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# The new physiology of vision—Chapter IV. Corpuscles of light and the perception of form

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The observations described in the preceding chapter provide us with a fresh insight into the nature of vision. Our visual sensations are the resultant of an immense number of discrete processes, each of which is a chance event, viz., an individual corpuscle of light being taken up by a receptor unit in the retina and transformed into an impulse which reaches the centres of perception. The superposition of these unit processes in large numbers does not necessarily result in every trace of their discreteness being effaced. The fluctuations of luminosity seen by an observer on the surface of a uniformly illuminated screen viewed by him are evidence to the contrary. As is to be expected, the character of the observed fluctuations is found to depend on the strength of the illumination of the screen, the distance from which it is viewed and on the spectral character of the illumination.

In the present chapter, we shall concern ourselves with the part played by similar considerations in the normal functioning of our visual organs. The binocularity of vision not only enables us to perceive the form of the objects around us but also to locate their relative positions in three dimensional space. We shall not here enter into this more recondite subject and will confine ourselves to the simpler aspects of vision, viz., the perception and recognition of the form and features of individual objects in two-dimensional space. Even here, we shall, in the first instance, begin by considering cases of a relatively simple type.

*Observations with test-charts*: Perhaps the most frequent use of vision in daily life is the reading of printed material of various sorts. Constant familiarity enables us instantly to recognise the letters of the alphabet when presented to us. It is, therefore, not surprising that in ophthalmic practice the material commonly made use of for examining vision and prescribing the corrective glasses needed in cases of defective eye-sight consists of sets of letters printed in black on white card, thus providing the maximum of contrast between the object and the background against which it is viewed. In the well known Snellen test-charts, there are in all eleven rows of letters, the first consisting of a single letter of large size, and the others following it containing letters of smaller sizes and in greater numbers. The standard charts are designed to be set at a distance of six metres between the chart and the observer, this being regarded as representative of distant vision. The sizes of the letters on the chart have been so adjusted that an observer with average normal vision can recognise and read the letters in the eighth line, but cannot proceed further. If he can read the lines beyond the eighth, his vision is better than the average normal. Ability to read the eleventh and last line on the chart indicates a visual acuity twice the normal average, but such cases are relatively rare.

If an ophthalmic test-chart is to serve the purposes for which it is intended, it should be adequately illuminated, either artificially or by ordinary daylight. For an investigation of the relationship between visual acuity and the level of illumination, it is necessary to have an arrangement by which the strength of illumination can be controlled and varied over a wide range. For this purpose, the author makes his observations in a darkened room into which skylight is admitted through a circular window set fairly high up and having a diameter of 25 cm. This window is covered by a large and specially made iris-diaphragm, the diameter of the opening of which can be varied from the full value of 25 cm down to 5 mm as desired, thereby providing for a reduction of illumination by a ratio of 2500:1. The test-chart is set facing the window and at such a distance from the observer that the eighth line of letters can be comfortably read. As the illumination is diminished progressively, the observer maintaining his distance from the chart, successive rows of letters, one after another, become indistinct, then unreadable and finally unobservable. At the lowest level of illumination, even the first large letter on the chart can scarcely be seen. But if at any level of illumination, the observer, instead of remaining at the same position, approaches sufficiently near to the test-chart, the letters become clear again, in other words, the effect of diminished illumination can be set off by diminishing the distance of observation.

The progressive fall in the acuity of vision with diminishing strength of illumination thus manifest is readily understood when it is realised that for perceiving an object clearly, it is necessary that the corpuscles of light reaching the retinae of the observer from all parts of the object are sufficiently numerous to give rise to an integrated perception of its entire form. The feebler the illumination, the less likely it is that this requirement is satisfied. We would then be unable to perceive the whole object, but only see parts of it which vary from instant to instant. In other words, a fluctuating and broken-up picture of the object is presented to us instead of a clear and complete image of it. With any further reduction in the illumination, the visual image would cease to be recognisable and would ultimately tend to disappear.

The foregoing is a statement of what is actually seen of the individual letters on the test-chart and correctly describes their appearance as the iris-diaphragm of the window is progressively closed down. Indeed, at the lowest levels of illumination, the phenomenon of an entire letter disappearing from sight and reappearing immediately afterwards is often noticeable. We may here raise and answer the question why when the observer comes sufficiently close to the chart, letters which were previously indistinct and even invisible come into view again. The answer is that the image of a letter on the retina is then much enlarged and at the same time, the number of light-corpuscles reaching the image is increased in the same proportion. In consequence, the fluctuations of the image would, relatively to its perceived size, be on a much smaller scale, and the resulting fragmentation of the image would not therefore prevent its form as a whole being perceived and recognised.

The foregoing description and discussion refers to the case of a Snellen chart of the standard size held at a considerable distance from the observer. Essentially similar observations can also be made with charts printed on a reduced scale so that the entire chart can be held at arm's length. The disappearance of the lines on the chart one after another as the illumination is reduced is also noticed in this case. But it is not quite so easy using the smaller charts to observe and follow the fragmentation of the images, as the fluctuations which cause such fragmentation are on a much smaller scale.

*Observations with monochromatic light*: As in the studies described in the preceding chapter, the use of monochromatic illumination instead of ordinary daylight is strongly to be recommended for the study of visual acuity. Using such light, e.g., the light of a sodium-vapour lamp, it is easy to recognise the relationship between the effects observed on a uniformly illuminated screen and those exhibited by a test-chart carrying printed letters. Putting the two side by side so that they are equally illuminated, it becomes evident that the fluctuations observed in both cases have a common origin and are closely related to each other. The moving areas of light and shade are of approximately the same size in both cases in any particular circumstances of observation. In the earlier chapter, it was remarked that using the $\lambda 4358$ radiations of the mercury arc, the fluctuations visible on a screen uniformly illuminated with such light are extremely conspicuous. It is to be expected that in these circumstances, the visibility of letters on a test-chart should be very low with such illumination. This is indeed made evident by actual observations. The contrast with the much higher visual acuity observed using the light of the sodium lamp is very striking.

*Binocular observations of visual acuity*: The noteworthy observation was recorded in the preceding chapter that the fluctuations of luminosity on a uniformly illuminated screen are more conspicuous when viewed with only one eye of the observer open (the other being closed) or *vice-versa*. It was remarked that this observation indicates the fluctuations of luminosity as seen by the retinae of the two eyes to be *independent* and the effect of binocular superposition is thereby to diminish their visibility. Having regard to these remarks, it is significant that when a test-chart is viewed under reduced illumination, the visibility of the letters is notably *improved* by using both eyes. *Per contra*, it is visibly diminished by closing one eye or the other. This is what we should expect if the diminished visibility of the letters is the result of fluctuations in the perceived retinal images. If both eyes are used, the binocular superposition would tend to suppress the fluctuations in the perceived images and thereby to improve their visibility.

*Scintillating charts*: An effective demonstration of the rôle played by fluctuations of luminosity in visual acuity and the perception of form is forthcoming when the Snellen charts containing rows of letters of diminishing size are replaced by charts in which the objects under view are all similar to each other and are arranged in regular geometric order. Charts of this kind can be readily prepared on white bristol board using Indian ink to cover up a succession of strips all of equal width, arranged both horizontally and vertically and set at equal intervals. We thus obtain a chart consisting of white squares on a black background, equidistant and all of the same size and arranged in rows and columns forming a regular pattern. It is useful to prepare a number of such charts in which the squares are of different sizes, e.g., 5 mm × 5 mm, 1 cm × 1 cm and 2 cm × 2 cm.

All the three charts may conveniently be set side by side and illuminated in the same fashion, so that they may be readily compared with each other. The monochromatic light provided by a sodium-vapour lamp is well suited for the purpose and by the use of an iris-diaphragm the illumination of the charts may be varied over a wide range of values. When the illumination is sufficient and the observer is not at a great distance from the charts, the white squares on all three charts are seen with clear and sharply-defined boundaries. But when the illumination is progressively reduced, this is no longer the case. The chart with the smallest squares first shows the alterations in appearance and is followed by the two others in the order of the sizes of the squares. The effects of increasing the distance of the observer also follow the same order. The most interesting cases are those in which the squares continue to be visible but with much less than the maximum definition. It is then noticed that the squares fluctuate in brightness, the difference between each square and its nearest neighbours being readily observable. In the case of the chart with the 5 mm squares, the changes in brightness give rise to an effect resembling scintillations. The charts with the larger squares also exhibit curious continuously changing deformations of the form of the white areas, while inside those areas irregular patterns of light and shade are visible; these patterns vary from square to square and also change continuously.