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NOISE AND THE VISUAL THRESHOLD

THERE have been two interesting recent attempts to treat the visual threshold as a problem of discriminating a signal from a noisy background[1-4]. It is known from neurophysiological studies[5] that there is a variable resting discharge in the completely unstimulated eye. This 'retinal noise', together with any noise that may be added more centrally, forms the 'dark noise' which, on this theory, limits the sensitivity of the eye at absolute threshold. If there were no dark noise, there would be no reason why a single absorbed quantum of light should not be seen ; if, however, the threshold of vision were set as low as this in the presence of dark noise, there would be a 'false-alarm rate', since the threshold criterion would be exceeded by the dark noise in the absence of external stimulation : thus the greater the variability of the resting discharge, the higher must the threshold be set to keep the false-alarm rate low. It is therefore important to know what is the average value and, more especially, the variability of the resting discharge.

The mean and variance of the resting discharge of single fibres can be obtained from direct electrophysiological studies. It would, however, be difficult to relate these figures to psychophysical thresholds and it would be useful to obtain estimates of the properties of the resting discharge from the psychophysical experiments themselves. Barlow[1,2] has tried to estimate simultaneously the variance of the resting discharge and the number of quanta necessary for vision from the shape of the frequency of seeing curve. His method is very ingenious but is also, unfortunately, rather insensitive and he was unable to estimate either of these quantities with any precision.

It is therefore very interesting that Gregory[3,4] has attempted to tackle this problem in another way. He has found that in differential threshold experiments, Weber's law :

$$\Delta I / I = C \qquad (1)$$

where C is a constant, does not hold exactly, but that when I is not too small, a much better fit is obtained by the relationship :

$$\Delta I / (I + k) = C \qquad (2)$$

where k is about 0·03 ft. lambert. In order to explain this, he supposes that r, the mean neural impulse-rate (using this term in a loose sense) corresponding to incident light of intensity I, is proportional to $\log(I+k)$. He also supposes that "the brain demands a constant fixed difference between impulse-rates arising from the comparison fields to make an intensity discrimination to a given fixed criterion". The difference between the mean neural impulse-rates is proportional to $\log(I+\Delta I+k)-\log(I+k)$, which when I is not too small is approximately $\Delta I/(I+k)$ (this can be shown by expansion in a Taylor series). Setting this equal to a constant, the observed relationship (2) is obtained.

This explanation of the empirical relationship (2) is the same as Fechner's explanation of Weber's law (1), except that r is supposed to be proportional to $\log(I+k)$ rather than $\log I$. It seems to us, however, that Gregory attaches a significance to the actual value of the constant k which it does not possess. For he says that "it is tempting to regard k as arising from the internal noise present in the system", and again that "We are tempted to regard this constant as arising from the mean internal noise in the system". The meaning of this statement is not very clear, but he seems to be arguing that, since r is proportional to $\log(I+k)$, then setting $I=0$, k is the equivalent, in light units, of the mean resting discharge. This interpretation of k is, however, incorrect, since equation (2) can be derived from any relationship of the form:

$$r=a+b\log(I+k) \qquad (3)$$

where a and b are any constants; for the constant a drops out when the difference between the two impulse-rates is taken. Gregory's interpretation of k rests on the implicit assumption that $a=0$, which there is no reason to suppose true.

A further criticism of Gregory's model is that he does not consider the variance of r. In any treatment of the threshold as a signal to noise discrimination, the variance of the response is obviously far more important than the mean. It might be possible to interpret the slope of the regression of ΔI on I in connexion with the variance in the same way as the Weber fraction, $\Delta I/I$, can be interpreted when the line passes through the origin.

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