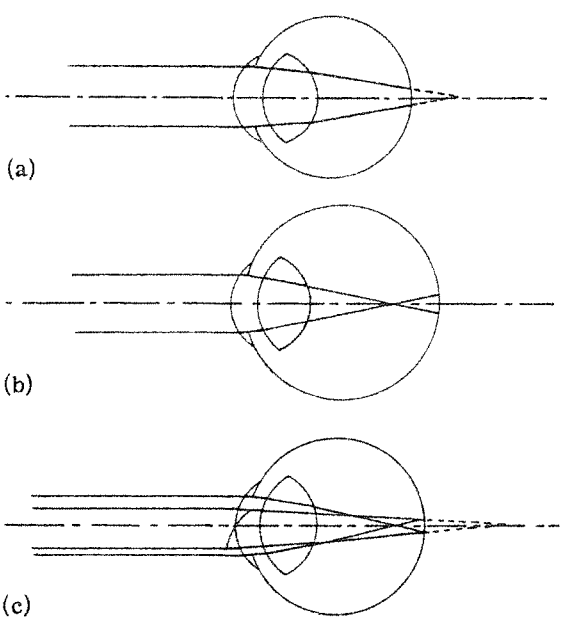

Fig. 1. (a) Hyperopia (b) myopia (c) astigmatism.

are usually at right angles, like the side of a wooden barrel, enabling the defect to be corrected by an appropriate lens of opposite power difference—usually with one lens surface toroidal or 'two-curve'. It is of course, possible to have hyperopic or myopic astigmatism, or sometimes for one meridian to be hyperopic and the other myopic. With the coming of middle-age the ability to accommodate (Fig. 2) tends gradually to decrease. This is presbyopia and is due to sclerosis of the crystalline lens of the eye. Additional optical power then needs to be prescribed for near vision. The amount of this near addition increases with age and with the nearness of the

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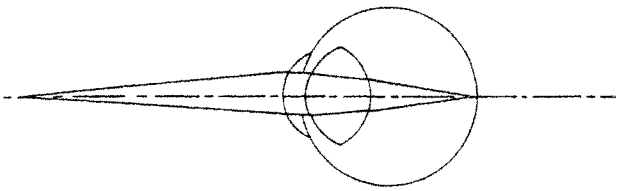

Fig. 2. Accommodation.

visual task to the eye. The greater this addition the more blurred is vision beyond the optimum near working distance, and the shorter the distance over which clear vision can be obtained. The additional correction required is therefore usually kept to a minimum. To avoid blurring of distance vision with a single lens near correction, and to avoid having to continually change spectacles, bifocal lenses may be prescribed. Additional power is incorporated, normally in the lower part of the lens, allowing clear near vision below the horizontal (see Figs. 3a, b, and c). In some cases it is possible to prescribe, in addition to the distance and near correction, additional intermediate segment-trifocals (Figs. 3d and e) or a lens of gradually increasing optical power, so that objects at all distances can more or less be seen clearly. Multifocal lenses are available with the near portion covering different areas of the lens to allow for different positions and widths of near vision, according to the needs of the patients. In general, when prescribing for near visual tasks, as much detail as possible should be given to the consultant so that he can advise on the most suitable type of correction.

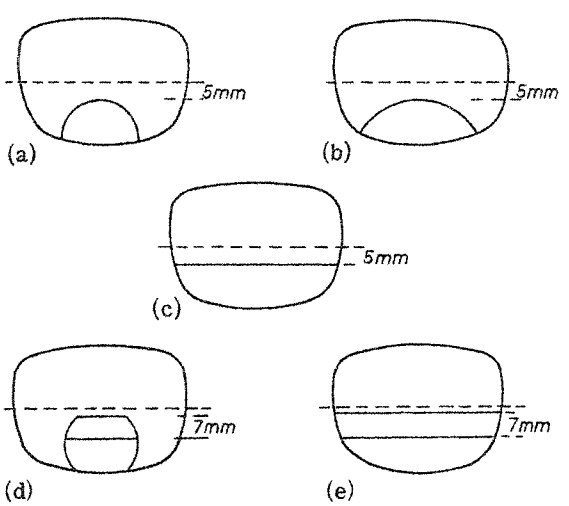

Fig. 3. Some types of multifocal lenses.
(a) 22m segment allowing approximately 10 inches width of near vision
(b) 38mm segment allowing approximately 14 inches width of near vision.
(c) Executive segment allowing full width of the whole lens for near vision.
(d) 22mm trifocal segments, flat-topped.
(e) Executive trifocals.

Where the refractive error is corrected by a spectacle lens placed in a plane beyond the eye to clear the eyelashes, the effect of the lens will be to alter the size of the clear retinal image compared with that which would have been seen by the unaided eye. The image size will be increased with hyperopic and presbyopic corrections, and reduced by a myopic correction. If both eyes have approximately the same characteristics and refractive errors, the magnifications will be approximately the same and unlikely to produce real difficulty. However, where there is appreciable difference in optical correction between the eyes, the new difference in image sizes may be more than 3 per cent, and significant enough to embarrass binocular vision, or even make it impossible. Initially binocular confusion can result until the patient can learn to suppress vision in one eye or, if young enough, to adjust in other ways.

If contact lenses are prescribed instead of spectacles, any difference in correction only introduces a minimal difference in image size, as the contact lenses are now in contact with the eye. In addition, as the lenses move with the eye, there can be less embarrassment of binocular vision, because unequal prismatic effects are much less compared to those with spectacle lenses. However, when small corneal lenses are fitted, as is usual, some slight movement of the lenses is necessary when the patient blinks, in order to achieve adequate corneal metabolism. Discomfort in wearing contact lenses can result from working in a dusty environment, and may sometimes arise with prolonged near vision, probably due to the effect of increased convergence effort tending to increase tension of the eyelids and to reduce the palpebral aperture or area between the lid margins[1]. Contact lenses also allow a more effective field of view compared with spectacles, particularly when the corrections are high.

2.2 Binocular vision

A normal person views objects with both eyes, and very fine coordination of the eyes is required if full benefit is to be obtained from binocular vision, and if comfort is to be maintained. For an object to be seen singly and in three-dimensions, the images must fall on corresponding retinal areas—Panum's fusional areas. The eyes do not, in fact, fixate steadily any visual detail which is being examined, but make short jerky fixations, or saccadic movements, of up to 40 m. sec. duration, allowing the image to be perceived in reflex pauses of 0.2-0.3 seconds. Fatigue of the receptor mechanism is therefore minimized, and scanning enhances contrast discrimination. Training and experience in viewing visual tasks determine, to a certain extent, how we use our eyes. It has been found for example that good inspectors make fewer visual fixations, need to look at the periphery of the object less, make more use of peripheral vision, and have more useful receptive visual fields.

To achieve the high degree of coordination required between the eyes in binocular vision, their movement is controlled by six extra-ocular muscles acting in pairs with opposing actions. These muscles are composed of finer fibres than any others in the body, and contain large numbers of nerve endings. They also contain proprioceptive fibres that indicate to the brain the degree of stretching taking place, and hence give a guide to eye position. Each muscle has an individual nerve route to its own nucleus in the brain.

Recent work indicates that binocular vision is a very much more complex and flexible function than has been realized in the past. Fender and Julez,[3] used a system of binocularly stabilized images, so that any eye movement was made to cause the object to move correspondingly, and its image to always fall on the same area of the retina. They found that

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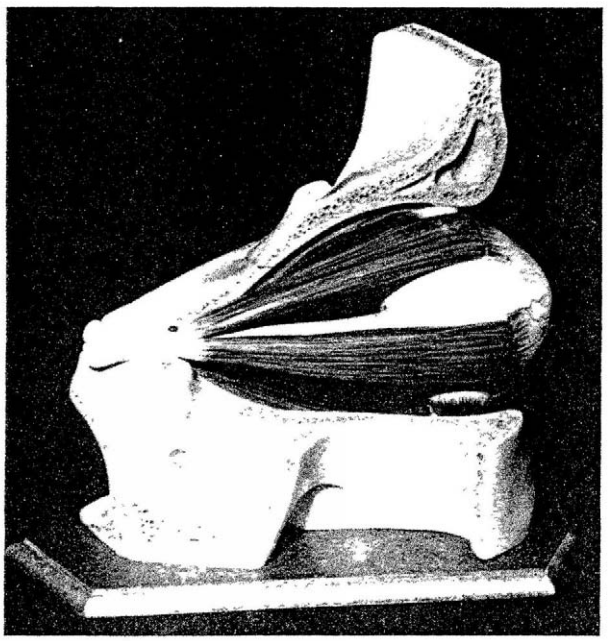

Fig. 4. The extra-ocular muscles.

if the images were initially brought within 6' of alignment to allow stereopsis, and then pulled apart slowly and without interruption, they could be displaced up to 6° horizontally without losing stereoscopic vision. Retinal correspondence appears, therefore, to be controlled by a supra-retinal function, and is influenced by the different factors related to the particular viewing situation. Smith[4], using a real-time computer method of recording, found that there could be a lag of approximately 35-50 ms between the eyes on binocular pursuit. The delay varied according to target velocity, and was increased when there was hand-eye feed back, or when the observer moved the target himself.

It is possible to study the actual movement of the eyes by a number of devices, in particular by recording the d.c. potentials developed across the eyes on eye movement—electro-oculography, photographically, or by using infrared illumination[5] and for example recording the position of the corneo-scleral boundary, as in the Eye-Trac instrument. Such a technique is particularly helpful when undertaking a work-study of visual movements required in a certain task, or when investigating aberrant eye movements in relation to poor near-visual performance. For example, the writer has been particularly interested in the visual aspects of reading disability. He has found that the disability tends to increase the greater the difficulty in maintaining the eyes in alignment on visual tracking, particularly when there is less difference in eye dominance, as with children who tend to be ambidexterous.

In clinical ophthalmic practice it is important to investigate whether there is any tendency for the eyes to deviate on dissociation—heterophoria (Fig. 5a)—as then the binocular system is likely to be under stress. A number of tests, e.g. fixation disparity, allow both binocular and monocular targets to be viewed simultaneously, as in everyday viewing tasks. The monocular targets tend to be out of line if a stress is present. Where an eye deviates under normal binocular viewing conditions, a squint or strabismus (Fig. 5b) is present. Here again if the

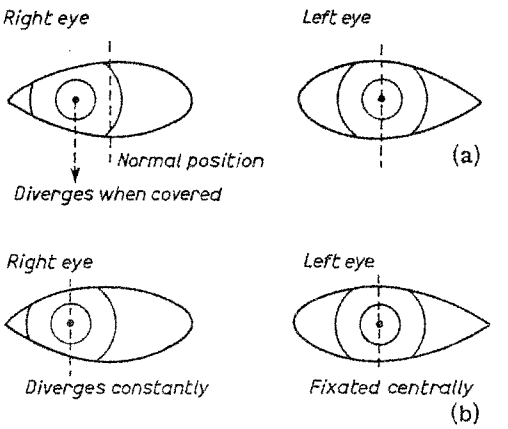

Fig. 5. (a) Exophoria—eye diverges on dissociation when covered. (b) Exotrophia—a divergent squint or strabismus.

eyes cannot remain easily in a stabilized relationship, visual problems may result. In some children with squints, a spectacle correction may be enough to keep the eyes straight. In others, exercises—orthoptics—or surgery may be necessary. Very few young children grow out of a squint without treatment.

2.3 Near vision and convergence

Where the object being viewed is other than at infinity, convergence of the eyes is necessary if the images are to fall on corresponding retinal areas of both eyes. In addition, it will be necessary for the eyes to accommodate if sharp retinal images are to be produced. There is thus a neural linkage between convergence and accommodation (and also with pupil contraction), though this relationship does not appear to be as rigid as was originally supposed.

Normally, when we undertake close work, we are looking at an object placed below the horizontal, with the eyes in a depressed state. Convergence is thus easier when we are looking down at near visual tasks than upwards, but can become more difficult as the eyes are raised, as, for example, when undertaking inspection or assembly on the underside of the equipment. In addition, there may be more difficulty in maintaining alignment of the eyes when looking at objects to the left or to the right than when looking directly down or ahead. In some cases there tends to be more imbalance between the muscular system on one side than the other, so that a copy-typist, for example, may find that there is a difference in comfort according to the side on which her copy is placed.

2.4 Near visual discomfort

Many people are commonly engaged for long periods on critical near visual tasks. It is, therefore, not surprising that a considerable number of symptoms appear to be related to close work. Provided that any basic refractive errors have been satisfactorily corrected, the author has found[6] that with most young patients discomfort appears to be due to a difficulty in maintaining a comfortable accommodation/convergence relationship. If convergence cannot be comfortably maintained, so that images fall on customarily used retinal correspondence areas, the eye(s) may tend to diverge relatively to the fixation point. The image(s) will then fall outside these corresponding areas. Binocular confusion will result unless the patient makes an effort to contain his convergence

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within pre-existing limits. Discomfort and/or poor near visual performance will usually be the consequence. If this condition continues for a long period, the eyes may adjust to the situation by allowing one eye to diverge relatively, fixating eccentrically during binocular vision. The other (dominant) eye still perceives its image on the central retinal area, whereas the other (non-dominant) eye receives its image on the para-central area. A neural adjustment appears to have been made to allow binocular correspondence under these new conditions, reducing the total convergence effort at the expense of full binocularity. In general, any difficulty in maintaining convergence is aggravated by fatigue, debility, ill-health, or the effect of certain types of drugs, e.g. contraceptive pills, under certain circumstances.

Furthermore, those patients who appear to have difficulty in maintaining binocular coordination of their eyes, often also appear to be light-sensitive or photophobic. Careful attention to anomalies of the binocular system is therefore very important. They may also tend to exhibit mild conjunctivitis or blepharitis (inflammation of the eyelids). Individuals who are nervous, or who have difficulty in relaxing generally, appear most likely to exhibit binocular instability or ocular stress states. Also people who tend to suffer from headaches, including migraine sufferers, are more likely to suffer discomfort from anomalies of the binocular system that have not been stabilized, than are non-headache sufferers, who may exhibit only reduced visual performance, e.g. in reading, about which they are unaware. The author has found that patients with an unstabilized binocular system but with a good ability to comprehend, may be able to read quickly by rapidly scanning along a line before the eyes have an opportunity to deviate. They may have greater difficulty in reading aloud because visual scanning here has to be slower, and often there is some emotional stress to aggravate the condition.

Clinical investigation of cases of visual discomfort, or poor near visual performance, can often be difficult and requires considerable experience and powers of clinical observation, otherwise significant clues may be missed. In general, there is usually a reason for most cases of visual discomfort or anomalous situations, e.g. holding the head to one side. It is important not to diagnose symptoms as being due to 'nerves' without eliminating more mechanical causes, though a state of nervous tension will always aggravate any anomaly present.

3 Vision, visual discomfort, and lighting

Over recent years much research has been undertaken on the relationship between lighting, vision, visual performance, and discomfort from glare. In spite of these efforts to produce well-designed lighting installations, however, there are still some complaints of discomfort. Today, fluorescent lamps are used for lighting most working interiors, and complaints therefore tend to be connected with the use of these lamps, whether or not the criticism is justified. In ophthalmic practice complaints about fluorescent lighting are so common amongst patients seeking advice because of visual discomfort, that they cannot summarily be dismissed. The full reason for this is not always readily apparent, and calls for a combined research effort by ophthalmic practitioners and lighting engineers. The following comments may be of interest.

One unfortunate aspect is that fluorescent lighting installations were initially introduced under wartime, and immediate post-war, conditions. Often bare lamps were used giving rise to considerable glare, and this combined with cosmetically unsatisfactory colour rendering produced an unfavourable psychological reaction. Nowadays glare is normally well controlled, and colour rendering very much improved. However, in many modern offices open-plan designs have been adopted and new lighting systems installed. Though many people may like working together, there are many others who do not. Sometimes, therefore, any criticism of the lighting installation may be aggravated by a psychological dislike of such changes in working conditions.

Even allowing for these considerations, however, there still seem to be many situations where what appears to be a good lighting scheme may be aggravating existing ocular discomfort.

In general, patients who exhibit binocular instability dislike high lighting levels, and prefer only enough illumination to perform their job satisfactorily. Light sensitivity is often extreme in patients who are migraine subjects; to a lesser extent, this applies also to those who suffer from mild conjunctivitis associated often with an unstable visual system. The full reasons for this are not very obvious, but possibly those patients who suffer from binocular instability and less difference in eye dominance may find that at higher illuminances the contrasts over the object viewed are increased. Any lack then of alignment of the two images received by the eyes results in a more obvious binocular confusion. In addition, in the case of migraine patients, the pupil may be dilated for part of the time, and the subject cannot therefore limit the amount of light entering the eye. Photophobic patients tend to reduce the light entering their eyes by screwing them up, so increasing lid tension and discomfort.

Over the long period of man's development, he has always been used to light provided from an incandescent source with a more or less continuous spectrum—e.g. the sun, or light from a flame—which is rich in reds and yellows, and is attractive cosmetically. Though technically it is possible to produce good colour rendering using fluorescent lamps, the visual results are not quite the same as from a hot-body radiator.

The problems of flicker from fluorescent lamps are well known. These effects have been much reduced in modern lamps, but when considering discomfort complaints it may be worth conjecturing that although the flicker may be below the critical frequency for central vision, it is not necessarily so for the periphery.

In conclusion, it is hoped that this paper has illustrated how important is cooperation between all concerned with visual comfort and efficiency.

Acknowledgements

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APPENDIX

Case histories

(1) Mrs L.; age 40

Mrs L. was employed as a wages clerk, and complained of eye strain at work. She wondered whether working under fluorescent-lighting was a contributory factor. She had not experienced the same discomfort when doing similar work some months previously in another office without fluorescent lighting. She also mentioned that she tended to be somewhat light sensitive.

On examination her existing correction for hyperopia, incorporating a slight tint, was found to be quite adequate for focusing, on accommodating, at near distance. Her main problem appeared to be one of trying to contain a weakness of convergence during near vision. This condition can not only cause discomfort, but also produce errors when entering figures in columns or squares because the eyes tend to become out of alignment on refixation, with consequent image confusion.

Instability of using both eyes together appears very often to be associated with photophobia, and under these circumstances higher illuminances may be uncomfortable. There is a tendency to screw up the eyes associated with convergence effort. The accompanying light-sensitivity and slight conjunctival irritation may be an associated symptom.

In this case the problem was overcome by incorporating prismatic relief for convergence stress in her near correction, and giving her exercises to improve convergence ability. A tint was again prescribed because of the photophobia.

(2) Miss V. L.; age 22

Miss V. L. had originally been a copy typist, but now had changed her job to one of a switchboard operator on a private branch telephone exchange. As well as operating the switchboard, she had to look up telephone numbers and write messages.

She complained of frontal headaches while working, and recently of slight dizziness. Her medical practitioner had advised a visual examination.

This patient was a myope, and her correction was found to be adequate for good visual acuity. There had been a history of some difficulty in maintaining convergence during her previous work, and this had been contained by suitable exercises.

With regard to her present work, she was now working on the switchboard of a very busy exchange, and the stress and fatigue factors therefore tended to be greater. Also she had to look at the various signal lights more or less directly in front of her, and then down to her keys and plugs. When there is a convergence weakness, it is much more difficult to contain a divergent tendency with the eyes elevated than when depressed. She was therefore experiencing more difficulty because of this factor, and also because the range of vision over which she had to use her eyes together was greater than for her previous employment.

She explained that she was less uncomfortable during daylight when she had a window at the back of her, than with the electric lighting system in which enclosed fluorescent luminaires were mounted above her and at right angles to the switchboard.

From the lighting aspect, she possibly found the overhead lighting more uncomfortable than with lighting from behind.

From the ocular point of view, an initial course of exercises to improve convergence was suggested. Because this was a general purpose correction, and there was no divergent tendency for distance vision, prismatic relief for near vision was felt inadvisable. If this should be required, it would probably need to be in the form of a separate near correction.

For a more complete management of the problem, the electric lighting system would need to be redesigned. Such a course was suggested, but without success.

(3) Mr S. A.; age 36

Mr S. A. was an instrument maker. He was experiencing discomfort and slight blurring for intermediate vision, both during work and when trying to read music while playing the piano accordion. He had no problems regarding distance vision, or reading normally.

On examination, his myopic correction was found to be perfectly adequate. For distance vision, the alignment between his eyes was stable, and he appeared to maintain central vision in both eyes. For near vision, he was markedly left dominant, and exhibited a stabilized slight divergent tendency in the right eye. For intermediate vision, however, which would apply to both his work and reading music, there was difficulty in maintaining convergence. In fact a slight divergent tendency on fixation was noticed in both eyes. In consequence he could, but only with difficulty, contain his images within habitually used retinal correspondence areas. Hence a tendency for blurring and image confusion.

In this case it was felt undesirable to incorporate prismatic relief in his correction. Exercises were prescribed to increase his convergence ability for intermediate viewing distances. There was no problem with photophobia, or complaints about the lighting installation. His case, however, illustrated the importance binocular vision plays in visual comfort, and that anomalies present can be rather obscure and easily missed.

When he reported one month later it was found that treatment by exercises had cured his symptoms.

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Discussion

J. B. Collins (Building Research Station): This paper is extremely valuable in helping lighting engineers to understand the purpose for which they are providing lighting. There are evidently some conflicting requirements. It is important to realize, for instance, that any correction for presbyopes is a compromise between clarity of near vision and distant vision, and however many multi-focal lenses you have, you cannot make the older eye as flexible as the younger eye for focusing at all distances. Another important point is the smaller image that myopes see. Should one allow for this when assessing the size of visual tasks as seen by a myope?

Lighting for form and contrast is evidently important in trying to compensate for the loss of stereoscopic vision suffered by those with an unequal correction or muscular imbalance. Knowledge of these facts is also important when explaining why a new lighting installation has not removed all complaints, and I welcome the proposals for collaboration between ophthalmic opticians and lighting engineers which would help these problems to be studied comprehensively.

I am surprised that there are still so many complaints about fluorescent lighting. Is it possible to study the proportion of the population who are either photophobic or suffer from vergence problems? This might give some idea of the proportion of people who are likely to be dissatisfied by high illuminances. Is the solution to provide these people with tinted lenses?

The author did not mention the problem of chromatic aberration. His opinion of the importance of this effect, particularly combined with the uneven spectrum from some of the discharge sources, would be valuable.

As the author says, flicker is troublesome to some people particularly when seen in the periphery. This happens most frequently from the flicker at the ends of fluorescent lamps. Has the author any views on whether flicker above the fusion frequency causes disturbance in the central nervous system?

The case histories are most interesting. It is certainly important to follow up any complaints, particularly when one knows that one has done one's best in providing the lighting installation and yet has not satisfied all those working under it.

J. B. Harris (Dept of the Environment): In my opinion, the only answer to flicker at the ends of fluorescent lamps is to shield the electrodes; this can be done by putting flicker shields inside the lamp itself. Many people seem to have an inherent objection to fluorescent lighting, possibly based on conditions prevailing when the lamps were first introduced, as was suggested by Mr Bedwell. However, I am sure that the Institute of Ophthalmology would not have installed fluorescent lighting if it was in any way detrimental.

When one's eyes are tested, near vision is tested with a small type card. Is this the best way of testing the near vision of, say, a manual worker who, in his daily work, is concerned with seeing 3-dimensional objects which may also be moving? Most people find difficulty in getting used to bifocal lenses, but many of us would probably benefit from tri-focal lenses. Are these any more difficult to get used to? Is it possible to get bifocal contact lenses?

I would like to know if opticians, during their training, receive any instruction on applied lighting.

F. Benham (Rank-Strand Electric Ltd): I agree with the comments made on flicker of fluorescent lamps but I am not hopeful that the problem will be put right. It is one of these things which seem so simple, but which will never be tackled properly, although the cost of putting it right may amount only to a penny or so in the price of a lamp.

With regard to complaints of fluorescent lighting, this is not something about which only older people complain; I find that some younger people complain of headaches. Poor installation and even poorer maintenance have much to answer for.

With regard to contact lenses, I believe they are marked to indicate left eye and right eye, but is there any special way in which they need to be placed on the eye in order to deal with defects such as astigmatism?

P. Arklow: Mr Bedwell has not referred to the fact that variations of colour temperature and of colour of the illuminant give very different results as regards the optical corrections necessary for some eyes. In my own case, if the standard chart is illuminated by incandescent light of around 2800 K, corrections of up to 2 dioptres have little effect, but under daylight or daylight type fluorescent lamps (4500-5000 K), the correction is extremely critical both as regards strength and cylindrical axis. At one ophthalmic hospital, correction was applied on the basis of equal vision of the standard chart under red and green light, but with the lenses so computed I was unable to read a traffic sign at 10 feet!

It appears that the medical profession have linked the susceptibility of some people to fits at discotheques to the frequency of the flashing lights ('strobes') in the range 10-30 a second, and as a result the GLC have now banned the use of all equipment in licensed premises which operates above eight flashes a second. It would be interesting to learn the mechanism of this undesirable effect.

A. E. Fothergill (Osram-GEC Ltd): Can the author tell us what happens through life to the eyes of a person who is by nature short-sighted? Do they eventually need bifocal lenses? I understood Mr Bedwell to say that the eyes work better when looking down. Does this mean that if a visual task is on the vertical plane it needs more light than if it was on the horizontal?

Will the move towards higher luminance have any effect on flicker sensitivity? Does adaptation level have any bearing on this problem? Is flicker influenced by colour, and/or brightness of the source, and how much flicker can the eye tolerate before there is any noticeable deterioration in visual performance? Does Mr Bedwell know of any trends in lighting techniques which might aggravate flicker, and can he suggest how this might be avoided, or at least minimized?

M. Wood-Robinson (S.W. Electricity Board): I notice that when tinted spectacles are prescribed the tinting is so light that the transmittance must still be about 0.7-0.8, so that apparent reduction in luminance can only be small. What, therefore, is the real purpose of the tinting?

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A. H. Nash (Thorn Lighting Ltd): Does Mr Bedwell have to rely only on the confused comments from his patients for information on the lighting scheme about which they complain?

R. Burgin (Osram-GEC Ltd): Can the author tell us if any of his patients complain about daylight?

Mrs Betty Sheldrake: I was interested by Mr Bedwell's comments on the dominance of one eye over the other. He showed traces taken from each eye which indicated where dominance moved from one eye to the other. Were these measured by the actual 'eye movement recorders'?

F. E. Large (Thorn Lighting Ltd): What is the reaction of the people who complain of the flicker from fluorescent lamps to watching television, which is a much more conspicuous source of flicker?

R. A. Hounslow (written contribution): Mr Bedwell did not seem to deal with the accepted view that visual efficiency decreases with age due to gradual loss of full transparency of the inner variable-focus crystalline lens (which also hardens). This is cited as a reason for advocating higher illuminances for older people, but what is not always realised is that this deterioration takes various forms, some of which are not amenable to this treatment. Over a period of six years I suffered from one 'central opacity' or polar cataract and can confirm that in this case clarity of vision decreased as illuminance increased, the contraction of the pupil allowing even less light into the eye around the damaged portion. I took advantage of my photometric laboratory facilities and with the cooperation of an ophthalmic optician, carried out experiments of raising illuminance to higher than standard levels; the results were negative.

During investigation into my condition, drugged drops were put in my eyes to hold the iris open at maximum diameter; the results were quite amazing while the effect lasted. My trouble has since been rectified by surgery.

The author (in reply): Mr Collins is right in saying that for presbyopes one often has to compromise regarding corrections prescribed for near work, and it is very important therefore that the consultant understands any particular occupational visual requirements. Fortunately the visual acuity requirements for most near visual tasks should not present particular difficulties to myopes, but good illumination is always essential. In cases of binocular instability, however, there often may need to be a compromise between a common associated photophobic tendency, and lighting required to produce adequate contrast and form. This is one reason why greater collaboration is required between those concerned with different aspects of vision.

As regards complaints against fluorescent lighting, these rate high amongst the symptoms of patients complaining of near visual discomfort. However, those exhibiting discomfort are probably only a small proportion of those working under fluorescent lighting. Tinted lenses often help, but the important clinical aspect is to realize that there is usually an underlying cause of binocular instability which is not always easily recognized.

It is hoped that a more comprehensive study into the various factors affecting visual discomfort and visual efficiency for near visual tasks will be started shortly. The possible effect of the uneven spectrum from discharge sources on visual comfort is interesting, as are possible problems due to flicker in the periphery, but the subject needs further study before an adequate answer can be given.

Obtaining suitable case histories for this paper has proved somewhat difficult, because it is not usually possible for the ophthalmic consultant to investigate readily actual working conditions, though often a good insight can be obtained. In clinical practice I find it invaluable in most cases of near visual discomfort to ask the patient to report back in two to three months' time to assess the effectiveness of any treatment prescribed. Though it is difficult, a similar approach to some selected lighting installations might prove very valuable. This answers Mr Nash's question to some extent, but it must be said that when one is accustomed to taking clinical histories from patients, a great deal of useful information can be obtained.

In reply to Mr Harris, the use of a small near vision type card is an unsuitable means of assessing the visual capacity of a manual worker for distance stereoscopic vision. Although trifocal lenses provide an additional intermediate vision, it is at the expense of having to depress the eye slightly lower for normal near vision work. I think, therefore, that prescribing multifocal lenses must depend on individual requirements. Bifocal contact lenses are a possibility, but the optical and visual problems are considerable, and they would not be a general solution in most cases.

Ophthalmic opticians do receive instruction on lighting and its applications, together with laboratory work on simulated model lighting schemes and other aspects of illumination, but this does not, of course, give them the practical experience essential for proficiency in lighting matters.

In reply to Mr Bentham, a bigger percentage of younger people appear to complain of headache and discomfort for near visual tasks than do older patients, provided, of course, that the latters' presbyopic correction is adequate. The reason may be that there is likely to be an unstable binocular situation, and convergence stress, in the younger patient, whereas the longer history of near vision of the older person has tended over the years to produce a more stabilized binocular situation to any anomalies that may have been present earlier on.

Contact lenses are marked 'right' and 'left', but only in certain circumstances do they need to be in a special position on the eye, e.g. for the correction of astigmatism in the contact lens. In this case, a special type of fitting is employed which ensures automatic correct location of the lens.

As Mr Arklow suggests, the eye does show chromatic abberation, but with an adequate correction given for white light or daylight, few problems usually arise. When using a standard refraction chart, the illuminance is very important, as colour can be for critical visual acuity assessment. In general, for driving a car a slight under-correction of a positive correction, or over-correction of a myopic correction, improves visual acuity, particularly as night-time approaches. However there is a limit to how much can be done to help the older patient in this way as intermediate vision will suffer. The use of a red and green duo-chrome test means avoiding blurring of the green targets for reasonable night-time vision.

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In reply to Mr Fothergill, a person who is by nature short-sighted will need a reduced myopic correction—achieved possibly by removing the correction or by reducing it by a bifocal addition—when they reach middle-age. In general for near visual tasks, it is easier to maintain binocular vision and convergence when the eyes are depressed, as this is the natural position for these tasks. Higher illuminances do affect critical frequency of flicker. Further research is needed to determine whether there is any noticeable deterioration in visual performance with different types of flicker.

Regarding Mr Wood-Robinson's question, it is interesting that clinically quite a small reduction in transmission by tinting often produces greater comfort, but usually there is an underlying binocular instability present as well which needs attention.

In reply to Mr Burgin, patients indeed do complain about daylight, either when out-of-doors, or often when working in the window-wall areas of modern office blocks. Here again there is frequently an associated binocular instability which may need attention.

Mrs Sheldrake raised the question of eye dominance. This is interesting and important, but its assessment presents many difficulties. In clinical practice, at least for near vision, I find the best approach is to observe the eye which tends to be more centrally fixated, as there is usually a slight difference between the two. This technique does, however, require considerable experience, and to be aided instrumentally by using eye-movement recording.

In reply to Mr Large, patients do not on the whole complain about flicker when watching television because here, I think, they are employing central vision, for which the critical flicker frequency is higher.

Mr Hounslow is right in saying that with certain forms of lenticular change or cataract higher illuminances reduce visual performance because of the contraction of the pupil. Some patients with lenticular changes are more comfortable out-of-doors with a tinted correction. Dilating the pupils, particularly of some older patients, with a mydriatic drop can well improve vision, but unfortunately this cannot normally be recommended as a routine procedure because the eye may become glaucomatous later.

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