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MULTIVARIATE ANALYSIS IN GENETIC STUDIES

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SUMMARY

The results are presented of a method of generalized distances calculated by a noncentral χ^2 test and applied to compare 63 twin pairs and 196 sib pairs. The advantage of this method in biometrical analysis lies in the fact that several measurements can be utilised simultaneously. Besides, it takes into account the distance of each relative to the centre of the population and also has the advantage of permitting the comparison of distances between pairs of relatives whatever their age or sex.

Generalized distances were calculated for four measurements of the head, five of the body and eleven of the face. For all three sets of measurements the influence of genetical factors was demonstrated. The body seems less influenced by environmental factors and more conditioned by genetic ones.

Defrise (1967, 1968, 1970) has described a method of generalized distance in pairs of twins, taking into account the distance of each twin to the centre of the population. The advantage of the application of generalized distances to biometrical analysis lies in the fact that several measurements can be utilised simultaneously and also that the comparison of the distances between same-sexed twin pairs is possible, whatever their age or sex. Therefore, each same-sexed twin pair must be considered in its own population of identical sex and age. A probability (P) that the distance between a random subject and twin A is smaller than the distance between twins A and B, can then be calculated by a noncentral χ^2 test, twin B being nearer to the centre of the population than twin A.

This method can also be applied to study the biometrical resemblance between sibs. In the present case, sibs do not belong to the same age and sex population as twins do: the measurements must be standardized, each child being placed in its own age and sex group. Provided that the correlation matrices of these age and sex groups are the same, we can standardize all the measurements and treat all the relatives as belonging to a single population. Therefore, only those measurements must be used whose correlation coefficients are not significantly different in the different groups.

MATERIAL

We present the results of this method for measurements of 50 brother pairs, 46 sister pairs, and 100 brother-sister pairs. Our material has been collected mainly in Brussels and covers 132 sibships with 287 sibs aged 17-40 years. The measurements were standardized

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for age and sex. To determine generalized distances between brother pairs, we used a correlation matrix calculated on standardized measurements of masculine subjects only; for distances between sister pairs, the correlation matrix was calculated in standardized measurements of feminine subjects only, and for distances between brother-sister pairs we used a common matrix calculated on masculine and feminine subjects.

We calculated these generalized distances for four head measurements (head length, breadth, and height, frontal diameter), five measurements of the body (standing and sitting height, arm length, breadth of shoulder and pelvis), and eleven measurements of the face (frontal diameter, bizygomatic and bigonial breadth, face length, upper facial height, nasal height, nasal breadth, interocular breadth, lip height, mouth breadth, nasal depth.)

We compared our results with those of Defrise (1970) concerning 30 serologically identical and 33 serologically nonidentical twin pairs (data of Professor Twiesselmann 1961). The distances were calculated on the same four head measurements, five body measurements, and eleven face measurements.

GENERALIZED DISTANCES BETWEEN RELATIVES

Four Head Measurements

Fig. 1 shows the results for serologically identical and nonidentical twin pairs as well as for sibs (brother pairs, sister pairs, brother-sister pairs.) The abscissa gives the probability (P) that the distance between a random subject and twin A is smaller than the distance between twins A and B. The ordinate gives the proportion of pairs having a given P value. The mean values of P are recorded in Table I, while the results of Student tests between these mean values of P and the results of χ^2 tests comparing the distribution of P values between twin pairs and sib pairs are recorded in Table II. The serologically identical twin pairs shown in Fig. 1 look very similar; their P values are significantly smaller than those of nonidenticals. This contrast proves the importance of hereditary factors in head form. But the serologically nonidenticals have, on the whole, smaller P values than the sib pairs (brothers, sisters, and brother-sister): this demonstrates the existence of environmental factors as well. Indeed, the genetic relationship between DZ twins as well as between sibs is equal to 1/2, but twins frequently live in a more similar prenatal and postnatal environment than sibs do. For the three types of sib pairs, the distribution of P values and mean values of P are not significantly different.

Five Body Measurements

The results shown in Fig. 2 and Tables I and II illustrate the contrast between the distributions of P values of serologically identical and non identical twin pairs: the body is surely genetically conditioned. However, the contrast between DZ twins and sibs is here less marked than for the head: χ^2 tests show that the observed differences between non identicals on the one hand, and brother, sister and brother-sister

Table I
Mean Values of P

	Identical twin pairs (N = 30)	Nonidentical twin pairs (N = 33)	Brother pairs (N = 50)	Sister pairs (N = 46)	Brother-sister pairs (N = 100)
Head measurements (N = 4)	0.034	0.127	0.210	0.198	0.226
Body measurements (N = 5)	0.080	0.164	0.263	0.194	0.207
Face measurements (N = 11)	0.019	0.056	0.191	0.138	0.175

Note: P = probability that the distance between a random subject and twin A is smaller than the distance between twins A and B.

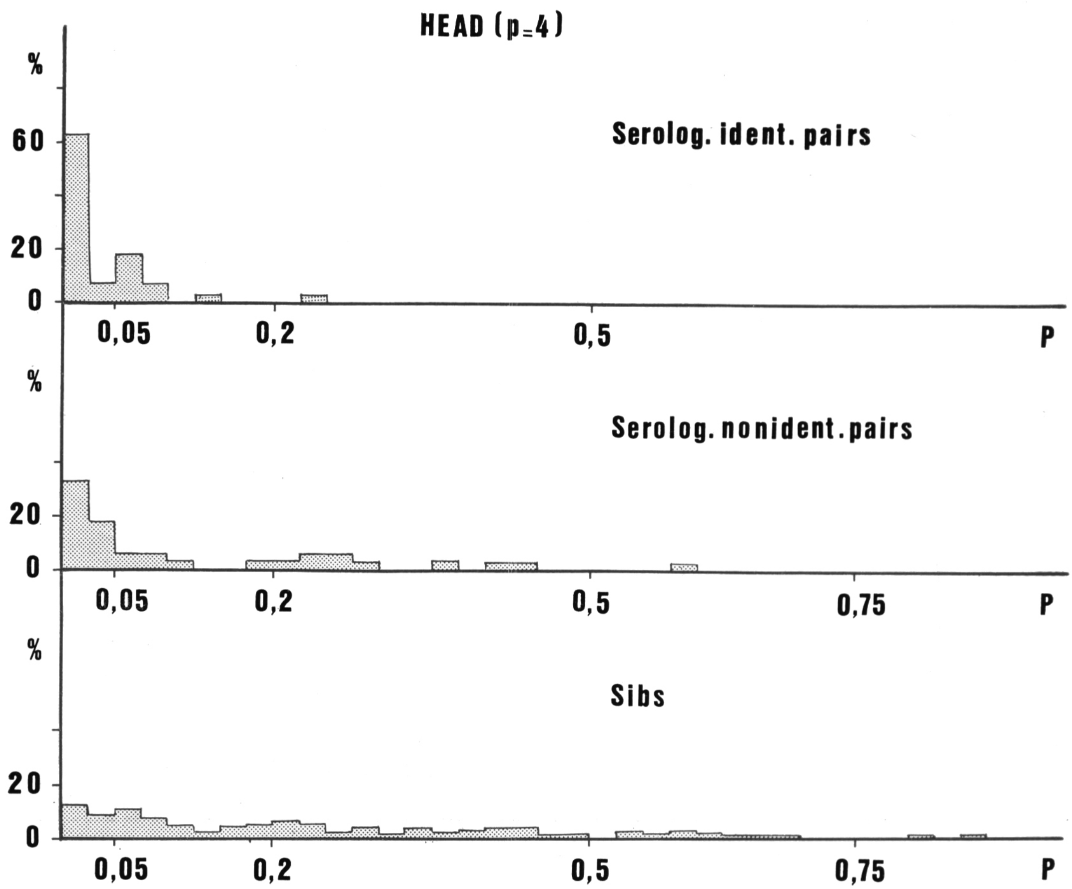

Fig. 1

Table II

Results of the Student Tests and the χ^2 Tests

	Head		Body		Face	
	t	χ^2	t	χ^2	t	χ^2
Identicals vs. nonidenticals	<0.01	<0.02	ns (<0.1)	<0.01	<0.05	<0.01
Nonidenticals vs. brothers	<0.05	<0.01	<0.05	ns	<0.01	<0.001
Nonidenticals vs. sisters	ns (<0.1)	<0.01	ns	ns	<0.02	<0.01
Nonidenticals vs. brother-sister pairs	<0.01	<0.02	ns	ns	<0.001	<0.001
Brothers vs. sisters	ns	ns	ns	ns	ns	ns
Brothers vs. brother-sister pairs	ns	ns	ns	ns	ns	ns
Sisters vs. brother-sister pairs	ns	ns	ns	ns	ns	ns

Note: Student tests are based on the comparison of the mean values of P; χ^2 tests, on the comparison of the distribution of P values between twin pairs and sib pairs.

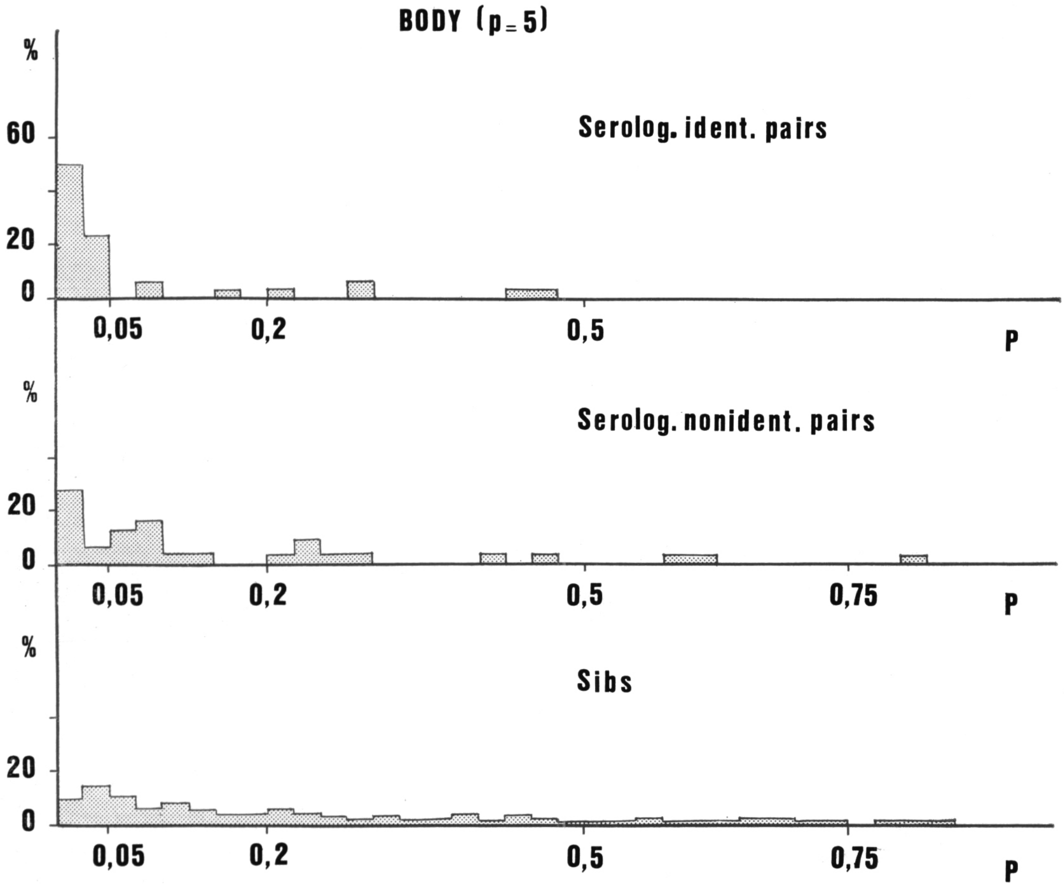

Fig. 2

pairs on the other hand, are not significant. The *P* values of the three types of sib pairs also are not significantly different. So, the five chosen body measurements seem less dependent on environmental factors than those of the head.

Eleven Face Measurements

For the face, Fig. 3 and Tables I and II show that the serologically identical twin pairs are very similar. However, many nonidenticals also have strikingly similar face measurements. So, the contrast between the two types of twins seems smaller for face than for head and body. However, the mean *P* value of DZ twins is three times higher than the mean value of identicals (only twice for the head and the body): this differ-

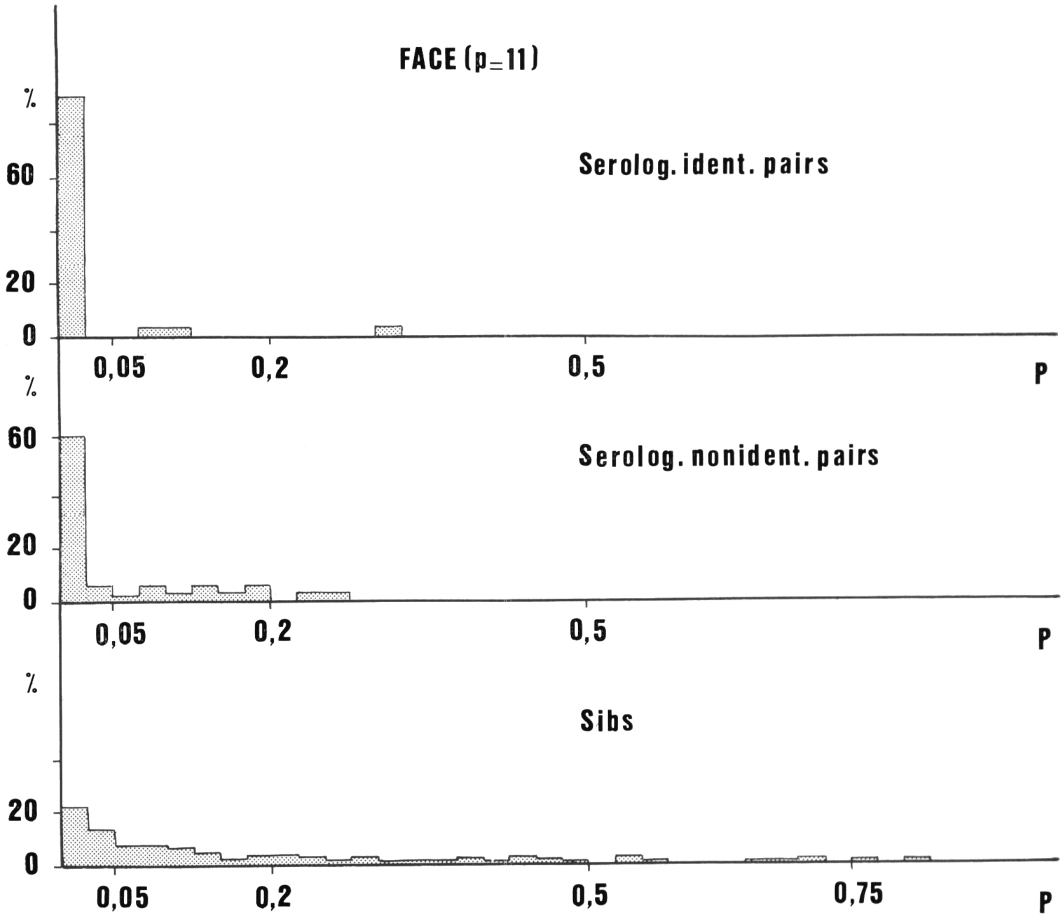

Fig. 3

ence is significant. The mean values of P are here much larger for sib pairs than for DZ twins, the distribution of P values are significantly different (see Table II). The P values of the three types of sib pairs are not significantly different.

Because non identical twin pairs are strikingly similar in facial appearance, the contrast between identical and non identical twin pairs is less marked than for the head and the body. This might lead us to suppose that the face is less dependent on genetic factors and more influenced by environmental factors.

CONCLUSIONS

Generalized distances can be used to compare twin pairs and sib pairs for various measurements. The described method has the advantage of permitting us to compare the absolute measurements, and their correlations and proportions, of the whole body, the head, and the face, within, as well as between, the two groups under consideration.

Our results show, for four head measurements, five body measurements and eleven face measurements, the influence of genetical and environmental factors. For our five measurements, the body seems to be more dependent on genetic factors and less conditioned by environmental factors.

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Riassunto

Vengono presentati i risultati di uno studio di distanze generalizzate basato su χ^2 non centrale e utilizzato per raffrontare 63 coppie di gemelli e 196 coppie di fratelli e sorelle. L'impiego di tale metodo multivariato ha il vantaggio di consentire l'analisi biometrica di più misure contemporaneamente. Inoltre, esso tiene conto della distanza di ciascun parente dal centro della popolazione e consente di raffrontare distanze fra coppie di parenti, quali che ne siano l'età e il sesso.

Tali distanze sono state calcolate per quattro misure della testa, cinque del corpo ed undici della faccia, dimostrando, per queste misure, un sicuro condizionamento genetico. Le cinque misure del corpo risultano comunque molto più dipendenti da fattori genetici, e dunque meno da quelli ambientali, che non quelle della testa e della faccia.

Résumé

Les résultats sont présentés d'une étude de distances généralisées basée sur un χ^2 non-central et utilisée pour comparer 63 paires de jumeaux et 196 paires de germains. L'emploi de cette méthode multivariée a l'avantage de permettre une analyse biométrique de plusieurs mensurations. De plus, elle tient compte de la distance de chaque apparenté au centre de la population et permet de comparer des distances entre paires de sujets apparentés quel que soit leur âge ou leur sexe.

Ces distances ont été calculées pour quatre mesures de la tête, cinq du corps et onze de la face, démontrant que, dans ces trois cas, les mesures utilisées sont certainement génétiquement conditionnées. Il semble cependant que les cinq mesures corporelles utilisées dépendent plus de facteurs génétiques et donc moins de facteurs mésologiques que la tête et la face.

Zusammenfassung

Wir stellen die Resultate einer Arbeit über verallgemeinerte Abstände dar, welche sich auf ein nicht-zentrales χ^2 begründen und gebraucht wurden, um 63 Zwillings- und 196 Geschwisterpaare zu vergleichen. Der Gebrauch dieser multivariierten Methode hat den Vorzug, eine biometrische Analyse mehrerer Messungen zu erlauben. Die Methode beachtet ebenfalls den Abstand jedes Verwandten zum Zentrum der Population, was einen Vergleich der Entfernung zwischen Verwandtenpaaren jedes Alters und Geschlechtes ermöglicht.

Wir haben diese Abstände für 4 Kopf-, 5 Körper- und 11 Gesichtsmessungen berechnet. Diese multivariierte Analyse zeigt, dass in den 3 Fällen die gebrauchten Messungen zweifellos von genetischen Faktoren abhängen. Es scheint trotzdem dass die 5 Körpermessungen mehr von genetischen Faktoren, also weniger von Umweltfaktoren, abhängen als die Kopf- und Gesichtsmessungen.

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