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Relationships between minute characteristics of finger ridges and pattern size and shape

D. Z. LOESCH and N. G. MARTIN

Research School of Biological Sciences, Australian National University, Canberra City

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Summary. We present results of a multivariate analysis of several characteristics of the ridge pattern on the tip of fingers III and IV of the right hand, with special consideration of the minute properties of ridges. The analysis is based on a sample of 38 females and 63 males of European origin.

Results of factor analysis for the male sample reveal that pattern type and size load on one factor. Furthermore, there are separate factors for the two types of minutiae. If characters on both fingers are considered jointly, there are seven factors, identical for both fingers on some variables, but unique for minutiae, especially for junctions, on each finger. These results are consistent with evidence obtained in our previous study that junctions and pattern type are largely independent correlates with tactile sensitivity.

1. Introduction

Although anthropologists and geneticists have traditionally worked on finger ridge counts and pattern intensity, there are other characteristics of single ridges (minutiae) or of the fields of parallel ridges, which develop simultaneously with finger patterns and may thus contribute to a better understanding of their morphogenesis. We included most of these characteristics in a parallel study (Loesch and Martin 1984) which showed that these variables, and also patterns, play a significant role in tactile sensitivity performance.

However, the interpretation of such data requires an understanding of the associations between these various aspects of finger ridges. Therefore, in this study we present the correlations between dermatoglyphic measurements in the samples of 38 Polish females, 34 males of Polish origin and 29 Australian males of European origin, which were included in our tactile sensitivity investigation (Loesch and Martin 1984), and the results of factor analysis, but only for males. Tactile sensitivity was tested on digit IV of the right hand (for the reasons already explained therein), but because small sample sizes can produce misleading factor structures, in the present study we also include similar dermatoglyphic measurements made on digit III to see if the results of factor analysis are consistent on both digits.

2. Description of variables

The following variables have been included in both these studies and all are illustrated in figure 1.

(1) Number of ridges between triradius and centre of a loop pattern. If there is more than one triradius (or loop) on a finger tip, only the greater count is taken for the *ridge count* (RC), but all are summed for the *absolute ridge count* (ARC).

(2) *Ridge breadth* (RB) or the *density of ridges* crossing the two sides of an inverted equilateral triangle, whose apex lies in the centre of the pattern and whose base is the dominant ridge joining the bottom of the two sides. The sides (length 10 mm) are, as far as possible, perpendicular to the stream of parallel ridges (see figure 1(*a*))

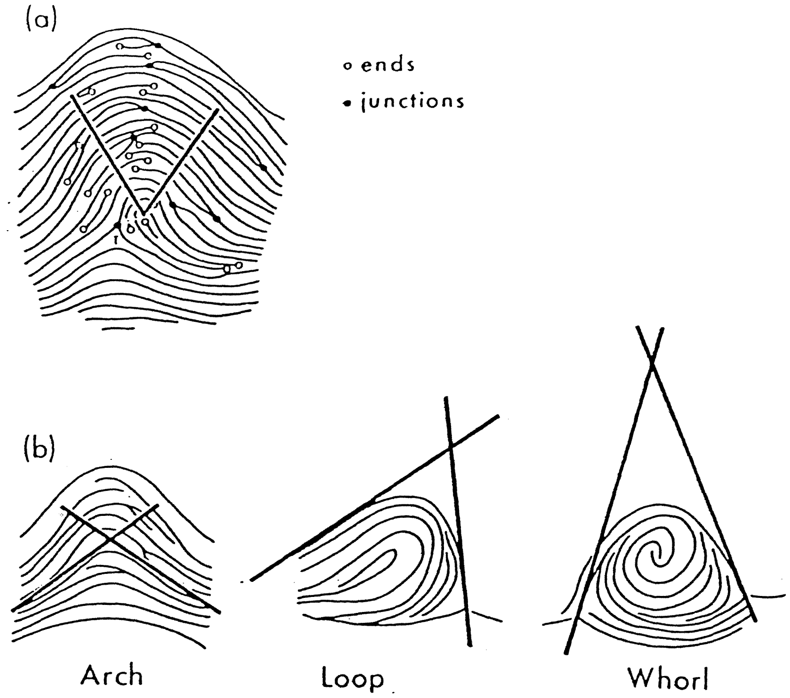

Figure 1.(*a*) Schematic representation of fingertip dermatoglyphic measurements.

Ridges are counted from the triradial point (T) to the centre of the pattern. In the case illustrated where there are two such counts, RC is the greater count and ARC is the sum of the two counts. Ends and junctions are counted within the triangle whose apical angle is 60° and whose sides are each 10mm. Ridge breadth is calculated by counting the number of ridges (n) intersected by the two sides of the triangle and $RB = 20/n$. There are 13 ridges intersecting one side of the triangle and 14 intersecting the other side so that the score for pattern asymmetry (APN) is 1.

(*b*) Method for measuring the angle of convexity of pattern (AP).

to ensure the uniform orientation of the triangle in every individual tested. Similar principles apply to an arch formation, except that an apex of the triangle lies in the centre of a finger tip instead of the centre of a true pattern. The breadth (density) of the ridges is taken to be the ratio of the length of the two sides (20 mm) divided by the total number of intersecting ridges on both sides. Although the density of ridges is a more appropriate term, we shall however, for convenience and consistently with the tactile sensitivity paper, refer to it as the ridge breadth.

(3) Minutiae counts, that is, the total number of *ends* (E) and *junctions* (J) inside the triangle, classified according to Loesch (1973). The sum of ends and junctions (*intensity of minutiae*, I) and the *ratio ends/junctions* (REJ) are also calculated.

(4) *Ridge/groove width ratio* (RG), scored arbitrarily as 1 if grooves are relatively wider than ridges, as 2 if the widths of the ridge and groove are approximately equal, and scored 3 if the width of the ridge appears greater than that of the groove. Although this rating may depend partly on the pressure applied during printing, we tried to minimize this influence.

(5) *Convexity of pattern* (AP), measured by the angle between two tangents to the pattern as shown in figure 1(*b*). Thus, more convex patterns have smaller angles.

(6) *Pattern intensity index* (PI) which is the total number of triradii (or loops) on the finger tip.

Table 1. Comparison between dermatoglyphic variables (means, standard deviations and skewness (g_1) on fingers III and IV, in two male samples and one female sample. Significant differences between fingers III and IV are indicated.

Variable	Males (Australian)				Males (Polish)				Females			
	n	$\bar{x}$	S.D.	g_1	n	$\bar{x}$	S.D.	g_1	n	$\bar{x}$	S.D.	g_1
Finger III												
RB	28	488·75*	46·93	1·41	34	458·94**	42·58	0·33	37	427·14	35·76	−0·04
RC	29	13·31	7·25	−0·34	34	14·50**	6·61	0·50	37	13·35**	5·18	−0·68
ARC	29	16·97	12·91	0·82	34	17·44**	11·86	1·53	36	14·81***	8·09*	1·29
E	26	7·58	4·27	1·36	32	9·38	3·25	0·72	33	8·88	3·58**	0·88
J	26	4·12	2·25	0·32	32	4·84	2·60	0·53	33	6·21	3·44	0·96
I	26	11·58	4·33	0·36	32	14·25	4·24	0·72	33	15·09	5·17*	0·70
REJ	26	3·19	4·10*	3·55	32	2·76	2·13*	1·71	33	2·12	2·30	3·66
RG	29	2·14	0·79	−0·26	34	2·00	0·65	0·00	37	2·54	0·51	−0·17
AP	29	89·07	15·54	−0·13	34	78·15	16·84*	0·39	37	77·00	9·55*	0·29
PI	29	1·17	0·47**	0·63	34	1·21**	0·48	0·60	38	1·11***	0·31**	2·68
APN	28	1·50	1·45*	0·82	34	1·50	1·42	1·45	37	2·16	2·01*	1·38
Finger IV												
RB	29	460·10*	38·22	0·15	34	438·71**	36·81	0·24	38	430·32	37·61	0·43
RC	29	15·79	8·11	−0·93	34	17·76**	5·63	−1·02	38	17·87**	5·89	−0·59
ARC	29	23·72	15·55	−0·11	34	25·62**	13·19	0·24	38	24·42***	12·11*	0·32
E	29	7·21	3·80	0·61	33	9·45	3·39	1·10	35	8·94	3·45**	0·36
J	29	4·38	2·48	0·45	33	5·36	2·36	0·10	35	4·97	3·20	0·49
I	29	12·03	3·91	0·39	33	14·82	3·83	0·21	35	13·91	3·75*	0·57
REJ	29	2·74	2·78*	2·58	33	2·28	1·53*	1·19	32	2·31	2·10	1·95
RG	29	2·28	0·75	−0·51	34	2·06	0·69	−0·08	38	2·58	0·60	−1·12
AP	29	92·59	15·75	0·37	34	81·71	12·02*	0·24	37	76·57	12·82*	1·16
PI	29	1·45	0·69**	−0·87	34	1·47**	0·56	−0·42	38	1·53***	0·51**	−0·11
APN	29	1·59	1·05*	0·94	34	1·97	1·62	0·86	37	1·65	1·40*	0·55

* $0{\cdot}01 < P < 0{\cdot}05$; ** $0{\cdot}001 < P < 0{\cdot}01$; *** $P < 0{\cdot}001$

Table 2. Correlations (× 100) between dermatoglyphic variables on fingers III and IV. Males upper triangle, females lower triangle.

	RB4	RC4	ARC4	E4	J4	I4	REJ4	RG4	APN4	AP4	PI4	RB3	RC3	ARC3	E3	J3	I3	REJ3	RG3	APN3	AP3	PI3
RB4		-27	-16	-45	-04	-47	-09	-07	-12	-00	-21	72	-10	-05	-23	-27	-34	15	-06	-20	02	06
RC4	01		88	14	-20	06	24	19	28	16	78	-23	77	66	19	-14	07	18	-13	16	14	50
ARC4	-13	88		06	-32	-05	29	11	28	19	88	-22	76	75	09	-18	-03	21	-11	11	25	62
E4	-36	23	33		-19	71	54	-03	-05	-23	10	-22	08	-10	55	11	53	20	11	17	-23	-12
J4	-21	-16	-24	-34		43	-68	13	12	-15	-30	-16	-19	-19	-05	36	17	-30	05	-04	-16	-24
I4	-50	10	13	69	45		10	04	-00	-16	-03	-34	01	-11	39	24	47	-01	05	19	-20	-16
REJ4	15	21	30	62	-67	08		-16	-07	10	25	07	18	07	32	-24	14	36	-11	10	04	03
RG4	11	-13	-13	-10	34	17	-04		26	-10	14	-06	02	-02	-17	02	-13	-06	51	-11	05	-05
APN4	-18	-38	-27	07	12	16	00	-06		-18	21	-24	28	25	12	-03	06	04	-04	01	07	25
AP4	03	10	18	00	-18	-14	21	02	-07		17	-06	15	18	-13	-28	-27	23	-32	09	61	16
PI4	-13	63	81	47	-31	21	46	03	-06	25		-15	62	58	09	-12	01	13	-01	25	21	46
RB3	72	15	07	-11	-16	-23	33	33	-11	07	17		-21	-22	-20	-09	-22	00	01	-01	-13	-12
RC3	20	65	64	32	-30	08	32	-11	-54	-06	46	17		89	13	-19	00	23	-15	-01	14	66
ARC3	-01	51	61	20	-26	-01	17	-15	-31	00	38	-06	82		-06	-19	-19	11	-19	-04	15	83
E3	-27	-04	03	41	-23	21	19	08	-02	21	08	-18	-08	05		-08	82	56	-07	25	-04	-06
J3	-31	-22	-03	11	17	24	00	-13	-05	21	07	-33	-12	-16	07		50	-59	06	-06	-20	-22
I3	-39	-17	00	36	-06	30	14	-03	-05	29	10	-34	-14	-06	77	70		13	-02	20	-14	-19
REJ3	-10	09	-07	17	-16	04	-08	19	-09	-15	-14	-08	-02	-01	42	-56	-06		-13	03	25	08
RG3	00	-26	-32	-21	40	10	-32	-04	44	10	-31	-16	-29	-24	-40	08	-24	-24		04	-20	-14
APN3	-01	09	-02	-06	29	16	-08	28	-22	-11	-04	25	13	22	18	-01	12	-07	-16		-09	06
AP3	16	38	41	-06	-10	-14	-06	-29	-33	12	36	14	49	39	-10	02	-06	-04	-25	-18		20
PI3	-13	36	54	-06	-12	-15	-07	-24	07	05	28	-18	39	74	-07	-12	-13	-05	-05	-01	36	

For significance levels (2-tail) less than 0·05, 0·01, 0·001, values of r must be greater than 0·25, 0·33, 0·41 in males and 0·33, 0·42 and 0·52 in females, respectively.

Table 3. Varimax rotated factor matrix for dermatoglyphic variables on Fingers III and IV in the male sample (bold type indicates moderate to high loadings).

	Contribution of factors							
	Finger IV				Finger III			
Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 1	Factor 2	Factor 3	Factor 4
RB	−0·22	**−0·52**	0·01	−0·09	−0·20	−0·24	0·11	0·15
RC	**0·89**	0·15	0·11	0·18	**0·87**	0·14	0·10	−0·15
ARC	**0·94**	0·01	0·19	0·12	**0·96**	−0·06	0·04	−0·17
E	−0·04	**0·90**	**0·43**	0·03	−0·01	**0·94**	0·33	0·09
J	−0·22	0·24	**−0·91**	0·14	−0·14	0·24	**−0·94**	0·02
I	−0·05	**0·93**	−0·23	−0·02	−0·10	**0·95**	−0·25	0·11
REJ	0·19	0·23	**0·74**	−0·15	0·05	**0·35**	**0·71**	−0·27
RG	0·10	−0·01	−0·09	**0·37**	−0·13	−0·07	−0·06	0·28
APN	0·19	0·02	−0·06	**0·64**	0·04	0·20	0·10	0·30
AP	0·28	−0·21	0·01	**−0·35**	0·11	−0·03	0·17	−0·45
PI	**0·87**	0·06	0·17	0·11	**0·82**	−0·09	0·10	−0·06

(7) *Pattern asymmetry* (APN) measured by the difference in the number of ridges intersected by the two sides of the inverted triangle; this may also be defined as the asymmetry of ridge density.

3. Results and comments

Means, standard deviations and skewness of the distributions of all characters are presented in table 1. Significance of differences in means and variances of all characters between fingers III and IV are estimated by two-tailed t and F tests respectively.

Comparisons between the samples included here were presented in the preceding paper (Loesch and Martin 1984). Because the male sample sizes are small and mean differences occur in only a few variables (AP and RB), and because correlations between these particular variables are not significantly different in the Polish and Australian male samples, we have combined them for factor analysis. However there are appreciable sex differences in means for RG and RB (both fingers) and in most variances of the finger III variables.

Correlations between all the variables on each of the two fingers are presented in table 2. Correlations between pattern intensity and both ridge counts are consistent with previous studies (Glanville and Huizinga 1966, Basu and Namboodiri 1971, Loesch 1971, Rigters-Aris 1979, Martin *et al.* 1982), so are the correlations in these variables between the two fingers (e.g. Holt 1951, Knussman 1967, Jantz 1977).

However, relationships with minutiae are worthy of particular note. There is a negative correlation between breadth of ridges (RB) and the number of ends (E) on finger IV and there is a similar tendency on finger III. On the other hand, junctions (J) tend to be negatively correlated with pattern intensity (PI) and, hence with the absolute ridge count (ARC). The general pattern emerging from the results of correlations between the two fingers is that the breadth of ridges and ridge counts are most closely associated, while the number of junctions is the least correlated. Moreover, the variables which are closely correlated within one finger-tip are also correlated between adjacent fingers, but at a lower level.

In order to investigate underlying patterns of relationship between these variables, we have used principal components analysis with interations and Varimax rotation (Nie *et al.* 1979). We present the results of factor analysis only for the male sample because it is larger than that of the females and their minutiae counts are more reliable (table 3). Four initial factors with eigenvalues greater than one were extracted for each finger. After rotation to orthogonal simple structure, it is apparent that there is essentially the same factor pattern on both fingers.

Factor 1 is clearly a *pattern type and size* factor with high loadings on RC, ARC and PI. Factor 2 is an *ends* factor with large loadings on E and I on both fingers. On finger IV there is also a substantial negative loading on ridge breadth (RB) indicating that narrow finger ridges are more likely to be interrupted by ends. Factor 3 is a *junctions* factor loading mainly on J and REJ but also on E and is thus the most general minutiae factor. Factor 4 is more difficult to interpret but appears to be a *shape of pattern* factor (AP, APN), with moderate loadings on the ridge/groove ratio (RG).

To see whether pattern and ridge characteristics are determined by the same factors on both fingers, a further factor analysis of the correlations between all 22 variables (shown in table 2) was performed. Seven initial factors were extracted and the loadings, after rotation to orthogonal simple structure, are shown in table 4.

Factor 1 is, as for each finger separately, a combination of both ridge counts and pattern intensity and it loads equally on both fingers. Factor 2 is a minutiae (Ends)

Table 4. Varimax rotated factor matrix for dermatoglyphic variables on fingers III and IV considered together in the male sample.

Variable	Factors 1	2	3	4	5	6	7
RB4	−0·10	−0·13	−0·81	−0·08	−0·08	0·23	−0·09
RC4	0·82	0·16	0·15	0·16	0·14	0·00	0·14
ARC4	0·90	0·09	0·05	0·24	0·20	−0·02	0·11
E4	−0·04	0·41	0·59	0·47	−0·37	0·11	0·02
J4	−0·19	0·06	0·21	−0·79	−0·12	−0·15	0·05
I4	−0·08	0·32	0·67	−0·07	−0·26	0·00	0·00
REJ4	0·10	0·20	0·09	0·79	−0·01	0·19	−0·11
RG4	0·10	−0·09	0·05	−0·14	0·02	0·01	0·79
APN4	0·35	0·10	0·07	−0·22	−0·02	0·06	0·18
AP4	0·08	−0·15	0·04	0·09	0·74	0·14	−0·21
PI4	0·75	0·12	0·06	0·28	0·20	−0·10	0·19
RB3	−0·21	−0·07	−0·67	0·18	−0·16	0·01	−0·02
RC3	0·88	0·04	0·08	0·03	0·00	0·15	−0·11
ARC3	0·93	−0·18	0·03	−0·05	0·00	0·11	−0·21
E3	0·04	0·88	0·21	0·08	−0·08	0·34	−0·09
J3	−0·14	0·21	0·16	−0·20	−0·17	−0·79	−0·02
I3	−0·06	0·92	0·24	−0·04	−0·16	−0·23	−0·09
REJ3	0·10	0·37	−0·07	0·18	0·21	0·72	−0·04
RG3	−0·12	−0·05	0·03	0·01	−0·25	−0·03	0·59
APN3	0·06	0·19	0·14	0·13	0·02	−0·02	0·00
AP3	0·14	−0·02	−0·02	−0·01	0·70	0·13	−0·03
PI3	0·74	−0·15	−0·07	−0·02	0·03	0·11	−0·17

factor, but it does not exhaust all the variation for these variables on both fingers: ends (E3) and the intensity of minutiae on finger III (I3) load mostly on this factor, while the same characteristics of finger IV load mainly on factor 3. Ridge breadth on both fingers also loads on factor 3. Factor 4 is also a minutiae factor for finger IV, but almost solely for junctions (J4, REJ4) with a smaller contribution of ends (E4); the corresponding variables for finger III load on factor 6. Factor 5 includes mainly the convexity of pattern on both fingers (AP3, AP4), and factor 7 the ridge/groove width ratio, also for both fingers (RG3, RG4).

In conclusion, these results indicate that, firstly, ends and junctions load mainly on separate factors and both load independently of pattern intensity or ridge count; the factors underlying minutiae counts, especially junctions, are also largely independent for each of the two fingers analysed here. Secondly, ridge breadth (or density) loads on the same factor as ends; this might explain the finger-dependent variation in minutiae count, as reported by Dankmeijer *et al.* (1980).

We must emphasize, however, that the present results should be confirmed on larger samples, as considerable errors in factor analysis may result from small sample size and from the differences between Polish and Australian males in means of two of the variables, and of the size of correlations observed between several others. However, the similarity of the factor structures on fingers III and IV suggests that any such errors do not obscure the underlying biological consistency. These data comply with evidence we have obtained in another study (Loesch and Martin 1984) that junctions and pattern type are largely independent correlates with tactile sensitivity. The independent nature of these two categories of dermatoglyphic variables is supported by results of genetic analysis (Loesch 1979) indicating considerable differences in the amount of genetic variance between patterns and minute ridge characteristics.

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Address correspondence to: Dr D. Z. Loesch, Department of Population Biology, Research School of Biological Sciences, Australian National University, P.O. Box 475, Canberra City, ACT 2601, Australia.

Zusammenfassung. Wir stellen die Ergebnisse einer multivariaten Analyse mehrerer Merkmale des Hautleistenmusters der Fingerbeeren III und IV der rechten Hand vor, mit besonderer Berücksichtigung kleiner Eigenschaften der Leisten. Die Analyse basiert auf einer Stichprobe von 38 Frauen und 63 Männern von europäischem Ursprung.

Die Ergebnisse der Faktorenanalyse der männlichen Stichprobe zeigen, daß Mustertyp und Größe einen Faktor laden. Weiterhin gibt es getrennte Faktoren für die beiden Typen von Minutien. Wenn die Merkmale beider Finger zusammen betrachtet werden, gibt es sieben Faktoren, die für einige Variablen für beide Finger gleich sind, aber getrennt für Minutien jedes Fingers, besonders für Verzweigungen. Diese Ergebnisse stimmen mit Befunden unserer früheren Untersuchung überein, daß Verzweigungen und Mustertyp im wesentlichen unabhängige Korrelate der taktilen Sensibilität sind.

Résumé. Nous présentons les résultats d'une analyse multivariée de plusieurs caractéristiques de la configuration des crêtes sur le bout des doigts III et IV de la main droite, avec une considération spéciale des caractères de détail des crêtes. L'analyse est basée sur un échantillon de 38 femmes d'origine européenne.

Les résultats de l'analyse factorielle pour l'échantillon masculin révèlent que le type de dessin et le format chargent un seul facteur. De plus, il y a des facteurs séparés pour les deux types de détails. Si les caractèrs des deux doigts sont considérés conjointement, il y a sept facteurs, identiques pour les deux doigts pour certaines variables, mais uniques pour les détails, particulièrement les jonctions, sur chaque doigt. Ces résultats sont cohérents avec l'information tirée de notre étude antérieure que les jonctions et le type de dessin sont des corrélats, largement indépendants, de la sensibilité tactile.