minor fractions common to two or more viruses of the group.

On the morphological basis of 'normal length', estimated by electronmicroscopy, Brandes⁵ has ranged chrysanthemum virus *B* in a group of viruses which among others includes CLV, PVM and PVS.

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PSYCHOLOGY

Theoretical and Empirical Confusion Functions

CROSSMAN¹ produced an empirical 'confusion function' with a value for a pair of stimuli proportional to the time taken to discriminate between them.

Hammerton², from a mathematical model of perception, has derived theoretical confusion values in good agreement with Crossman's for, roughly, $3 > x_2/x_1 > \frac{1}{3}$, where x_1 and x_2 are the two stimulus values. Welford³ has pointed out that $K \frac{(x_2 + x_1)}{x_2 - x_1}$ differs by very little from Crossman's confusion

function $\frac{1}{\log_2 x_2 - \log_2 x_1}$ (K a constant) except when x_1 and x_2 are very different, and then Welford's formula gives good agreement with Hammerton's confusion values. Unfortunately, this agreement is coincidental and results from an unjustified assumption made by Hammerton.

The model assumes "that (a) an act of perception is based on a population of values—perhaps, for example, of neurone firing-rates—normally distributed about the correct magnitude; that (b) the standard deviation of such a population bears a constant ratio (taken as unity for simplicity of computation) to the value of the mean", that is, if we take $\frac{\text{standard deviation}}{\text{mean}} = k$, then it is assumed that $k = 1$. This is the unjustified assumption.

The theoretical confusion function is $C \propto \frac{1}{1-A}$ where A is the area of the overlap of the distributions of x_1 and x_2 , and:

$$A = \frac{1}{\sqrt{2\pi} k} \left\{ \frac{1}{x_1} \int_{-\infty}^p \exp \left[-\frac{(x-x_1)^2}{2k^2 x_1^2} \right] dx + \frac{1}{x_2} \int_p^{\infty} \exp \left[-\frac{(x-x_2)^2}{2k^2 x_2^2} \right] dx + \frac{1}{x_1} \int_q^{\infty} \exp \left[-\frac{(x-x_1)^2}{2k^2 x_1^2} \right] dx \right\} (1)$$

and p and q are the roots of:

$$\frac{(x-x_1)^2}{2k^2 x_1^2} - \frac{(x-x_2)^2}{2k^2 x_2^2} - \ln \frac{x_2}{x_1} = 0 \quad (2)$$

Now it is seen that if the population of values is in fact that of neurone firing-rates, then the substitution $k = 1$ is unrealistic or unjustified, since negative firing-rates are impossible and consequently the distribution of values must be markedly non-normal; so that putting $k = 1$ in equations (1) and (2) would give incorrect values for A .

Further, we should expect that C would bear some relation to errors. In fact, if $p(x_1) = p(x_2) = 0.5$, and if $p(e)$ is the probability of an error, then we must have $p(e) \geq A/2$. In that case, if $k = 1$ and $x_2/x_1 = 2$, $p(e) > 0.3$, which is far too high a value, even for Crossman's experiments, in which errors were appreciably higher than the minimum possible.

Finally, $p(e)$ decreases with increase in observation time (up to about $\frac{1}{2}$ sec⁴) and so, conceivably, k changes during an observation.

Thus it is difficult to justify the assumption that k has any particular value, and especially difficult to justify the assumption that it has a value as large as 1, and yet p , q , A , and consequently C , are all sensitive to changes in k .

Table 1. VALUES OF THEORETICAL AND EMPIRICAL CONFUSION FUNCTIONS

	x_1/x_2							
	0	0.5	0.67	0.75	0.80	0.83	0.86	0.88
Hughes	0.00	1.00	1.71	2.41	3.13	3.82	4.51	5.18
Crossman	0.33	1.00	1.67	2.33	3.00	3.67	4.33	5.00
Welford								
Hammerton								
$k = 1$	0.34	1.00	1.64	2.28	2.92	3.57	4.25	4.86
$k = 1/14$	1.00	1.00	1.00	1.05	1.11	1.25	1.39	1.54

Values of the theoretical C are tabulated for $k = 1$ (from Hammerton), and $k = 1/14$, together with the corresponding values of the expressions put forward by Crossman and Welford. The values for $k = 1$ were all multiplied by Hammerton by a constant factor to give $C = 1$ for $x_1/x_2 = 0.5$. Similarly, a constant factor, $K = \frac{1}{3}$, is required in Welford's formula to give $C = 1$ for $x_1/x_2 = 0.5$, and since in both formulae the uncorrected value of $C \rightarrow 1$ as $x_1/x_2 \rightarrow 0$ or ∞ , the agreement of corrected values of C for extreme values of x_1/x_2 clearly depends on the value of k chosen in Hammerton's model. For $k = 1/14$ $A < 0.000005$ and $C = 1$ very nearly when $x_1/x_2 = 0.5$; so that no correction factor is needed. It is seen that values of C for $k = 1/14$ are markedly different from those of the other formulae apart from the arranged agreement at $x_1/x_2 = 0.5$; and yet this value of k , far from being unrealistically small, may still be over-large, since it corresponds to $p(e) = 0.02$, 0.08 and 0.17 for $x_1/x_2 = 0.75$, 0.8 and 0.875. It would, of course, be possible to arrange agreement among the formulae at some value of x_1/x_2 other than 0.5, but this would produce no general improvement, nor would it remove the apparent paradox, which is in fact the result of adjusting Hammerton's formula, that the smaller the value of k , that is, the greater the separation of x_1 and x_2 in standard deviations, the larger the adjusted value of C for $x_1/x_2 = 0$.

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