THE EYES HAVE IT*

Ellis L. Rabben, U. S. Forest Service, Washington, D. C.

ABSTRACT

Stereoscopic acuity is only one of the visual skills needed for photo interpretation. Other requirements include good distance vision, acceptable near vision, good reserves for accommodation and convergence, good extra-ocular muscle balance and the visual capacity to maintain an exacting search for small details.

Defects which affect these visual requirements are present in a significant proportion of the civilian and military populations. Latent defects are usually unknown to individuals and they may not cause visual screening failures, but they affect photo interpretation adversely. In most cases, the defects can be corrected by proper diagnosis and prescription.

Psychological accommodation and convergence may cause suitable applicants to fail vision tests. Vision tests which are specifically designed for photo interpreters and others using stereo vision instruments should be used periodically to detect latent and manifest visual defects.

IT IS common knowledge that stereoscopic vision is important to photo interpretation. What is *not* so common is an awareness of the extent to which other ocular functions affect stereoscopic vision. Moreover, there are additional visual needs which are at least as important to a photo interpreter as stereopsis.

When photo interpretation is analyzed in terms of visual requirements, it may be seen that an individual may perform very well in a stereo acuity test despite the fact that his ocular mechanism may be unsuitable for photo interpretation. Conversely, an individual who fails such a test may still have eyes which are admirably suited to the art. How can this be? To answer this question consider how our eyes work when we interpret a photograph.

When we look at a pair of aerial photographs through a stereoscope, the instrument lenses take care of the focusing for the eye-to-photo distance. If the prints are oriented properly, the eyes do not converge. This visual positioning is the same as that which would be required if we were to gaze at a distant mountain. In this distant scene however, an interpreter must search for very small items. He must examine detail which often approaches the borderline between visible and invisible. Despite the nearness of the photographs, this visual task is similar to the one required of a sailor who must search the ocean for a periscope.

Interpreters examine such details daily for long periods at a time. Therefore, the interpreter's ocular mechanism must be able to *maintain* visual efficiency throughout the work period. A crude analogy may be made with the ability to run. We need the equivalent of the runner who can maintain a minimum rate of speed for five miles every day, rather than the sprinter who can run at a remarkable clip for a quarter of a mile once a week.

Another requirement is the ability to perceive small differences in parallax. This permits exploitation of the exaggerated stereo effect which results from the tremendous aerial eyebase. An interpreter must be able to appreciate not only the gross, but also the very smallest differences in parallax.

Finally, the last requirement is to be able to screen through many photos in order to choose those which are to be studied in detail with a stereoscope, and to write reports once the interpretation is finished. For both of these tasks, good near vision is necessary. This visual capability is the same as the one needed to read a book.

On the basis of what a photo interpreter must do, it may be said therefore that he should be able to:

1. See well at a distance.
2. See well at near.
3. Maintain visual efficiency throughout the work day.
4. See stereoscopically.

* This is a part of the Panel on Photo Interpretation held on March 8, 1955 during the Society's Annual Meeting.

These requirements seem simple. Any normal pair of eyes should be able to perform well enough. However, the problem must be viewed in the light of the concentration on detail which is required in interpretation. Factors which can be ignored safely in everyday vision become important to an interpreter because of the strain on his ocular mechanism.

An an example, consider the interpreters who have 20/20 vision. They can see detail which subtends an angle of one minute at the eye nodal point. Even with the magnification provided by the stereoscope lenses they need vision which is this good. The fact that they have 20/20 vision tells us only what they can see at the moment of the test, but not how long they can keep on seeing that well under conditions involving strain. To understand why this is so, look at the mechanics of human refractive error.

A lens which is made of living tissue varies the focal length of an eye automatically. This lens is made more or less convex by the contraction or relaxation of a thin ring of muscle. The range of action of which the lens is capable, and therefore the range of focus of the eye, is called its amplitude of accommodation.

Now many people with 20/20 vision are actually hyperopes. This means that when their eyes do *not* strain to see, they do not have enough lens power to produce a clear image of objects at infinity. According to the laws of optics, these people should not see well at a distance. However, human eyes do not behave altogether like well designed optical systems. Hyperopic eyes compensate for their poor natural focus by stealing some of the focusing power which is supposed to be reserved for near vision.

The significance of this involuntary drain on accommodative power is that individuals who are sufficiently hyperopic tend to lose interpreting efficiency easily. Hyperopic interpreters develop a complex of symptoms known as astenopia. Their eyes begin to tire in the afternoon. Their eyes may itch, twitch, burn or water; they feel as if there is sand under the lids. Their eyes may look bloodshot even after complete sobriety and nine hours of sleep. Headaches occur. Only will power enables these men to keep on examining photographs. They are in the forefront of those who complain that the quality of aerial photography is not what it used to be. This fatigue causes many items to be missed, others to be poorly interpreted, and the job takes much longer than it should. These individuals are the sprinters; they *cannot* maintain the pace unless the hidden hyperopic condition is remedied.

The same accommodative power which supplements the focal power of hyperopic eyes is itself a cause of trouble. Accommodative amplitude is at its maximum when we are about ten or twelve years old. Thereafter it decreases steadily until we are about seventy, when it is usually all gone. This means that at some time in our lives we reach a point where we do not have enough focusing power for our usual reading distance. We are then said to be presbyopic. Presbyopes notice that they cannot find names in the telephone book, or that they fall asleep when they read, or most commonly, that their "arms are not long enough" to hold reading matter far enough away to see it.

The significance of presbyopia to interpretation is that long before he notices that he cannot see well, a presbyope has the same interpretation difficulties as a hyperope.

Of equal importance are latent defects of the neural coordinating mechanisms which control the extra-ocular muscles that move the eyes. This coordination is easily disarranged, and the effect on interpretation when this happens is bad. For example, the eyes may have a tendency to converge or to diverge when the visual axes should be parallel. These tendencies do not mean that the victim is cross-eyed, but they do mean that an extra effort must be made to keep both eyes aimed at the same object all the time. This effort causes fatigue and it affects clear vision. It works in this way:

When the eyes accommodate for some particular distance they also converge in proportion. This relationship becomes very strong. It is so strong a bond that each time that the eyes *try* to accommodate or converge, whether they succeed or not, the other part of the reflex tries to respond in the appropriate amount. The attempt to overcome hyperopia, for instance, causes convergence. Similarly, an attempt to control the tendency to converge causes corresponding focusing changes.

During these attempts at compensation,

the response of the other half of the accommodation-convergence reflex causes blurred vision. This is particularly noticeable when the visual task is most delicate or when extra concentration is required. When an interpreter has to overcome these tendencies, his vision becomes more blurred at the very time that he needs clear vision most.

The accommodation-convergence relationship also explains why "naked stereo," or viewing photos stereoscopically without a stereoscope, is so difficult. It requires that the eyes focus on photographs at near distance while the visual axes are positioned for far. *This* requires deliberate disassociation of accommodation and convergence, and since neither of these is ordinarily a voluntary control it takes long practice to split them apart at will.

These difficulties are all related to stereoscopic vision, for an ocular mechanism which operates easily and efficiently is essential to stereopsis. For example, individuals with uncorrected refractive errors, or with poor extra-ocular muscle balance, often have substandard stereoscopic acuity also. Most defects influence stereopsis by disturbing fusion.

Fusion is a measure of the tenacity with which the brain insists on seeing a single image of a single object. This is not as simple as it sounds, since *two* images of a single object are sent to the brain, one from each eye. In general, poor fusion is caused whenever the two images are more than slightly dissimilar.

The permissible degree of image difference varies with the kind of difference, with the individual, with the time of day, with the general state of health, and with many other factors. However, the most important factors which tend to disturb fusion are differences in size, in shape, in brightness and in color. For instance, if the two eyes have refractive errors which are appreciably different, a condition known as anisometropia, the images presented to the brain are likely to be sufficiently dissimilar to cause poor fusion. Moreover, even when this condition is corrected with spectacles, the differing magnifications of the correcting lenses perpetuate the image disparity.

The way in which other disturbances of the ocular mechanism affect stereoscopic acuity is simulated by two well-known phenomena. One is the new interpreter's inability to keep his photographs as far apart as his eyebase. The other is the poor performance, in stereoscopic vision testing, of individuals who actually have excellent binocular depth perception.

In both of these instances, psychological factors create the same difficulties which can also be caused by latent defects. When looking through a stereoscope, the target is viewed at optical infinity. Therefore, both accommodation and convergence should be at zero. However, the individual *knows* that the photographs are actully only a few inches away. Without conscious awareness, psychological controls take over. The new interpreter experiences "proximal accommodation" or "proximal convergence" or both. The attempt to accommodate or to converge causes a blur, since it is the correct response to the real, not the optical condition. The interpreter can often overcome most of his proximal accommodation, but the *attempt* to accommodate remains. Together with the psychological stimulus to converge, it causes his eyes to actually converge toward the desired proportion demanded by the accommodation-convergence relationship. When this happens, the image remains flat. The situation is resolved when the interpreter discovers that if he moves the photos closer together they not only look clearer but he can also sense depth. He has to move the photos just enough so that both eyes see the same point while they are partially converged in response to the reflex. What is significant is that fusion is affected, and the interpreter sees little or no depth until the mechanism is allowed to operate easily.

During stereo vision testing, the process is the same up to the point where the interpreter would like to move the prints closer together. But the test prints are fixed in relation to each other. Therefore the interpreter continues to see a relatively flat image despite the fact that in a normal situation his fusion and stereoscopic acuity may be better than average.

Not everyone is affected to the same degree by psychological accommodation and convergence, but those individuals who are most acutely attuned to their environment are the most susceptible. These are the same individuals who are likely to make the best interpreters, so that when the stereo test is used alone it can weed out the best instead of the worst.

Even if more were known about the visual requirements for photo interpretation, the most important questions would be these: How common are significant visual defects? Are visual requirements really worth investigating? Consider then, the incidence of visual defects in the general population.

A full 100 per cent of healthy individuals eventually become presbyopic if they live to middle age. Hyperopia, myopia and astigmatism, the most common refractive errors, affect an estimated 35 to 45 per cent of the population. If it is considered that errors which are insignificant in ordinary life may be important in photo interpretation, this could easily be 60 per cent. It is inconceivable, if these few ocular defects are so common in the population at large, that their incidence is negligible among photo interpreters.

Latent defects are rarely suspected by the patient, yet these are most significant to photo interpreters. Most people realize that something is wrong with their visual apparatus only when they eventually have to admit to themselves that they actually cannot see, or when they have ocular pain. It cannot be assumed that interpreters will know that they have visual defects because of the effect on their work.

Nor can we rely on natural selection to choose for us those individuals whose vision is suitable for photo interpretation. It would be just as reasonable to say that people who drive taxicabs must be good drivers or they would not be driving taxicabs.

* * *

The best vision tests which are now used to screen potential photo interpreters have targets for distance vision, for near vision, and for stereoscopic acuity. They do not test for latent refractive errors, for tendencies to converge or to diverge, for the degree of fusion, or for the ability to maintain visual efficiency when interpreting.

If photo interpreters are to be selected intelligently, and if experienced photo interpreters are to have guides by which they can maintain visual efficiency, then a battery of vision tests will have to be devised which is related to the requirements. Such tests moreover, should be administered annually.

* * *

It is well to remember this about photo interpretation: Eventually, after the aircraft has come back with the film, and after the photography has been processed, after vast sums have been spent to procure fine photography, a pair of photographs are laid in front of an interpreter and he has to look at them. The photographs may be dripping with resolution and oozing with intelligence, but if the photo interpreter has a faulty sensing mechanism at that moment, then nothing happens.

If photographs begin to be converted to intelligence when an interpreter examines them, then whatever affects the interpreter's ocular mechanism may affect the intelligence. This is worth investigating. This approach to better utilization of the photography that can be obtained now has been relatively neglected.

* * *

It would take only a little bit of research to tell us where we stand on this matter. There is good reason to believe that at least a key to better performance is readily available, and that the eyes have it.

Discussion of Dr. Rabben's Paper

QUESTION: It was about four years ago that I was able to develop ability to see stereoscopically without using an instrument. Since then I have had difficulty using floating-dot mechanisms, because when I look at the dots in any one position, they seem to vary widely in distance. Is there any explanation for that effect, or anything I can do about it?

DR. RABBEN: I didn't mention in the paper, because of the time limitation, that if you disturb the natural accommodation-convergence relationship by forcing it apart, that is, by using naked stereo and using if for long periods and frequently, then this common relationship doesn't work so well any more, and you begin to have all sorts of difficulty when you are not interpreting. This is something that should be expected. It is one of the hazards of not using a stereoscope or other instrument in order to see stereoscopically. In fact, one way in which treatments are given to people who are cross-eyed is first to thoroughly disassociate their accommodation and convergence, and then build it up again in the manner desired. The remedy in this instance might be to rehabilitate your accommodation and convergence relationship.

QUESTION: In view of the fact that in the long run eyes become affected, whether it be in interpreting photographs with a stereoscope or with a magnifying glass, is any instrument, conventional or electronic, better suited for interpretation than the eyes?

DR. RABBEN: That is something I cannot answer. I don't know much about electronics and the capabilities of such sensing mechanisms. I suppose at least on a theoretical basis that it would be possible to extract intelligence from photographs without a human being looking at the photographs, but I suspect that this is a little bit far in the future, and at the moment we still have to use our eyes and minds in attempting to make intelligence out of the photograph.

DR. ROSCOE: Dr. Duncan Macdonald has said if he is awarded a million dollars and allowed a space of about the size of a room, that he can build a machine which will interpret objects on an aerial photograph of about the size of say an airfield.

DR. RABBEN: I think human beings are way ahead of his machine and they are cheaper.

QUESTION: Is there is a test whereby one can tell in advance whether a person would make a good Multiplex operator.

DR. RABBEN: There is no such test now. The kind of test which I feel should be developed to test the photo interpreters for their visual capacity would be equally applicable to any individual using stereoscopic equipment or working with stereo models. This would most certainly apply to Multiplex operators, but at the moment the only test which could be so used would have to be administered by a doctor. I envision the ideal test to be one which does not have to be administered by a doctor, which can be made rapidly, which is very inexpensive, and which can be done in any agency or office where there are people who have to work with stereo instruments.

DR. ROSCOE: In addition to the physician and physiologist do you think that perhaps the psychiatrist or the psychologist should be involved in the preparation of such a test?

DR. RABBEN: That goes into the question of what are the requirements for a photo interpreter generally, rather than just what are his visual requirements.

DR. ROSCOE: I was thinking in terms of the tricks the mind will play, as well as the latent defects of the eyes.

DR. RABBEN: I believe that would be a very interesting and certainly fruitful research project. It could be quite a small one which would deal with psychological vision—those psychological aspects of vision which cause an interpreter to see things which are not there, and which cause him not to see things that are there—and these would be aspects quite unrelated to optical aspects of vision.

QUESTION: Dr. Rabben, what physiological eye strain is placed on the eyes when the focal plane shutter is operated first with the line of flight and then against the line of flight and using different magnifications, different scales, in just the one direction?

DR. RABBEN: These stains are related to the factors which tend to disrupt fusion—in other words, differences of size which may well occur in this case, certainly differences of shape, of color, and of brightness. It is much the same as a strain placed on a mechanism when two photographs are taken too far apart, or when the stereo base is too large for the eyes to be able to see them comfortably—there is a point at which slightly dissimilar objects can no longer be fused. Where this point is it is impossible to say as a generalization. The location varies and the range of variation is so large for humans that we cannot say that if the size difference is 3 per cent then everyone will see these things double instead of singly, or if the size difference is 1 per cent, that everyone will see it singly. This is related to the subject of aniseikonia, which is a natural condition occurring in some eyes whereby the retinal images are not of the same size; in some cases the size difference is only $\frac{1}{2}$ of 1 per cent. Some individuals have aniseikonia, yet other individuals with perhaps $1\frac{1}{2}$ or 2 per cent size difference, experience no trouble whatsoever. So this is the same problem, as I see it.

QUESTION: If one wishes to determine a person's visual suitability for interpreting color photographs, what additional tests beyond those which you describe could be given?

DR. RABBEN: There are two. There is no such thing as color blindness. Instead there are degrees of color vision, as there are degrees of ordinary vision, so that someone may well see all three colors and yet not have enough qualification to interpret color. We are using a lot of technical words; let's throw in another one. Such a person has what is known as anomalous trichromatia. He is a person who sees all three colors but doesn't see them properly.

The tests which can be given to determine degrees of color vision are two: the first is called the Holmgren-Wolls test; it consists in letting the individual examine quite a large number of pieces of wool strands which have been dyed with standard colors. From this we can tell whether he sees red or green as the same color, that is, shades of gray, or whether he does not. In other words if he can distinguish whether they are actually red or green.

A more sensitive and definitive test, according to the American Medical Association and most eye authorities, is the Eldridge-Lanter test. This is used for defective color vision testing for flying personnel. A lantern throws onto a standard screen a number of standard colors and combines them. The individual then can be tested very accurately as to his degree of color vision. Such tests I think, would be mandatory for an interpreter who analyzes color photos if his interpretation is to be relied upon

QUESTION: Dr. Rabben, what do you regard as an ideal light source for photo interpretation? Also how about the level of intensity of that light?

DR. RABBEN: That is one of the things that should be included in the little research project. While I can speak only from my own experience, I have seen a lot of people interpreting photographs and in most cases the light is quite inadequate, because while it is frequently provided, the PI often doesn't use it. I think that the ordinary two-tube Dazor lamp, which is often provided, is very satisfactory when it is used, and when it is held close to the photograph; but this is an entirely subjective opinion. I couldn't say, nor do I think there are any data at the moment concerning the nature of the light source or the intensity which is most desirable for PI. There are studies, particularly by Lukirk and others, that indicate that a very high level of intensity is desirable, but this has never been tested for PIs. I don't know of anyone who can give a definite objective answer to that.

DR. ROSCOE: Studies have been made about the light intensity required for viewing transparencies. But this usually amounts to a rheostat controlling a light source underneath the transparencies, with the interpreter adjusting this for what he thinks is the maximum recovery of information from the particular part of the transparency he is working on.