

LETTERS TO THE EDITOR

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FAMILIAL CORRELATIONS OR THE MULTIVARIATE GENERALISATIONS OF THE INTRACLASS CORRELATION

THE characters of individuals in a family or a group are influenced by two types of factors (i) the common factors which are characteristic of the group and (ii) the random factors which are independent of the group. The former type causes resemblance among the individuals of a group, while the latter brings about their variation. One of the problems, in the study of heredity, is to measure the strength of group characteristics. If we assume that there are a finite number of group factors effecting the characters of the individuals in a group, then suitable measures may be obtained by studying only a few characters for the individuals in a group. In this note, familial correlations, obtained by the multivariate generalisation of the intraclass correlation, have been introduced as suitable measures of the strength of group characteristics and their sampling distributions have been obtained.

2. Let  $x_{ijm}$  ( $i = 1, 2, \dots, n$ ;  $j = 1, 2, \dots, k$ ;  $m = 1, 2, \dots, p$ ) represent the observation on the  $m$ -th character of the  $j$ -th individual in the  $i$ -th family. Following Fisher's technique, we replace the observations on the  $p$  characters of an individual by their linear combination and choose the compounding coefficients so as to maximise the intraclass correlation coefficient. If we maximise the function  $t^2 = [1 + (k-1)r]/[1-r]$  instead of  $r$ , we get  $t$  as a root of the determinantal equation.

$$|b_{rs} - t^2 w_{rs}| = 0 \tag{2.1}$$

where  $b_{rs} = \sum_j k (\bar{x}_{i,r} - \bar{x}_{i,s}) (\bar{x}_{i,s} - \bar{x}_{i,r})$

$$w_{rs} = \sum_j \sum_j (x_{ijr} - \bar{x}_{i,r}) (x_{ijs} - \bar{x}_{i,s})$$

and  $k \bar{x}_{i,r} = \sum_j x_{ijr}$ , etc.

There are, in general,  $p$  roots  $t_1, t_2, \dots, t_p$  for the determined equation giving rise to  $p$  correlations  $r_1, r_2, \dots, r_p$  which may be called the *familial correlations*. The following results have been obtained.

(a) The familial correlations are invariant under linear transformations of the variates.

(b) There exist familial correlations  $\rho_1, \rho_2, \dots, \rho_p$ , which are constants of the population obtained by employing the above principle to the population at large.

(c) The joint distribution of the familial correlations  $r_1, r_2, \dots, r_p$ , obtained from samples tends to the  $p$  variate independent normal distribution with

$$E(r_i) = \rho_i \text{ and}$$

$$V(r_i) = (1 - \rho_i)(1 + k - 1\rho_i) / \sqrt{2}nk(k-1)$$

when the size of the sample ( $n$ ) is increased.

(d) To carry on suitable large-sample tests the following transformations are suggested. Instead of  $r_i$ , we construct the statistic

$$z_i = \frac{1}{2} \log \frac{1 + k - 1r_i}{1 - r_i}$$

whose variance being  $k/2(k-1)(n-2)$  is independent of  $\rho_i$ .

(e) To test whether the familial correlations are simultaneously zero we use the statistic  $\sum z_i^2 / V(z_i)$  which is distributed as  $\chi^2$  with  $p$  degrees of freedom in large samples.

(f) The exact sampling distribution of  $t_1^2, t_2^2, \dots, t_p^2$  on the non-null hypothesis involves only  $r_1, r_2, \dots, r_p$  defined by

$$r_i = \frac{1 + (k-1)\rho_i}{1 - \rho_i} \tag{2.2}$$

and is given by

$$\text{const. } A \prod_{i,j=1}^p \frac{C_{ij}}{(\tau_i^2 + \tau_j^2)^{\frac{1}{2}}} \prod_{j=1}^p t_j^{n-p-1} \prod_{i=1}^p dt_i \tag{2.3}$$

$$\times \left| \prod_{i < j} (t_i^2 - t_j^2) \right|$$

where  $A = \left[ \sum_{i,j=1}^p \frac{D_{ij}^2}{(\tau_i^2 + t_j^2)} \right]^{\frac{nk-p-2}{2}}$   
and  $D_{ij}$  is the coefficient of  $c_{ij}/(\tau_i^2 + t_j^2)^{\frac{1}{2}}$  in the determinant  $|c_{ij}/(\tau_i^2 + t_j^2)^{\frac{1}{2}}|$  and  $c_{ij}$ 's are defined as

$$c_{ij} = 0, \quad c_{ij}^{2m+1} = 2^{\frac{2m+1}{2}} \Gamma\left(\frac{2m+1}{2}\right)$$

$$c_{ij}^{2m+1} c_{i'j'}^{2n+1} = 2^{\frac{m+n+1}{2}} \Gamma\left(\frac{2m+1}{2}\right) \times \Gamma\left(\frac{2n+1}{2}\right)$$

where  $i \neq i'$  and  $j \neq j'$

These substitutions are to be made only after expanding out A and multiplying it with other factor in (2.3). The distribution of  $r_1, r_2, \dots, r_p$  are obtained from (2.3) by making the transformations

$$t_i^2 = \frac{1 + (k-1)r}{1-r_i} \quad (i = 1, 2, \dots, p) \quad (2.4)$$

(3) It is interesting to observe that the distribution (2.3) is similar to the distribution of the  $p$ -statistics of Roy (1942) on the non-null hypothesis. A fuller discussion of this subject will be attempted in a paper to be published in *Sankhya* shortly.

Statistical Laboratory,  
Presidency College,  
Calcutta,  
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1. Roy, S. N., *Sankhyā*, 1942, 6, 16-34.

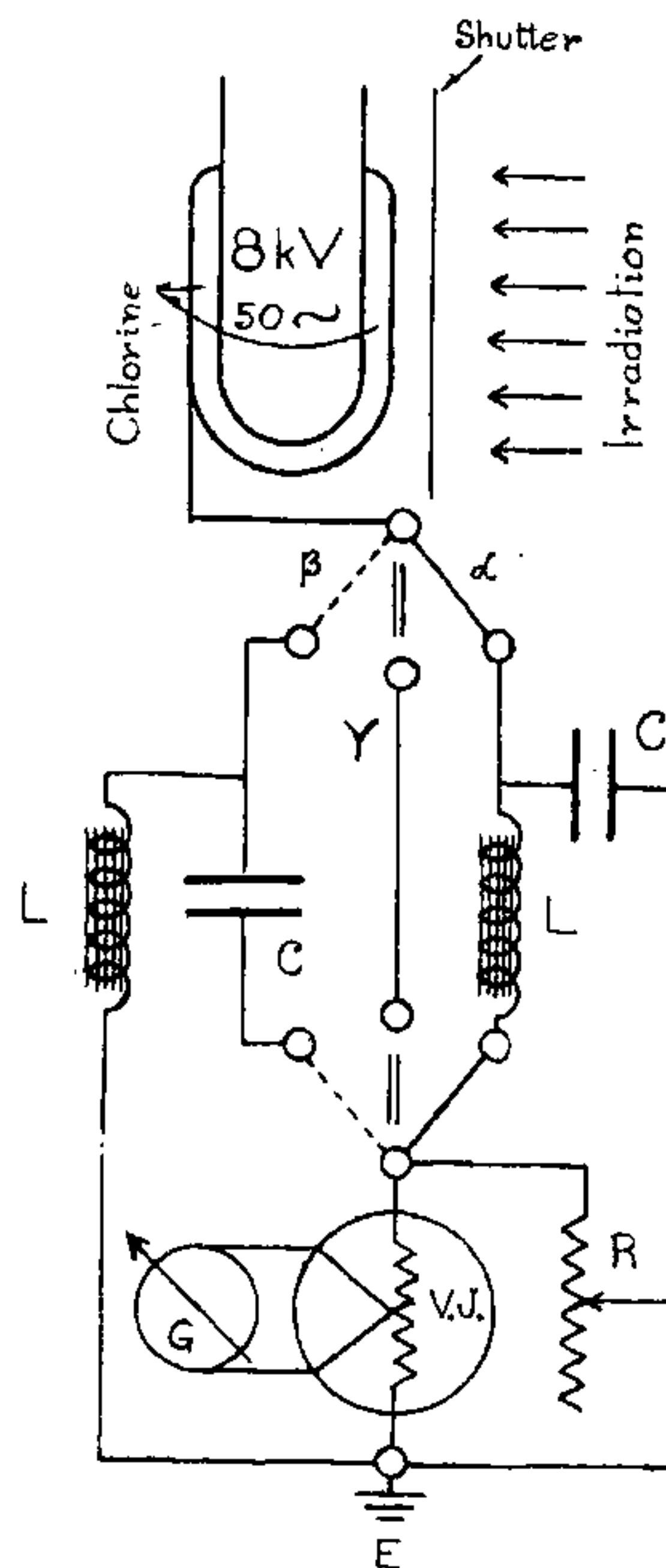
### THE PREFERENTIAL INCIDENCE OF THE LIGHT-EFFECT IN THE HIGH FREQUENCY REGION OF THE DISCHARGE CURRENT

THE apparent variation of the light-effect  $\Delta i$ , with the mode of the measurement of the discharge current  $i$ , was noticed soon after the discovery of this phenomenon.<sup>1</sup> Thus, e.g., when  $i$  was observed with some soft diodes, the light-effect was negligibly small; using triodes, tetrodes, pentodes as also certain metal oxide type rectifiers, the proportionate effect  $\% \Delta i$ , i.e., the current decrease under light expressed as a percentage of  $i$  in the dark, was marked but variable. Usually,  $\% \Delta i$  was greater with a vacuo-junction than an oxide type A.C. indicator.<sup>1</sup> This was traced to limitations in the latter's efficiency of rectification observed *inter alia* under certain conditions of the container surface exposed to the discharge;<sup>1</sup>  $n$ , the frequency of the A.C. supply; and especially the strength and the range of frequencies generated under the discharge; these last are the chief determinant of  $\Delta i$ .<sup>2,3,4</sup>

Fig. 1 shows the main apparatus used for a study of the distribution of light-effect amongst H.F. and L.F., the high and low frequency components of  $i$ . This enters the vacuo-junction (V.J., Fig. 1) via  $\alpha, \beta$  or  $\gamma$ . In  $\alpha$ , the iron core inductance  $L$  admits preferen-

tially L.F. and inhibits H.F.; the latter are bypassed by the capacity  $C$  which comparatively impedes L.F. Similarly,  $\beta$  filters out L.F. and

Fig. 1



admits H.F. In  $\gamma$ ,  $i$  consists of both the L.F. and H.F. characteristic of the discharge.

Table I shows a typical set of results. The ozoniser (Fig. 1) filled with chlorine was excited at  $V = 8$  kilo-volts and 50 cycles frequency. The net effect  $\Delta i$  is largest for  $i$ , the

TABLE I

R (ohms)	Circuit	$i$ in dark	$i$ in light	$\Delta i$	$\% \Delta i$
300	$\alpha$ L.F.	2.0	1.23	0.77	39
	$\beta$ H.F.	5.57	3.16	2.41	43
	$\gamma$ H.F. + L.F.	6.78	3.88	2.90	43
1000	$\alpha$ L.F.	4.58	2.65	1.93	42
	$\beta$ H.F.	12.7	6.9	5.8	46
	$\gamma$ H.F. + L.F.	16.4	8.7	7.7	47

unfiltered, i.e., the total discharge current;  $\Delta i$  is sensibly greater for the high than low frequencies. The presence of these frequencies, in addition to  $n$ , and the instantaneous diminution on irradiation of their amplitudes, was observed in the oscillographic studies of this phenomenon.<sup>2,3,4</sup> From the amplitude-changes in the oscillograms,  $\Delta i$  appeared