polarity of plants changes independently of polarity of growth. A study of processes primary to the above reactions, namely the protoplasmic streaming, leads towards the explanation of these phenomena.

The optical system used for the observation of protoplasmic streaming had a high resolving power, and only the smallest visible moving particles were used as a measure.

The coleoptiles were not cut lengthwise and placed in water but were kept intact in air, with a small piece of tissue on the lower side removed in order to yield a better visibility. The objective of the microscope was immersed directly upon the tissue with a special immersion oil. This immersion medium of the correct refractive index had no effect upon the living cells and increased the visibility of the smaller particles through its capacity to diminish scattering of light due to intercellular airspaces, etc.

No decrease of the protoplasmic streaming due to lack of oxygen was observed with this technique (over a period of 10 to 18 hours). Electric currents of 0.01–500 μ amp. were applied to the coleoptile over a distance of 2 cm by means of Ag AgCl electrodes.

Constant strong currents yield an effect after only a few seconds, and ultimately disintegrate the protoplasm. Currents of about 4 μ amp. cause cessation after 5 to 10 minutes, while recovery takes place after several hours. Currents of about 0.1–0.01 μ amp., however, cause a decrease of rate of streaming after 15 to 30 min. The threshold for the different cells varies, due to differences in conductivity, which can be measured in this way. Short exposures to currents cause comparable changes in streaming.

Under the conditions of our experiments no marked difference in the effect on streaming velocity was detected when the current flow opposed the "inherent" electric polarity of the coleoptile, or when it supplemented the "inherent" polarity.

Growth measurements with a horizontal microscope made simultaneously on different plants after application of the same currents show identical decreases in growth. Measurements of transport by means of curvatures in parallel experiments show the relation between protoplasmic streaming, transport of auxins and growth. Together with the data of Bottelier[4] on the parallelism between phototropic and protoplasmic spectral sensitivity, and the other data reported previously, this third parallelism between protoplasmic streaming, transport and growth supports the viewpoint that changes in bio-electric potentials have an effect similar to that of applied potentials. These changes in bio-electric potentials, due to modifications in external and internal conditions, change the protoplasmic streaming, and hence the transport of auxins, and finally the growth. The differences between electric and growth polarity can thus be understood.

[4] H. P. Bottelier, *Rec. d. Trav. bot. neer.*, 32: 287, 1935.

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THE RELIABILITY OF PRINCIPAL COMPONENTS

THE principal components of a set of intercorrelated statistical observed variables can be obtained by applying the Hotelling technique to the matrix of intercorrelations among the observed variables.[1] The principal components thus obtained are independent variates, which as Girshick[2] has shown, may be as many or fewer than the number of observed variables. Moreover, in the same paper, Girshick demonstrates that the component loadings obtained from the Hotelling technique are maximum likelihood statistics, and further that the principal components are obtained in order of their importance. The first principal component, therefore, is shown, under certain general conditions, to be the independent variate which has the least error variance, and the greatest mean-square correlation with the observed variables. The second principal component is the independent variate which has the next least error variance and the next greatest mean-square correlation with the variables, etc.

If a set of observed variables is resolved into principal components, the observed variables can be expressed in terms of the independent variates. In terms of Hotelling's development

$$\gamma = \frac{a_j z_j}{k}$$

where γ is a person's score in the terms of the independent variate, where $\frac{a_j}{k}$ are the weights to be applied to the z_j which are the observed variables expressed in standard score form.

An estimate of the reliability of the principal component scores may be obtained if it were possible to estimate the correlations of the γ scores from one battery of observed variables with the Γ scores from a comparable battery of observed variables. Such an opportunity was given by the testing of a group of 107 individuals made available to the senior author by the Emergency Relief Bureau of New York City and by a partial grant-in-aid by the Columbia University Council for Research in the Social Sciences. The individuals were given all the Thurstone Scales for the "Measurement of Social Attitudes" in print in July, 1934. The Form A of each scale was given first, then after a lapse of two weeks, the comparable Form B of each of the same scales was given.

[1] Harold Hotelling, *Jour. Educ. Psychol.*, 24: 417–441 and 498–520, 1933.

[2] M. A. Girshick, *Jour. Am. Statist. Asn.*, 31: 519–528, 1936.

For purposes of analysis, five of the scales were selected for resolution into principal components. These scales were:

Attitude toward the Bible	Scale No. 29
Attitude toward God (the reality of God)	Scale No. 21
Attitude toward Sunday observance	Scale No. 26
Attitude toward censorship	Scale No. 28
Attitude toward treatment of criminals	Scale No. 9

The Hotelling principal components for each of the batteries is given in Table 1.

TABLE 1

THE PRINCIPAL COMPONENTS FOR TWO COMPARABLE BATTERIES OF THURSTONE ATTITUDE SCALES

	γ_1	γ_2	γ_3	γ_4	γ_5
Principal Components for Battery A					
Root	2.97	.48	.37	.19	.12
Per cent. of total variance	72	11½	9	4½	3
Correlation of the γ's of Battery A with					
Bible A	.83	−.00	−.27	−.26	.17
God reality A	.87	−.01	−.28	.07	−.25
Sunday observance A	.69	.56	.14	.14	.07
Censorship A	.75	−.14	.45	−.18	−.09
Criminal A	.69	−.39	.04	.27	.14
Principal Components for Battery B	Γ_1	Γ_2	Γ_3	Γ_4	Γ_5
Root	3.03	.49	.30	.26	.06
Per cent. of total variance	73	12	7	6	2
Correlation of the Γ's of Battery B with					
Bible B	.86	−.22	.09	−.21	.17
God reality B	.89	−.25	.04	−.14	−.18
Sunday observance B	.76	.25	.35	.26	.00
Censorship B	.68	.53	−.23	−.16	.00
Criminal B	.69	−.20	−.33	.32	.02

Each individual's score was resolved into γ and Γ scores for each of the two batteries. The correlations between the γ and Γ scores were then computed. These are reported in Table 2.

TABLE 2

THE INTERCORRELATION OF PRINCIPAL COMPONENT SCORES DERIVED FROM TWO COMPARABLE TEST BATTERIES OF THURSTONE ATTITUDE SCALES*

	γ_1	γ_2	γ_3	γ_4	γ_5
Γ_1	.95	.01	−.01	.06	−.03
Γ_2	.01	.20	.65	−.20	.10
Γ_3	.02	.61	−.13	.05	−.02
Γ_4	−.04	.06	.16	.58	.15
Γ_5	.07	.01	−.04	−.22	.32

* Where γ refers to the principal components of Battery A and Γ refers to the principal components of Battery B.

In a sense, the correlations of Table 2 are an estimate of the reliability of the principal components, since they are correlations between a test and, presumably, a comparable form, *i.e.*, considering Γ_1 a comparable form of γ_1; Γ_2, a comparable form of γ_2; etc. The reliabilities thus are .95, .20, −.13, .58 and .32. Obviously all components beyond the first are too unreliable for individual prediction. In other words, information of the five scales might have been obtained best by one good test. Further, it should be noted that $r_{\Gamma_2\gamma_3} = .65$ and $r_{\Gamma_3\gamma_2} = .61$, indicating that an inversion in the order of importance of the principal components occurred in Batteries A and B.

If account is taken of the inversion the reliabilities of principal components are in order .95, .65, .61, .58 and .32 indicative of increasing error variance with decreasing importance of the principal components. This is to be expected, since each successive component contains less of true information and more of error variance. As a matter of fact, the Hotelling method squeezes the error to the last and least important component.

The intercorrelations of the γ's of Battery A are zero, except that $r_{\gamma_1\gamma_1}$, $r_{\gamma_2\gamma_2}$, etc., equal 1. Similarly, the intercorrelations of the Γ's of Battery B are zero, except that $r_{\Gamma_1\Gamma_1}$, $r_{\Gamma_2\Gamma_2}$, etc., equal 1. Yet certain of the intercorrelations between γ and Γ, excepting those between γ_1 and Γ_1, γ_2 and Γ_3, γ_3 and Γ_2, γ_4 and Γ_4 and γ_5 and Γ_5 differ significantly from zero.

The causes of the lack of stability in the results may be due, among others, to the lack of comparability in the scales, the relative unreliability of the scales, the smallness of the sample, the variability in the subjects and the like. Nevertheless, it seems reasonable to require an additional condition of statistical factor methods, *viz.*, reliability of components.

The reliability of principal components beyond the first is such as to lead one to believe that psychological nonsense may be a consequence of a too devoted dependence upon factor methods. Traits beyond the first will be inadequately identified and, hence, frequently misnamed.

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