12 Structured Targets

As intimated in the previous chapter, there are various forms of structure existing in many of the objects of interest met with in real life. These range from gross trends in luminance (e.g. Fig. 11.2) to multiple levels of luminance (Fig. 11.1), fine profile detail (Fig. 11.3) and surface texture. The aim of this chapter is to present a survey of laboratory data which shed some light on this problem of target structure. These data will be considered in terms of the contour modelling of threshold of Chapter 7 where appropriate. From the findings the possibilities of extending modelling to cover certain forms of simple recognition will be considered.

12.1 THE ANNULUS/DISC EXPERIMENT

One experiment which is considered to shed some light on the influence of target structure on thresholds is that carried out at BAC (GW) and known as the 'annulus/disc experiment'[1]. In this experiment, originally aimed at distinguishing between area and contour theories of visual processing, a series of three disc stimuli and three annular stimuli of equal outside diameter were presented to a group of observers in random order. The presentations were made with positive contrast and at high (approaching visually perfect) quality on a back projection screen at an adaptation luminance of 55 cd/m^2. Presentation times were fixed at 1/3 second and all presentations were made at a known, central position on the screen. The stimuli subtended angles of 3, 6 and 9 mrad when viewed from a distance of 1 m. The annuli were of such form that a central disc of diameter one third the outer diameter was removed, the central region thus having the same luminance as the background. The stimuli were presented in random order to each of 16 observers, the thresholds being determined by the threshold tracking technique[2].

The results of the experiment are shown in Fig. 12.1, where it will be seen that the relative detectability of the annulus and disc depend strongly on the angular subtense. At the largest size (9 mrad) the annulus is the more easily detected, despite the reduced area relative to the disc, whilst for the smallest size (3 mrad) the converse is true. In order to study these unexpected results further the original object shapes were convolved with the eye's spread function as measured by Westheimer and Campbell[3], with the results shown in Fig. 12.2. It will be seen from this figure that the retinal images of the three *disc* stimuli are all fully resolved – that is, there is an illuminance plateau in the centre of the image. On the other hand, of the retinal images of the *annuli*, only the largest of the three contains a plateau region. Of the other two the 6 mrad annulus has the

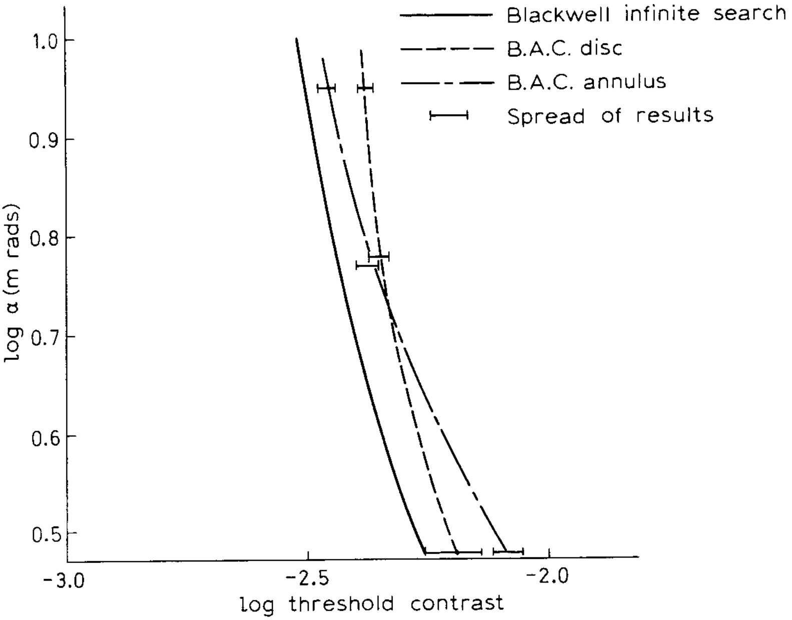


Fig. 12.1. Comparative detection thresholds for annular and disc stimuli of various outside diameters.

outer profile just resolved, whilst the inner profile is softened by some 15–20%. The 3 mrad annulus, on the other hand, has both outer and inner profiles softened, the inner some 15–20% *more* than the outer. If it is assumed that the differential softening of the inner contour by 15–20% is sufficient to suppress its influence effectively, as was discussed in Section 7.7 for parts of a blurred profile, then it is found that the remaining contour, relative to that of the equivalent disc stimulus, is just sufficient to account for the observed results. For the 9 mrad annulus there is a threshold enhancement equivalent to that for a 30% increase in contour length relative to the 9 mrad disc – as provided by the inner contour. For the 6 mrad annulus the threshold is as for the disc, i.e. the outer contour only. Finally, for the 3 mrad annulus the degradation is as expected for the softening of the outer contour, again assuming this to be the only one contributing to the threshold.

The annulus/disc experiment was, of course, only able to provide any information for one high photopic luminance level. Other data of a similar nature exist for lower light levels, particularly for the scotopic region (e.g. Hills[4]), which appears to show similar behaviour to the photopic region but at a much larger scale. Similar comparative behaviour has been observed between photopic and scotopic light levels in forms of *receptive field* studies (see Section

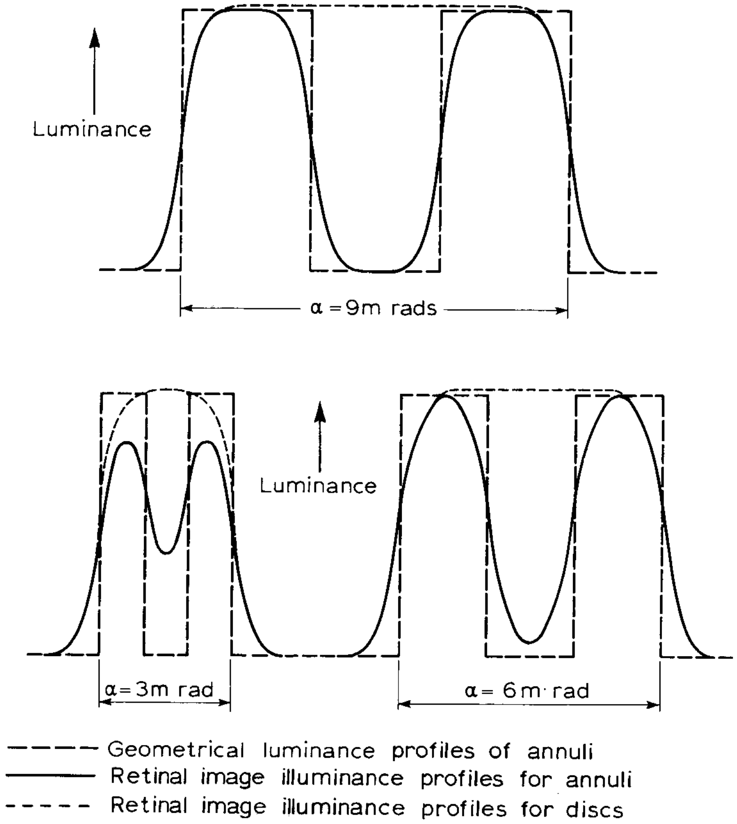


Fig. 12.2. Cross-sections of the luminance and retinal illuminance distribution for annular and disc stimuli of various sizes.

13.1) which suggests that, although not presently modelled, there may be similar effective illuminance gradient sensitivity for scotopic (or rod) vision as we appear to have found for photopic (or cone) vision.

12.2 THE MULTICONTRAST EXPERIMENT

In an attempt to provide guidelines for modelling of the detection and recognition thresholds for the simplest form of multicontrast stimulus an experiment was carried out by BAC (GW) in which the size thresholds associated with a high contrast square and a set of low contrast appendages were studied[5]. The basic material for this experiment is illustrated in Fig. 12.3; it consisted of

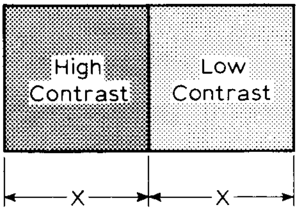


Fig. 12.3. The form of stimulus used for the multicontrast experiment.

transparencies of two high contrast squares (nominal contrasts of -0.89 and -0.66), each permuted with a series of medium to low contrast squares. The material was viewed, in random presentation order, by eight observers against a high luminance (3200 cd/m^2) back illuminated screen, the observers being able to move towards the stimuli from a distance of some 38 m by means of a very slowly moving, motorised chair. The only limit on viewing time was that associated with the slow, but finite, growth rate of the target.

The essence of the experiment was that observers were required to report firstly when they detected the presence of the total stimulus, and secondly when they could detect the presence of the appendage. As a supplementary exercise stimuli comprising the appendage only were also provided, and a similar exercise was carried out to determine the thresholds for the various contrast appendages in isolation. This was considered desirable to check how closely Blackwell's Tiffany findings[6] could be reproduced with the particular experimental arrangement used for this study. The results are shown in Fig. 12.4. It will be seen that the mean detection sizes for the appendages in isolation are in very satisfying agreement with the Tiffany results, except for the lowest contrast, where the size required is considerably higher than found by Blackwell. The agreement is particularly satisfying, since no serious attempt was made to provide uniform illumination over the entire visual field, as attempted by Blackwell. It is suspected that the degraded performance for the lowest contrast appendage is as a result of decisions being made at free choice level, as opposed to Blackwell's forced choice decisions (see Section 3.3). This would be expected to increase δ in Equation 7.4 without affecting K_1, the result being a degradation of large size (low contrast) thresholds whilst leaving small size (high contrast) thresholds relatively unaffected (see Fig. 4.1).

Having established that the thresholds for the appendages in isolation are in agreement with those by other workers, we are in a position to consider the thresholds for the complex targets. If we firstly consider the thresholds for the *detection* of the complex targets we find them to be hardly different from those for the high contrast squares in isolation, until such time as the appendage contrast is approaching that of the basic square. Then, progressively, the threshold size falls to that which would be expected from a simple rectangular stimulus comprising the main square and the appendage at equal luminance. More spectacular are the results for detection of the existance of an appendage.

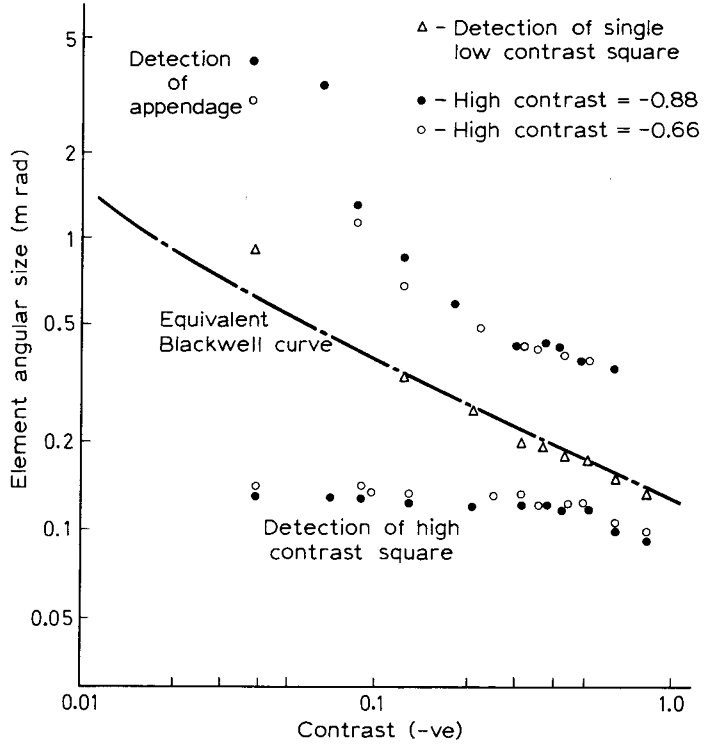
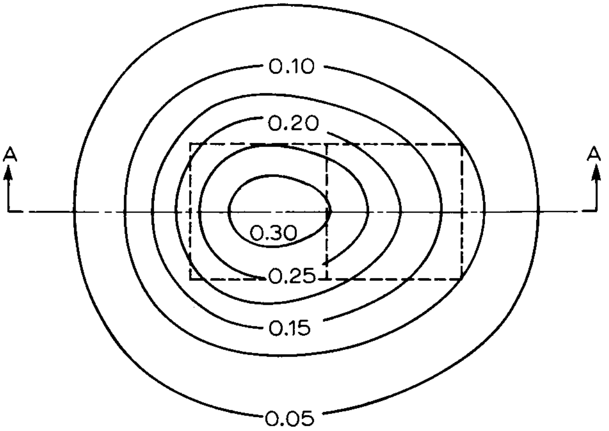


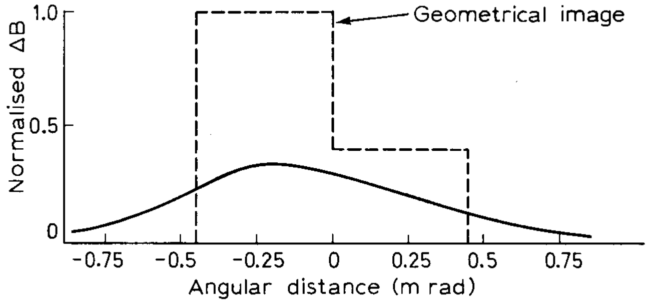
Fig. 12.4. Detection thresholds for presence of an appendage attached to a high contrast square compared to the thresholds for simple square stimuli.

For the majority of contrasts the thresholds for presence of an appendage are displaced by a constant factor of approximately 0.3 in logarithmic size (linear) or 0.6 in logarithmic contrast, suggesting that the effective 'size' contributing in the Ricco's Law region is constant at 50% of the appendage size! This seems to apply *whatever* the contrast between the main square and the appendage, so long as all detections are made in the Ricco's Law region.

In an attempt to shed light on the form of this detection task, a stimulus of basic dimension 0.44 mrad, with an appropriate appendage threshold contrast, was convolved with the Westheimer and Campbell eye spread function. The resulting retinal image isophot diagram, together with a cross-section illuminance profile, are shown in Fig. 12.5. It will be seen that there is no semblance of the two separate illuminance plateaux left in the cross-section, and that there is only a small tendency to an ovoidal shape in the isophot diagram to indicate the existence of an appendage. Detailed modelling of this form of stimulus has not been pursued at this date, but once again there appears to be evidence that



(a) Isophot diagram



(b) Illuminance profile at section AA

Fig. 12.5. Retinal image illuminance profile and isophot diagram for a multicontrast stimulus consisting of high and low contrast squares of 0.44 mrad side length.

differences of retinal image illuminance gradient of some 20% are controlling factors in producing differential threshold performance.

12.3 CONTRAST SENSITIVITY AND THE MACH EFFECT

With the information gained from the study of the complex targets of Sections 12.1 and 12.2 it is now time to look in depth at the contrast sensitivity functions described in Section 4.14. The form of unsharp object used, which has received considerable attention in recent years is, at its simplest, a one dimensional, modulated sine bar pattern as described in Section 10.2. Such a pattern exhibits a series of long borders of maximum gradient which is proportional to the spatial frequency since

$$\frac{\mathrm{d}B}{\mathrm{d}x} = (\Delta B')_{\mathrm{max}}\ \omega \cos(\omega x).$$

Therefore, from the reasoning in Chapter 7 and Section 12.1, the visual system might be expected to have a response which increases with spatial frequency. However, the normal optical degradations due to the spread function, tremor, drift and retinal diffusion all tend to lead to degradation of performance with increasing frequency (the common 'low pass' filtering of most linear systems). Also, although the receptor pair differences are absolutely related to maximum gradient dB/dx for very low frequencies, at other than very low frequencies the gain is not linear with frequency due to the finite receptor spacing. With high spatial frequencies there is a progressive loss rather than gain due to the effective integration over more than half a cycle. The overall result of the above is a predicted foveal frequency response for the complete visual system which

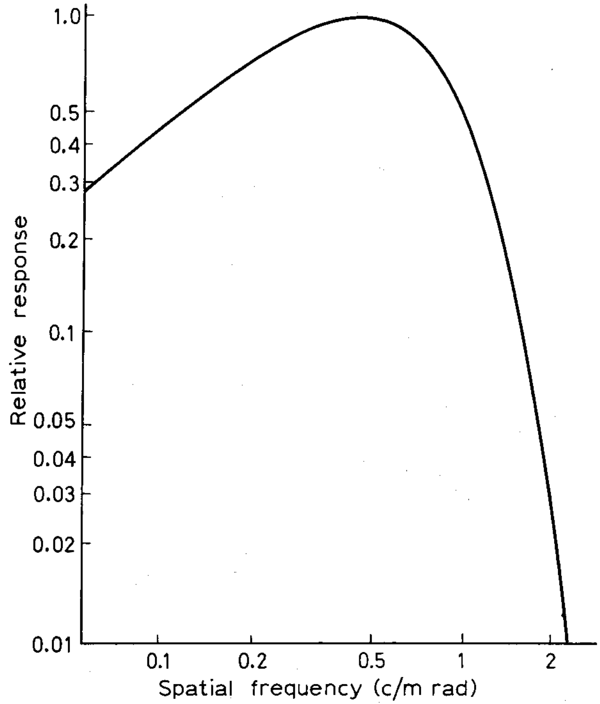


Fig. 12.6. Typical foveal contrast sensitivity curve as predicted from the combined frequency response functions due to optical degradations, eye movements, retinal receptor spacing and finite receptor size.

increases from zero at zero spatial frequency to a maximum around 0.35 to 0.6 c/mrad and then progressively reduces again[7]. A typical predicted response is shown in Fig. 12.6. Reference back to Figs. 4.21 and 4.22 will show a striking similarity except for a slight shift of the position of peak response. It is believed that this difference in frequency for peak response is in keeping with field size effects discussed later in this section, the typical extent of patterns used by Campbell and co-workers being around 2 degrees diameter.

It was found[8,9] that the predicted contrast sensitivity curve was relatively insensitive in its shape to retinal receptor spacing within the range 0.15 to 0.3 mrad and to change of pupil diameter for small pupils. It was, however, found to be considerably sensitive to the amounts of tremor and drift assumed and to the actual shape of the eye's spread function. It was concluded that the insensitivity to receptor spacing was a desirable feature, since retinal receptors could not all be regularly distributed within close tolerances – in fact Østerberg's work[10] suggests they are not. The lack of sensitivity to pupil diameter, on the other hand, is probably a result of the well balanced spread functions of the refraction optics for pupil diameters from 1.5 mm to at least 3 mm[11].

Having shown that the basic contrast sensitivity functions experimentally measured by Campbell and co-workers could be predicted in form by the simple maximum edge gradient concept, it was of interest to consider what the result of carrying out an inverse Fourier transform and integration on such a function would be. It will be remembered from Section 10.2 that the MTF is the Fourier transform of the line spread function. The line spread function is, in turn, the 1st differential of the edge response function of a system. Thus, if we inverse Fourier transform and integrate the contrast sensitivity function (which is essentially a frequency response function similar to the MTF), we should obtain the edge response function of the complete visual system if the system may be considered in any sense linear. Figure 12.7 shows the result of such a computation. This will be seen to bear a strong similarity to the enhancement of borders known as the Mach effect (Section 2.9). It would thus appear that the Mach effect is possibly a necessary side effect of the mechanisms of retinal processing which can be predicted readily for a given viewing situation.

To this point contrast sensitivity has been considered as a general form of frequency response function, without giving any serious consideration to its constancy of form. In fact it is found that the form of the function, whilst always retaining, to some extent, its band-pass properties, does change shape and absolute frequency dependence as a function of size of test field, retinal position of test field and luminance level.

Hoekstra *et al*[12] have studied the variation of contrast sensitivity as a function of test field size for foveally-centred fields and have found that, as the test field is increased, so the low frequency attenuation is reduced, whilst the high frequency attenuation remains largely unaltered (Fig. 12.8). They suggest that this is due to insufficient cycles of the test pattern for small test fields and

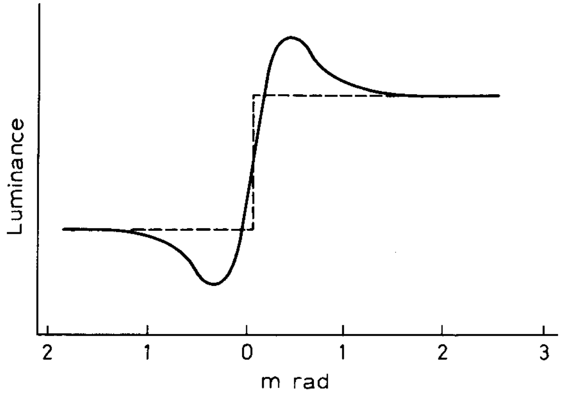


Fig. 12.7. The predicted Mach effect obtained by inverse Fourier transformation of a typical foveal contrast sensitivity function.

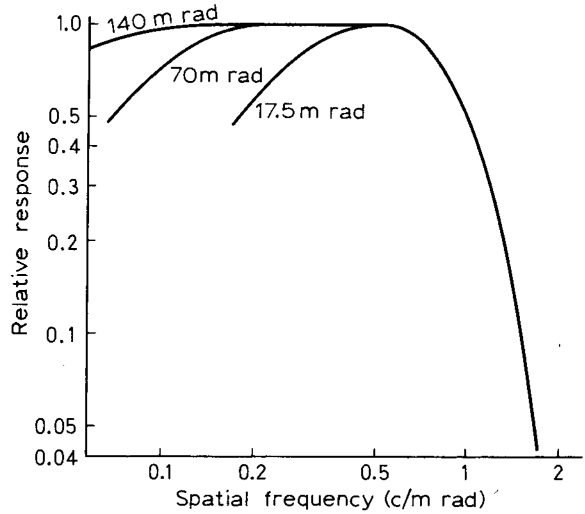


Fig. 12.8. The observed effect on contrast sensitivity of increasing the size of the test field. (Reproduced from Hoekstra et al.[12] *by courtesy of Pergamon Press).*

low frequencies. The author does not like this as a complete explanation, since Hoekstra *et al* find a significant low frequency attenuation even with several cycles of test pattern present. However, it must be true that, in the limit, if frequency is reduced to a *very* low value, such a low frequency attenuation will occur. In fact, according to McCann *et al*[13], at the *lowest* of frequencies detection is controlled by contrast (or modulation depth) and number of cycles present, not being dependent on gradient at all. An alternative explanation, of all but the very lowest frequency region, which is in keeping with observed evidence of 'parallel processing' (see Section 12.4) is that, for each local region of the retina, there is a contrast sensitivity function of the form shown in Fig. 12.6, this comprising the composite MTF of the refraction optics, involuntary eye movements and retinal diffusion, together with the sampling function due to the retinal mosaic. However, due to the varying quality factors and retinal spacing, this function has a frequency scale which is dependent on retinal position. If only a small foveal field is presented, then the central foveal contrast sensitivity is all that applies. If, however, the field is of several degrees diameter, then there are a whole series of annular zones exhibiting different pass-band contrast sensitivities, and the overall response will be governed by the envelope containing all possible contrast sensitivities. The series of such envelopes will obviously have a common high frequency response and a gradually widening low frequency response much as found by Hoekstra *et al.* The foregoing is discussed

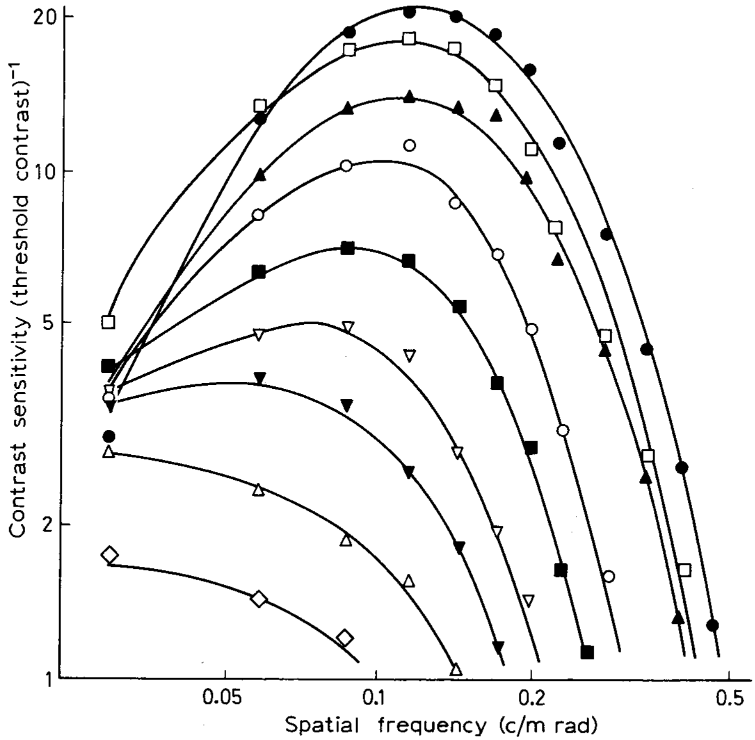


Fig. 12.9. The effect of field luminance on the contrast sensitivity measured at 0.21 rad from the fovea. (Reproduced from Daitch and Green[14] by courtesy of Pergamon Press).

in detail by the author[7], and predictive modelling of Hoekstra's results carried out.

Some indication of the effect of retinal position and luminance on contrast sensitivity is to be found in the work of Daitch and Green[14], who carried out experimentation with a small test field centred 0.21 rad from the fovea at various field luminances. Their collected findings are shown in Fig. 12.9. As can be seen, the contrast sensitivity remains fairly stable at low frequencies for all luminances, whilst falling markedly at high frequencies as the luminance is reduced. Similar trends as a function of luminance for foveal vision were found by Valois *et al.*[15] These results are believed by the present author to be as expected due to the composite effects of quality factors, neural noise and quantum noise. It will also be seen, if the high luminance function in Fig. 12.9 is compared to the foveal contrast sensitivity as shown in Figs. 4.21, 12.6 and 12.8, that at 0.21 rad from the fovea the whole function has shifted to lower frequencies. If the overall quality is assumed to fall off inversely as receptor spacing, as has been found desirable to fit Taylor's peripheral thresholds (Section 7.5), then it is found that a very good prediction of Daitch and Green's high luminance results is obtained[7]. Further support for the foregoing is to be found in recent unpublished work by Williams[16].

12.4 COMPLEX PERIODIC PATTERNS

Over the last few years a miscellany of experiments have been performed using complex periodic patterns. These have variously been claimed to imply that the visual system contains a multitude of band-pass filters which process visual data in parallel and that the visual system contains marked non-linearities.

Some of the first experimenters to propose existence of parallel processing by tuned circuits were Campbell and Robson[17], who found that such an assumption appeared necessary to explain their threshold trends for detection of periodic patterns of square wave, triangular wave and rectangular wave profiles when these were compared with thresholds for simple sinusoidal gratings (see Section 4.14). The finding was greatly strengthened by the work of Graham and Nachmias,[18] who found that, when two incoherently related sinusoidal patterns of frequencies in the ratio of 3:1 were presented together, the threshold for the composite was nearly the same as that of the more prominent of the two, regardless of relative phase. The findings were yet further confirmed, for frequencies of ratio greater than 2:1, by Sachs *et al*[19]. However, it has been shown by the author[7] that all these threshold trends can be predicted by assuming that the visual process is one of detecting 1st differences of retinal illumination in the presence of noise at *each point* on the retina, the 'parallel' processing being a necessary outcome of the graded retinal receptor spacing in regions away from the fovea.

Whilst the foregoing studies have been going on, Burton[20] has been investigating the visual performance when complex periodic patterns are presented which consist of two sinusoidal patterns of nearly the same frequency, or nearly in the ratio of 2:1. He has found that, under certain conditions, it is possible to see the 'beat' frequency when neither of the two presented patterns is above threshold. This, he argues, shows the existence of a non-linearity at an early stage of processing, since only the two frequencies can be present in the analysis networks. The present author has pointed out[7] that in such a situation, as in electronic systems, it is quite possible to redefine the composite waveform in terms of the sum and difference frequencies and that, having done this, there is a range of frequencies (almost exactly that range used by Burton) over which the difference signal will be more detectable than the two component signals due to the band-pass characteristic of the contrast sensitivity function.

12.5 BRIGHTNESS ILLUSIONS

As was intimated in Section 2.9, a range of visual phenomena given the general title of brightness illusions appear to be closely related to the Mach phenomenon. It is found that certain forms of sudden luminance discontinuity in the visual field result in the perceived brightness being grossly distorted. Cornsweet[21] has studied this subject and reported at some length, whilst Mach himself, as reported in Ratliff's recent collected translation[22], experimented with many forms of local field discontinuity. Now brightness illusions are usually assumed to be subjective, but it is the present author's belief that they are largely explained in terms of the combination of optical degradation of the retinal image and the signal/noise situation in which the visual response is obtained.

As an illustration of the mechanisms by which the author believes the general range of brightness illusions are generated, let us consider two of the more striking, yet simple, ones described by Cornsweet – firstly the case of a circular, complex border as shown in Fig 2.12 applied to an otherwise uniform field, and secondly a similar, but stronger, border applied to a field whose centre is lighter than the surrounding annulus, as shown in profile in Fig. 12.10. Both of these patterns are *observed* as having a centre *darker* than the surround. If we now consider one edge of each of these borders, and derive the forms of the retinal images by convolution, we find that the resultant illuminance profiles each exhibit relatively gentle positive gradients and much stronger inverse gradients. Now it was suggested in Chapter 7 that one of the characteristics of the visual system required to explain threshold performance, and one in keeping with the known responses of bipolar and ganglion cells, was that there should be a threshold of response followed by a relatively linear increase in response to subsequent increases in retinal illuminance gradient. With this in mind, and looking again at Fig. 12.11, it can be seen that certain of the bipolar responses on the shallow portions of the illuminance profile will be suppressed due to

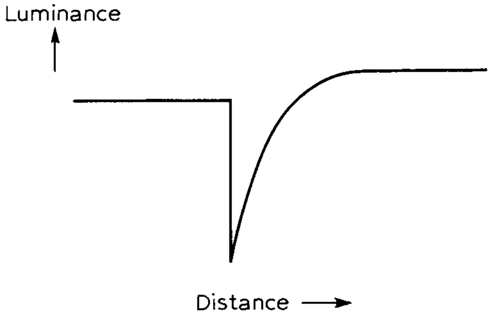


Fig. 12.10. A form of luminance profile used to yield an illusion of a brightness reversal of the centre and surround.

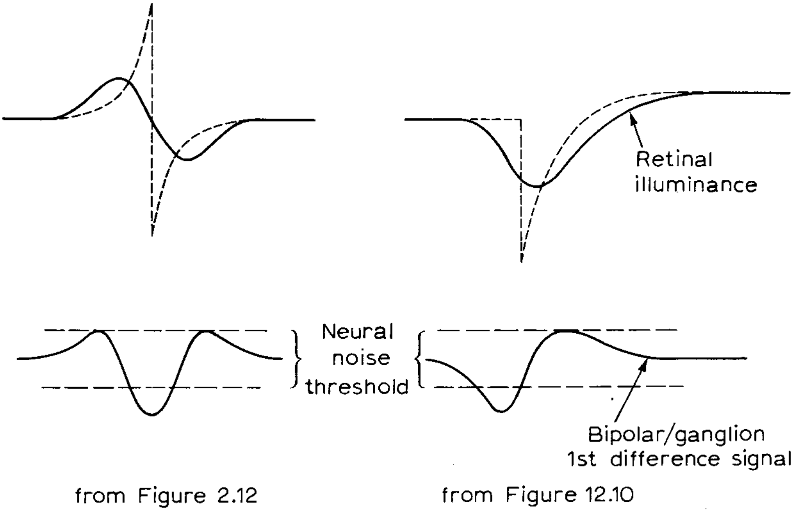


Fig. 12.11. The retinal image illuminance profiles of the two illusionary figures whose profiles are shown in Figures 2.12 and 12.10. The 1st differences are also shown, together with a typical threshold 'clipping' of local response.

insufficient signal. Conversely the inverse gradient region will produce a strong response. In the limit *only* the inverse gradient portion might be expected to yield a response. In such circumstances the brightness illusions observed are a necessary and predictable outcome of the response functions of bipolar and ganglion cells. To the author's knowledge no controlled studies allied to this explanation of brightness illusions have been carried out at this time but it is expected that most, if not all, brightness illusions should be predictable from this approach.

12.6 MODELLING OF SIMPLE RECOGNITION

Thus far all our modelling has been concerned with 50% thresholds for *detection.* In practical visual situations it is much more frequent that we are concerned with recognition rather than detection. As an introduction to the attempted modelling of recognition let us consider what possible contributory factors allow the recognition decision. Firstly we have an object which has certain characteristics which differentiate it from its surroundings. Let us consider this statement for a moment. 'Differentiate' suggests, as with our detection modelling a differencing technique, but this time it is not a simple difference of luminance on adjacent receptors but a difference of local luminance structure from that which would be expected for an alternative, confuseable, object. Again consider the wording 'would be expected'. Expectation implies a required input from the memory – it is only by experience that we can learn what visually discriminates one object from another. Thus immediately, with recognition, we have a problem – how do we define state of learning and ability to recall from memory? These are variables associated with the human observer and have been discussed to some extent in Chapter 3. A deeper study than discussed there is beyond the scope of this book.

Returning to the more straight-forward problem of differentiation, it must again be remembered, possibly more importantly than with detection, that the differential effects for which one is looking must be differences *in the retinal image*, not in the original object. This is an important difference, as can be illustrated by convolution of the profiles of various complex objects with the eye's spread function at 50% recognition size threshold. For instance Fig. 12.5 shows the retinal image isophot for 50% recognition threshold of the presence of the appendage in Lavin's multicontrast experiment[5] for a 0.44 mrad square. It will be seen that very little of the basic structure of the original object remains. Gone are the corners of both squares and gone also is the luminance step between the high and low contrast squares. What remains is an egg-shaped spread function which provides enough data from the right-hand portion to allow the recognition decision to be made. Similarly, reference back to Figs. 5.10 and 5.11 will illustrate the gross degradation of the retinal images of certain complex shapes at recognition threshold.

An attempt has been made to predict the recognition thresholds of certain relatively simple shapes where the recognition task was believed not to be seriously confounded with learning effects – in particular the prediction of the recognition sizes of the four individual high contrast objects used in the experiment on recognition of simple shapes described in Section 5.1[2 3]. In order to do this it was first necessary to attempt to assess what parts of the contour of the object probably constituted a 'recognition' profile. The shapes are shown in Fig. 5.3, together with the names ascribed to them. They were all constructed from six unit blocks and were presented at high contrast. The recognition decision, when they were presented singly, was the choice of one of the four, all

TABLE 12.1. Estimated and Predicted Recognition Threshold Data for 'Castle', 'Church', 'Line' and 'Block' Targets (from Lavin and Overington[23]).

Target	Mean steepest slope over interrogation region (cd/m^2/receptor spacing)	Predicted equivalent circle circumference (mrad)	Estimated contour for interrogation at mean recognition range (mrad)
Line	29.5	1.17	1.17
Church	26.0	1.25	1.15 to 1.3
Castle	39.5	1.02	0.9 to 1.05
Block	62.0	0.82	0.73

of them being familiar to the observers. It was considered that one could fairly confidently define the regions of contour which it would be necessary to 'interrogate' in order to decide which one was being viewed. These were essentially the 're-entrant' portions of the 'castle' and 'church', and the upper edges of the 'block' and 'line'. It was found that the retinal images of the castle and church had significantly attenuated illuminance gradients along a well-defined region associated with the re-entrant portions of the objects. When these gradients were taken, together with the gradients associated with the upper regions of the block and line, the lengths of contour for simple detection in terms of Blackwell's disc stimuli agreed very closely with the predicted portions of contour required for recognition (see Table 12.1). This was considered very significant, and was taken as tentative verification of the concept that recognition is achieved when important portions of differential contour associated with a particular object reach their own simple detection threshold. Much more work remains to be done in this area of modelling in order to determine, if possible, just what parts of a contour are important in a given recognition task, and whether it is the sum of the parts, or each individually, which must reach detection threshold in a complex situation. It is the author's current belief that it is only necessary for the contour represented by the sum of the individual differential parts to rise above simple detection threshold.

12.7 THE EFFECT OF TEXTURE

As mentioned in Section 11.3, the effects of texture in a target are dependent on whether that texture is random noise or 'intelligence' structure. Furthermore, whether random texture is classified as noise or intelligence depends on the characteristics of the background. If an object of interest and its background are both imaged on a grainy film, then the random graininess overlaying both the object and its background serves to break up the outline of the object, and hence degrades its detection threshold. The effects of 'granularity'* have been studied theoretically by Selwyn[24], Fry[25] and Jones[26], amongst others. Equally the practical effects of graininess** have received attention in experimentation by Fry and Enoch[27], Jones and Higgins[28], Selwyn[29], Charman and Olin[30] and Freiser and Biedermann[31]. Unfortunately only limited agreement between models of granularity and observed graininess have been found, which is suspected by the author to be partly due to the effects of the eye's own noise and the effective differentiation believed to take place in the retina.

If, instead of object and background having common imposed texture due to film grain, the object alone has its own discrete texture, there is a chance that the threshold may be enhanced. This chance of enhancement would seem to depend on whether the total 'strength' of stimulus due to the multitude of small local gradients within the object of interest is greater than the total 'strength' of the stimulus due to the outline. To the author's knowledge there is only a small amount of literature on this subject, and from what there is it is difficult to draw common conclusions. However, certain experimental studies recently reported provide at least qualitative information on the effects of texture. For instance Greenwood[32] has studied the contrast sensitivity for grain patterns and compared it to that for sine bars. He finds the same broad form of function, but with the contrast sensitivity for the grain patterns studied being only about 1/25th of that for sine bars. Other studies on the contrast sensitivity of grain patterns are those of Koenderink and Doorn[33,34]. Meanwhile Spillman and Coderre[35] have studied the thresholds for striped and plain flash-presented test fields of 0.5 rad diameter. They have found major interactions between the spatial frequency of the stripes and the retinal illuminance, there being a major decrease in thresholds for striped fields compared with uniform fields at high photopic levels, whilst the reverse is true at scotopic levels. It is believed by the author that this reversal may possibly be explained by considering that the perimeter of the 0.5 rad test field, which is broken up by the striped pattern, occurs at an optimum part of the visual field for scotopic response, whilst the stripes should provide strong foveal stimulation at photopic levels.

A further study worthy of mention concerned with texture is that of Rietveld *et al*[36] who have studied the visual evoked response (EEG) for a variety of checkerboard, striped and blank test fields. In particular they find that there is a stronger response from striped fields than from blank fields and a yet stronger response from checkerboard fields. Also they have studied checkerboard patterns of a fixed size (approximately 0.2 rad square with 6 mrad square pattern elements). For these they have studied the variation of EEG as a central circular portion of the pattern is progressively obscured. They find that the response reduces markedly with the central 35 mrad obscured and that is is almost non-existent with the central 70 mrad obscured.

**Granularity* is the objective microstructure of a grainy or textured image.

***Graininess* is the subjective visual appearance resulting from the microstructure

A possible but largely untried approach to the predictive modelling of the effects of graininess and texture on thresholds has been suggested by the author[37,38]. It is suggested that the vision model developed in Chapter 7 contains, in its constant K_1, a term which is largely dependent on the spatial noise in the input to the eye. However, whilst it is easy to see, in principle, how Gaussian or Poissonian noise functions can be combined in this term K_1, it is by no means so clear how one is to combine other frequency dependent noise functions due to texture with the Poissonian noise due to the quantum nature of light.

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