An Information and Discriminant Analysis of Fingerprint Patterns Pertaining to Identification of Mongolism and Mental Retardation

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The ways to identify mongolism range from clinical observation of specific somatic features to cytological examination of chromosomal anomalies. Certain dermatoglyphic characteristics of the palm, such as the simian crease and position and angles of the triradii, have been known to be associated with mongolism (Penrose, 1953, 1954; Penrose and Delhanty, 1954; Reed, 1955; Ledley and Ruddle, 1960; Patau, 1960; Penrose, 1961; Uchida *et al.*, 1962; Pons, 1964; Uchida *et al.*, 1964; Ledley, 1965; Achs and Harper, 1966).

Although there are numerous investigations concerning the association of mongolism and fingerprint patterns, nonmongol mental retardation has not been so extensively studied in this manner. The results of most of the studies using mongols can only be presented in descriptive and qualitative terms, for the analytical techniques used were in terms of averages and percentages, indicating at most only the absence or presence of an association. While knowledge that an association exists is useful, it cannot afford a quantitative measure of the amount of information pertaining to the identification of mongolism contained in the fingerprint patterns. The information inquiry is important, because if the amount of information is large, then ways and means of utilizing this information should be found to serve as diagnostic tools; if the amount of information is nil, then we should dismiss such endeavors as idle sport.

The amount of information of mental-status identification contained in the fingerprint patterns may be measured by the very powerful tool, entropy, developed in recent years in the repertoire of information theory (Quastler, 1953; Goldstein, 1961). Although the employment of information analysis does not tell one how to identify a mongol, it does show the amount of information available which may be used for identification. For instance, information analysis shows that, by three successive weighings with a balance, it is possible to identify a counterfeit coin, which may be either lighter or heavier, mixed with eleven genuine coins. It does not tell us, however, how the three weighings should be made; the exact weighing procedure constitutes the construction of a discriminant function.

The purposes of this paper are twofold: (1) to determine how much information

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pertaining to identification of mongolism and mental retardation is contained in fingerprint patterns and (2) to utilize the information available to construct discriminant functions for identification purposes.

SUBJECTS AND DATA

A sample of 943 individuals in Oregon state institutions was used for this study. The sample consisted of 363 mongols (203 males and 160 females) and 281 mental retardates (170 males and 111 females) from the same institutions and 299 normals (143 males and 156 females) from state orphanages.

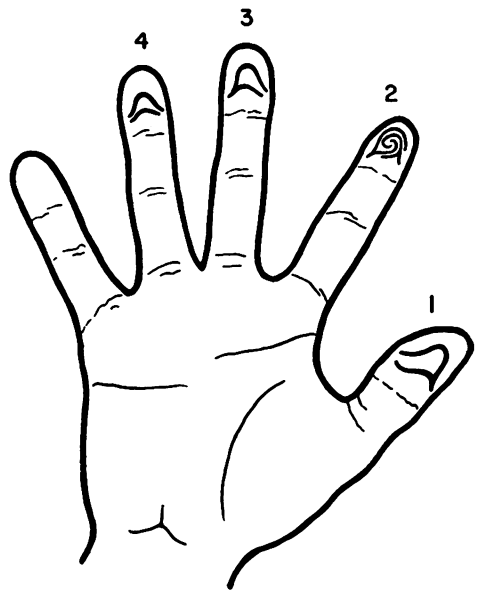

FIG. 1.—Diagrammatic sketch of fingerprint configurations

The fingerprint patterns of each finger of each individual were classified and coded by the professional personnel of the state institution into five categories, namely, (1) ulnar loop, (2) whorl, (3) radial loop, (4) arch, and (5) unidentifiable. A sketch of the four identifiable configurations is shown in Figure 1.

A ten-digit number where each digit may assume values of 1, 2, 3, 4, 5 (the fingerprint configuration) is used to identify uniquely specific patterns by the following scheme: the first, second, third, fourth, and fifth digits denote the right-hand fingers from the thumb to the little finger, respectively, and the sixth, seventh, eighth, ninth, and tenth digits denote the left-hand fingers from the thumb to the little finger, respectively.

Thus a number 11111 11111 indicates that all fingers are ulnar loops, and 11121 11223 indicates the right ring finger has a whorl; the left middle, ring, and little fingers have whorl, whorl, and radial loops, respectively; and all remaining fingers have ulnar loops.

Preliminary χ^2 tests on the relative frequencies of fingerprint configurations showed

no significant difference between sexes; hence, sex was not considered a factor, and the data were pooled for the present study.

PRELIMINARY ANALYSIS

The relative proportions of each configuration type of each finger for each of the three groups are given in Table 1. The findings in Table 1 agree fairly well with earlier investigations (Holt, 1953, 1961, 1964).

A point which deserves some comment is that the occurrence of a radial loop on the

TABLE 1

RELATIVE PROPORTIONS OF FINGERPRINT CONFIGURATION ACCORDING TO MENTAL-STATUS GROUP

	Ulnar Loop 1	Whorl 2	Radial Loop 3	Arch 4	Unidentifiable 5
	Mongols				
R 1	0.7521	0.2231	0.0000	0.0220	0.0028
R 2	.9036	.0606	.0083	.0275	.0000
R 3	.9146	.0689	.0055	.0110	.0000
R 4	.7218	.1983	.0496	.0303	.0000
R 5	.7989	.1433	.0413	.0138	.0028
L 1	.6860	.2479	.0000	.0579	.0083
L 2	.8650	.0606	.0138	.0606	.0000
L 3	.8760	.0826	.0083	.0330	.0000
L 4	.6722	.2287	.0496	.0441	.0055
L 5	0.8402	0.1129	0.0220	0.0220	0.0028
	Retardates				
R 1	0.5338	0.4413	0.0000	0.0249	0.0000
R 2	.3310	.3701	.1673	.1246	.0071
R 3	.7082	.1779	.0320	.0819	.0000
R 4	.5160	.4626	.0071	.0142	.0000
R 5	.8256	.1601	.1036	.0107	.0000
L 1	.5801	.3737	.0000	.0427	.0036
L 2	.3452	.3238	.2100	.1068	.0142
L 3	.7153	.2028	.0107	.0641	.0071
L 4	.6121	.3594	.0036	.0249	.0000
L 5	0.8434	0.1352	0.0036	0.0178	0.0000
	Normals				
R 1	0.5886	0.3980	0.0000	0.0134	0.0000
R 2	.3244	.2809	.1806	.1839	.0301
R 3	.7726	.1237	.0167	.0803	.0068
R 4	.5719	.3846	.0134	.0301	.0000
R 5	.8562	.1137	.0000	.0301	.0000
L 1	.6388	.3043	.0033	.0401	.0134
L 2	.3645	.2341	.2374	.1572	.0067
L 3	.7726	.0936	.0201	.1137	.0000
L 4	.6555	.3010	.0033	.0401	.0000
L 5	0.8562	0.1037	0.0000	0.0401	0.0000

ring and small fingers has been cited as having particular significance as an indicator of mongolism. The present data do show that among the mongols the specific respective proportions are considerably higher than among the retardates and the normals. A "standard" mongol hand has been depicted as having all ulnar loops except for the ring finger, which has a radial loop (Penrose, 1953, 1961). According to present data, the so-called standard mongol fingerprint pattern is not the most frequent one. Indeed, the modal ten-finger pattern is all ulnar loops (11111 11111); for example, of 363 mongols examined, 116 of them have all ulnar loops.

The distribution of individuals according to fingerprint patterns and types of mental status is given in Table 2. It is of interest that of 459 different patterns observed, 110, 131, and 139 patterns appeared exclusively in the mongol, the retardate, and the normal groups, respectively; a total of 60 patterns appeared in only two of the three groups. Only 19 patterns were shared by 320 individuals of the three groups. It

TABLE 2

FREQUENCIES OF FINGERPRINT PATTERNS ACCORDING TO MENTAL-STATUS GROUPS

FOUND IN	NO. OF PATTERNS	FREQUENCIES			
		Mongols	Retardates	Normals	Total
M only	110	130	0	0	130
R only	131	0	140	0	140
N only	139	0	0	158	158
M and R	11	34	11	0	45
R and N	36	0	52	53	105
M and N	13	27	0	18	45
M, R, and N	19	172	78	70	320
Total	459	363	281	299	943

is of special interest that one pattern among the 19 patterns, in which all fingers are of ulnar loops (11111 11111), was found in 153 individuals. These 153 individuals consisted of 116 mongols, 25 retardates, and 12 normals. Table 2 indicates that fingerprint pattern is associated with the type of mental status of the individual.

INFORMATION ANALYSIS

A Brief Sketch of Information Analysis

Let there be k equally likely outcomes of trial α and m equally likely outcomes of trial β. If $m > k$, one would expect more uncertainty in trial β than in trial α. Thus the number of outcomes is a measure of uncertainty. For convenient reasons, Shannon (1948) suggested that the amount of uncertainty associated with trial α is defined as $\log k$. Since the k outcomes are equally likely, we see that $(1/k) \log k$ is the amount of uncertainty associated with a single outcome. We observe that

$$P_i = Pr\{\text{trial } \alpha \text{ ends in a particular outcome } i,\ i \in k\}$$

$$= \frac{1}{k}.$$

Consequently,

$$\frac{1}{k}\log k = -\frac{1}{k}\log\frac{1}{k} = -p\log P,$$

and

$$k\left[\frac{1}{k}\log k\right] = \log k\,.$$

We define the amount of uncertainty, called entropy of trial (α), whose outcomes may not be equally likely, as

$$H(\alpha) = -\sum_{i=1}^{k} P_i \log P_i\,. \tag{1}$$

Suppose trials α and β were performed in succession; it can be shown that the entropy of the compound trial ($\alpha\beta$) has entropy $H(\alpha\beta)$ such that

$$H(\alpha\beta) = H(\beta\alpha)\,. \tag{2}$$

If trials α and β are independent, then

$$H(\alpha\beta) = H(\alpha) + H(\beta)\,. \tag{3}$$

If they are not independent,

$$H(\alpha\beta) = H(\alpha) + H_\alpha(\beta) \tag{4a}$$

$$= H(\beta) + H_\beta(\alpha) \tag{4b}$$

$$= -\Sigma P_{ij}\log P_{ij}\,, \tag{4c}$$

where $H_\alpha(\beta)$ is the conditional entropy of trial (β) given the knowledge of trial α.

In more colloquial language, it denotes the amount of uncertainty remaining after we have knowledge of the outcome of trial α. Similarly, $H_\beta(\alpha)$ is the conditional entropy of trial α given the knowledge of trial β.

We shall now introduce the concept of information. Let $I(\alpha\,|\,\beta)$ be the amount of information pertaining to trial α contained in trial β, and

$$I(\alpha\,|\,\beta) = H(\alpha) - H_\beta(\alpha)\,. \tag{5}$$

Note that the amount of information of trial α contained in trial β is the difference between the entropy $H(\alpha)$ and the conditional entropy $H_\beta(\alpha)$. Analytically, it is the amount of uncertainty in trial α removed by having knowledge of trial β. Thus, the amount of uncertainty removed must be the information of α contained in β.

For the present study, we shall use the logarithm of base 10, whereas in communication inquiries the entropy has been expressed with the logarithm of base 2. Obviously there is an advantage in using the logarithm of base 2 in communication systems, because a signal could be either on or off. For our present purpose, we adopt the logarithm of base 10 because of the ready availability of common log tables. Had we used the logarithm of base 2, our unit of entropy would have been measured in terms of the uncertainty of a trial of two equally likely outcomes. In the present case, the unit of uncertainty is that of a trial of ten equally likely outcomes. Regardless of which logarithm is used, the relative amount of information is the same.

Now suppose the population consists of mongols and nonmongols; we thus have a

trial with two possible outcomes, with unequal probabilities. Let us call the identification of mongols and nonmongols trial α. Let some m convenient classifications of fingerprints be called trial β; then by equation (5) we can compute $I(\alpha|\beta)$ (Khinchin, 1957; Yaglom and Yaglom, 1960).

Results of Information Analysis

Prior to information analysis, the seven broad categories of fingerprint patterns in Table 2 are reclassified into fourteen pattern groups (see Appendix) and are shown in Table 3. In all subsequent analyses, the types of mental status (mongol, retardate, and normal) are defined as trial α and the fingerprint-pattern groups as trial β.

TABLE 3

FREQUENCIES OF FINGERPRINT PATTERNS CLASSIFIED INTO FOURTEEN GROUPS ACCORDING TO OCCURRENCE IN THREE MENTAL-STATUS GROUPS

FOUND IN	FINGERPRINT-PATTERN GROUP NO.	FREQUENCIES			
		Mongols	Retardates	Normals	Total
M only	1	130	0	0	130
R only	2	0	140	0	140
N only	3	0	0	158	158
M and R	4	27	4	0	31
	5	7	7	0	14
R and N	6	0	52	53	105
M and N	7	21	0	7	28
	8	2	0	7	9
	9	4	0	4	8
All (M, R, N)	10	116	25	12	153
	11	24	7	6	37
	12	2	6	21	29
	13	3	15	6	24
	14	27	25	25	77

The information analysis consisted of four parts: (1) all three mental-status groups, (2) mongols versus retardates, (3) mongols versus normals, and (4) retardates versus normals. The frequency tables from which the entropy and information were computed are given in Tables 4, 5, and 6, respectively. The pertinent findings of the four analyses are given in Table 7.

From Table 7, we observe that, although the information is incomplete, surprisingly large amounts of information pertaining to identification of types of mental status are contained in the fingerprint-pattern groups: 72% for the mongol-versus-normal analysis, 65% for the mongol-versus-retardate analysis, 63% for the mongol-versus-retardate-versus-normal analysis, and 59% for the retardate-versus-normal analysis.

As mentioned earlier, information analysis tells us how much information of trial α is contained in trial β, but it does not tell us how to utilize this information for discrimination purposes. A discriminant function will be constructed for identification purposes.

TABLE 4

FREQUENCIES OF FINGERPRINT PATTERNS CLASSIFIED INTO NINE GROUPS ACCORDING TO OCCURRENCE IN MONGOLS AND RETARDATES

FINGERPRINT-PATTERN GROUP NO.	FREQUENCIES		TOTAL
	Mongols	Retardates	
1+7+8	157	0	157
2+6	0	192	192
4	27	4	31
5	7	7	14
10	116	25	141
11	24	7	31
12	2	6	8
13	3	15	18
14	27	25	52
Total	363	281	644

TABLE 5

FREQUENCIES OF FINGERPRINT PATTERNS CLASSIFIED INTO TEN GROUPS ACCORDING TO OCCURRENCE IN MONGOLS AND NORMALS

FINGERPRINT-PATTERN GROUP NO.	FREQUENCIES		TOTAL
	Mongols	Normals	
1+4+5	164	0	164
3+6	0	211	211
7	21	7	28
8	2	7	9
9	4	4	8
10	116	12	128
11	24	6	30
12	2	21	23
13	3	6	9
14	27	25	52
Total	363	299	662

TABLE 6

FREQUENCIES OF FINGERPRINT PATTERNS CLASSIFIED INTO EIGHT GROUPS ACCORDING TO OCCURRENCE IN RETARDATES AND NORMALS

FINGERPRINT-PATTERN GROUP NO.	FREQUENCIES		TOTAL
	Retardates	Normals	
2+4+5	151	0	151
3+7+8+9	0	176	176
6	52	53	105
10	25	12	37
11	7	6	13
12	6	21	27
13	15	6	21
14	25	25	50
Total	281	299	580

DISCRIMINANT ANALYSIS

A Sketch of the Discriminant Analysis

Let $P(t) = Pr\{$an individual chosen at random from a given population to be of mental status t, $t = m, r, n\}$, m = mongols, r = retardates, and n = normals such that $P(m) + P(r) + P(n) = 1$. Let B_i = the ith group of fingerprint patterns and $i = 1, 2, \ldots, 14$. Let us define the following conditional probabilities:

$$P(m, B_i) = Pr\{\text{individual } X \text{ has } B_i | X \text{ is mongoloid}\},$$

$$P(r, B_i) = Pr\{\text{individual } X \text{ has } B_i | X \text{ is retarded}\},$$

and

$$P(n, B_i) = Pr\{\text{individual } X \text{ has } B_i | X \text{ is normal}\}.$$

TABLE 7

ENTROPY, CONDITIONAL ENTROPY, AND INFORMATION OF MENTAL STATUS CONTAINED IN FINGERPRINT PATTERNS ACCORDING TO FOUR DIFFERENT INFORMATION ANALYSES

	All Three Groups	Mongols vs. Retardates	Mongols vs. Normals	Retardates vs. Normals
$H(\alpha)$	0.47445	0.29750	0.29900	0.30082
$H(\beta)$	0.99512	.76890	.77680	.76286
$H(\alpha\beta)$	1.17431	.87186	.86170	.88760
$H_\beta(\alpha)$	0.17920	.10297	.08491	.12474
$H_\alpha(\beta)$	0.69986	.57436	.56271	.58678
$I(\alpha \mid \beta)$	0.29525	.19453	.21409	.17609
$I(\alpha \mid \beta)/H(\alpha)$	0.63231	0.65390	0.71603	0.58535

Then $P(m)P(m, B_i) + P(r)P(r, B_i) + P(n)P(n, B_i)$ is the total proportion of the population that has fingerprint pattern B_i. Now suppose we choose an individual at random from the population and find that he has B_i; then we define:

$$\pi(m, B_i) = Pr\{\text{the individual } X \text{ is mongoloid} | X \text{ has } B_i\}.$$

From the Bayesian point of view, we deduce that

$$\pi(m, B_i) = \frac{P(m)P(m, B_i)}{P(m)P(m, B_i) + P(r)P(r, B_i) + P(n)P(n, B_i)}.$$

Similar equations can be developed for $\pi(r, B_i)$ and $\pi(n, B_i)$. Clearly,

$$\pi(m, B_i) + \pi(r, B_i) + \pi(n, B_i) = 1.$$

If we are dealing with two groups only, say, the mongols and the normals, then $\pi(r, B_i)$ does not apply, and the term $P(r)P(r, B_i)$ in the denominators of $\pi(m, B_i)$ and $\pi(n, B_i)$ should be deleted. In practice, the retardates and the normals may not be segregated in the data, in which case we may redefine our groups as mongols versus nonmongols. Under this new definition, the denominator would be $P(m)P(m, B_i) + (1 - Pm)[1 - P(m, B_i)]$. The $\pi(t, B_i)$ thus computed are useful in assessing the

likelihood as to which group (m, r, n) an individual with fingerprint pattern B_i might belong (Parzen, 1960; Dobrushin, 1961; Good, 1965).

A complication of the above approach is that the application of Bayes theorem invokes the parametric values of $P(m)$, $P(r)$, and $P(n)$ of the population, which in many instances are unknown or known to be varying from population to population. We therefore may seek a more primitive discriminant function, which does not depend on the knowledge of $P(m)$, $P(r)$, and $P(n)$ (Smith, 1954; Walker, 1957).

Let us divide the numerator and the denominator of $\pi(m, B_i)$, say, by $P(m, B_i)$. We have

$$\pi(m, B_i) = \frac{P(m)}{P(m) + P(r)[P(r, B_i)/P(m, B_i)] + P(n)[P(n, B_i)/P(m, B_i)]}.$$

Note that the ratios $R(r, m) = P(r, B_i)/P(m, B_i)$ and $R(n, m) = P(n, B_i)/P(m, B_i)$ have rather interesting properties: For constant $P(r)$ and $P(n)$, (1) if $R(r, m)$ and $R(n, m)$ are both large, then $\pi(m, B_i)$ will tend to zero. It implies that the individual in question is not likely to be a mongol. (2) If $R(r, m)$ and $R(n, m)$ are both small, then $\pi(m, B_i)$ tends to one. It implies that the individual in question is likely to be a mongol. We see that $\pi(m, B_i)$ varies inversely with $R(r, m)$ and $R(n, m)$. It is also clear that $\pi(m, B_i)$ varies inversely with the quantity

$$R(r, m) + R(n, m) = \frac{P(r, B_i) + P(n, B_i)}{P(m, B_i)}.$$

We now wish to define a discriminant that varies proportionally with $\pi(m, B_i)$. We note that the reciprocal of $R(r, m) + R(n, m)$ has this property. We therefore define the discriminant

$$\lambda(m, B_i) = \frac{P(m, B_i)}{P(r, B_i) + P(n, B_i)}.$$

For practical purposes, let us decide, say, if $\lambda(m, B_i) \geq 2$ (i.e., $P(m, B_i)$ is at least twice as large as the sum of the other two conditional probabilities), we classify the individual to be a mongol. If $\lambda(m, B_i) < 2$, we refrain from making a decision. Similar expressions are used for $\lambda(n, B_i)$ and $\lambda(r, B_i)$, and the same rule of discriminant decision applies. We declare the individual as indeterminate when all $\lambda(t, B_i) < 2$, for $t = m, r, n$.

We see the use of $\lambda(t, B_i)$ is quite equivalent to the use of $\pi(t, B_i)$ for $t = m, r, n$. The advantage of using λ is that the computation of $P(t, B_i)$ does not depend upon the parametric knowledge of $P(m)$, $P(r)$, and $P(n)$.

For discrimination between two groups, we only need to define the following: $\theta(j, B_i) = P(j, B_i)/P(t, B_i)$, where $j \neq i$ and $i, j = m, r, n$. Again the same decision rule is applied.

Results of Discriminant Analysis

From Tables 3, 4, 5, and 6, we compute the conditional probabilities $P(t, B_i)$, where $t = m, r, n$ and $i = 1, 2, \ldots, 14$. In Tables 8, 9, 10, and 11, the decision rule is applied. We make the discriminant decision in the last columns of these tables. The results based on the above discriminant analyses are in Table 12 and are summarized in Table 13.

TABLE 8

DISCRIMINANT ANALYSIS AMONG MONGOLS, RETARDATES, AND NORMALS ACCORDING TO FINGERPRINT PATTERNS

Fingerprint-Pattern Group No.	Mongols	Retardates	Normals	Primitive Discriminant Decision
1	0.3581	0.0000	0.0000	Mongol
2	.0000	.4982	.0000	Retardate
3	.0000	.0000	.5284	Normal
4	.0744	.0142	.0000	Mongol
5	.0193	.0249	.0000	Indeterminate
6	.0000	.1851	.1773	Indeterminate
7	.0579	.0000	.0234	Mongol
8	.0055	.0000	.0234	Normal
9	.0110	.0000	.0134	Indeterminate
10	.3196	.0890	.0401	Mongol
11	.0661	.0249	.0201	Mongol
12	.0055	.0214	.0702	Normal
13	.0082	.0533	.0201	Retardate
14	0.0744	0.0890	0.0836	Indeterminate

TABLE 9

DISCRIMINANT ANALYSIS AMONG MONGOLS AND RETARDATES ACCORDING TO FINGERPRINT PATTERNS

Fingerprint-Pattern Group No.	Mongols	Retardates	Primitive Discriminant Decision
1+7+8	0.4325	0.0000	Mongol
2+6	.0000	.6833	Retardate
4	.0744	.0142	Mongol
5	.0193	.0249	Indeterminate
10	.3196	.0890	Mongol
11	.0661	.0249	Mongol
12	.0055	.0214	Retardate
13	.0082	.0533	Retardate
14	0.0744	0.0890	Indeterminate

TABLE 10

DISCRIMINANT ANALYSIS BETWEEN MONGOLS AND NORMALS ACCORDING TO FINGERPRINT PATTERNS

Fingerprint-Pattern Group No.	Mongols	Normals	Primitive Discriminant Decision
1+4+5	0.4518	0.0000	Mongol
3+6	.0000	.7057	Normal
7	.0579	.0234	Mongol
8	.0055	.0234	Normal
9	.0110	.0134	Indeterminate
10	.3196	.0401	Mongol
11	.0661	.0201	Mongol
12	.0055	.0702	Normal
13	.0082	.0201	Normal
14	0.0744	0.0836	Indeterminate

The primitive discriminant function is more effective in discriminating for mongols versus normals and mongols versus retardates than others. The retardates versus normals is the least effective, as it should be, as indicated by the smallest amount of information (Table 7). Whereas in the analysis dealing with all three groups it has slightly less information than mongols versus retardates, it also has to discriminate among three groups at once; hence it is less effective.

The estimates of mongolism incidence vary among different populations. Some observed incidences are given in Table 14. Instead of computing the $\pi(m, B_i)$ for different populations, the $\pi(m, B_i)$ for various incidences ranging from 1/400, 1/450, . . . , 1/800 for the mongol-versus-normal group are given in Table 15.

The probabilities $\pi(t, B_i)$ are calculated from $P(m) = 1/400, 1/450, 1/500, \ldots, 1/800$. In Table 15, both $P(m)$'s and $\pi(t, B_i)$ are converted in terms of number of incidences per 10,000 births. From Table 15, we may observe the improvement of the

TABLE 11

DISCRIMINANT ANALYSIS AMONG RETARDATES AND NORMALS ACCORDING TO FINGERPRINT PATTERNS

Fingerprint-Pattern Group No.	Retardates	Normals	Primitive Discriminant Decision
2+4+5	0.5373	0.0000	Retardate
3+7+8+9	.0000	.5886	Normal
6	.1851	.1773	Indeterminate
10	.0890	.0401	Retardate
11	.0249	.0201	Indeterminate
12	.0214	.0702	Retardate
13	.0533	.0201	Retardate
14	0.0890	0.0836	Indeterminate

probabilities. As a rule, mongolism is a rare occurrence. For instance, let us take pattern 10, which is all ulnar loops (11111 11111). If the natural incidences of mongolism were 25 and 12 per 10,000 births, respectively, with the information that an individual's fingerprints are all ulnar loops, his probability of being a mongol is increased to 196 and 99 per 10,000 births, respectively. We may also observe that in those patterns which favor normalcy, the probabilities $\pi(m, B_i)$ are less than the natural incidence.

From the foregoing, it appears that fingerprint patterns could be a useful aid to diagnosis, since fingerprints are postnatally invariant. This should not replace the more precise, definitive procedures of diagnosis; especially with the advent of clinical and chromosomal investigation, the identification of mongols is rapidly becoming objective.

The sample sizes in this study are not small, but could be much larger; it is hoped that a large-scale investigation will be conducted in the future so that the $P(t,B_i)$ may be estimated more precisely. Furthermore, one of the main limitations of the present study is that many other possible fingerprint patterns probably were not observed in this sample. It is also likely that, in a much larger sample, some of the patterns here observed in one group only would be found in other groups as well.

TABLE 12

CONTINGENCY TABLES OF ACTUAL FREQUENCIES VERSUS FREQUENCIES DETERMINED BY DISCRIMINANT ANALYSIS

PRIMITIVE DISCRIMINANT DECISION	ACTUAL FREQUENCIES			
	Mongols	Retardates	Normals	Totals
	Three-Group Discriminant			
Mongols	318	36	25	379
Retardates	3	155	6	164
Normals	4	6	186	196
Indeterminates	38	84	82	204
Total	363	281	299	943
	Mongols vs. Retardates			
Mongols	324	43	.....	367
Retardates	5	213	.....	218
Indeterminates	34	25	.....	59
Total	363	281	.....	644
	Mongols vs. Normals			
Mongols	325	.....	32	357
Normals	1	.....	238	245
Indeterminates	31	.....	29	60
Total	363	.....	299	662
	Retardates vs. Normals			
Retardates	.....	191	18	209
Normals	.....	6	197	203
Indeterminates	.....	84	84	168
Total	.....	281	299	580

TABLE 13

PERCENTAGE OF CORRECT CLASSIFICATION, MISCLASSIFICATION, AND INDETERMINACY OF FOUR DISCRIMINANT ANALYSES

	All Three Groups	Mongols vs. Normals	Mongols vs. Retardates	Retardates vs. Normals
Correct classification:				
Mongol group	87.60	89.53	89.26	.....
Retardate group	55.16	.....	75.80	67.97
Normal group	62.21	79.60	.....	65.89
Misclassification	8.48	5.89	7.45	4.14
Indeterminacy	21.63	8.06	9.16	28.97

TABLE 14

INCIDENCE OF MONGOLISM IN VARIOUS POPULATIONS

Mongolism Incidence	Population	Investigators
1/636	Chicago	Jenkins (1933)
1/776	Liverpool	Malpas (1937)
1/435	Sweden	Böök and Reed (1950)
1/660	London	Carter and MacCarthy (1951)
1/754	Denmark	Øster (1953)
1/618	Denmark	Øster (1953)
1/688	Australia	Collmann and Stoller (1962)

TABLE 15

CONDITIONAL EXPECTED MONGOLISM INCIDENCE FOR KNOWN FINGERPRINT PATTERNS AS COMPARED TO THE UNCONDITIONAL EXPECTED INCIDENCE (PER 10,000 BIRTHS)

MONGOLISM INCIDENCE PER 10,000 BIRTHS	FINGERPRINT-PATTERN GROUP NO.							
	7	8	9	10	11	12	13	14
25	62	6	21	196	82	2	10	22
22	55	5	18	174	73	2	9	20
20	49	5	16	157	60	2	8	18
18	45	4	15	143	60	1	7	16
16	41	4	14	131	55	1	7	15
15	38	4	13	121	50	1	6	14
14	35	3	12	113	47	1	6	13
13	33	3	11	105	44	1	5	12
12	31	3	10	99	41	1	5	11

In view of the vast amount of data now existing in various public institutions, an investigation of sufficient scope is entirely possible and its consummation is devoutly to be wished.

SUMMARY AND CONCLUSIONS

1. Fingerprint patterns of 943 individuals (363 mongols, 281 mental retardates, and 299 normals) were investigated for information useful in the identification of mental status.

2. An information analysis showed that the information pertaining to the identification of mental-status types contained in the fingerprint patterns is 63% for all three groups, 65% for mongols versus retardates, 72% for mongols versus normals, and 59% for retardates versus normals.

3. A discriminant independent of parametric values of the mentality groups was constructed. The results showed that percentage of correct diagnosis for mongols was about 89% for the sample studied.

4. By using the information on fingerprint patterns, the Bayesian estimates of likelihood of mongolism are increased considerably for certain specific patterns.

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APPENDIX

GROUP 1. FOUND IN MONGOLS ONLY

PATTERN		N	PATTERN		N	PATTERN		N	PATTERN		N
Right	Left		Right	Left		Right	Left		Right	Left	
11111	11122	1	11122	11111	1	11211	11121	1	21122	21112	1
11111	11132	1	11122	11121	1	11222	11123	1	21122	21121	1
11111	11133	1	11122	11123	1	11222	11221	1	21122	21222	1
11111	11211	3	11122	21112	1	11222	21122	1	21122	22111	1
11111	11344	1	11122	21222	1	11222	21211	1	21122	22252	1
11111	11441	2	11122	22222	1	11222	42222	1	21131	11141	1
11111	14121	1	11123	11111	2	11223	11224	1	21133	51121	1
11111	14141	1	11123	11212	1	11311	11111	1	21211	11111	1
11111	21121	3	11123	11223	1	12121	11113	1	21222	11121	1
11111	21131	1	11123	21122	1	12221	41221	1	21222	21122	1
11111	21154	1	11123	41111	1	12222	21222	1	21222	21222	1
11111	21211	1	11131	11111	5	14111	44411	1	22112	22221	1
11111	21441	1	11131	14115	1	14121	14114	1	22122	22122	1
11111	41113	1	11131	21131	1	14141	11141	1	22221	21221	1
11111	44111	1	11131	44421	1	14411	44444	1	22221	52221	1
11112	11111	3	11132	11112	1	21111	11121	3	22222	11122	1
11112	11121	1	11132	11121	2	21111	11131	1	22222	22211	1
11112	11122	1	11132	11131	1	21111	21122	2	23221	43221	1
11112	21112	1	11133	11121	1	21111	21131	1	23321	23221	1
11112	21121	1	11133	11122	1	21111	21132	1	41111	11111	2
11113	11111	1	11141	11111	3	21111	21321	1	41112	51111	1
11113	11121	1	11141	11131	1	21111	22221	1	41131	41111	1
11114	41111	1	11141	11441	1	21112	21111	2	41133	41133	1
11114	41144	1	11142	11132	1	21112	21112	1	44111	11444	1
11115	12111	1	11143	11111	1	21113	21122	1	4441f	41431	1
11121	11131	1	11144	11133	1	21121	21221	1	51111	21112	1
11121	11221	1	11144	11141	1	21121	22121	1			
11121	21111	1	11211	11111	1	21122	12122	1			

GROUP 2. FOUND IN RETARDATES ONLY

PATTERN		N	PATTERN		N	PATTERN		N	PATTERN		N
Right	Left		Right	Left		Right	Left		Right	Left	
11111	11113	1	12122	11122	1	14443	44444	1	22222	21222	1
11111	13121	1	12122	12112	1	15111	13121	1	22222	22111	1
11111	13411	1	12122	12221	1	15222	12221	1	22222	22121	1
11111	23111	1	12211	13121	1	21111	22122	1	22321	12211	1
11111	23411	1	12221	11221	1	21111	22211	1	22421	22111	1
11112	21222	1	12221	12121	1	21111	23111	1	22421	23211	1
11114	14414	1	12221	12222	1	21111	23112	1	23111	13111	2
11121	11141	1	12222	11112	1	21111	24111	1	23111	21111	2
11121	11222	1	12222	12122	1	21112	21121	1	23111	23211	1
11121	12121	1	12321	12111	1	21112	21122	1	23112	23111	1
11121	13121	1	12411	11111	1	21121	21111	1	23121	21111	1
11121	14121	1	12414	11441	1	21121	22112	1	23122	13111	1
11121	15121	1	13111	43111	1	21121	23221	1	23221	12121	1
11122	11112	1	13121	14111	1	21122	11122	1	23311	21111	2
11321	11111	1	13121	15511	1	21221	21121	1	23321	22111	1
11411	13111	1	13121	22121	1	21221	22222	1	23321	23121	1
11411	13122	1	13221	22221	1	21321	13211	1	23411	23121	1
11441	13144	1	13311	13111	1	22111	12111	1	23421	11111	1
12111	13121	1	13411	13411	1	22111	22121	1	23431	12411	1
12111	15121	1	13411	14111	1	22121	12121	2	24111	13111	2
12111	22111	1	13411	43341	1	22121	22221	1	24111	24131	1
12111	22221	1	13421	12221	1	22121	25221	1	24111	24411	1
12111	23111	1	14111	13421	1	22122	12211	1	24121	13221	1
12121	11111	1	14111	41111	1	22122	12222	1	24121	51121	1
12121	11121	1	14111	44111	1	22122	21121	1	24122	24221	1
12121	12111	2	14121	11111	1	22122	22121	1	24411	24111	1
12121	12211	1	14121	14411	1	22122	22212	1	41121	41121	1
12121	12221	2	14211	12521	1	22221	11121	1	42111	41121	1
12121	12222	1	14221	13221	1	22221	12211	1	42121	44111	1
12121	13211	1	14411	13311	1	22221	12221	1	43121	44111	1
12121	13421	1	14421	13412	1	22221	22222	2	43124	44414	1
12121	21121	1	14441	13441	1	22221	23212	1	44431	41121	1
12121	22111	2	14441	14444	1	22222	12221	1			

GROUP 3. FOUND IN NORMALS ONLY

PATTERN		N	PATTERN		N	PATTERN		N	PATTERN		N
Right	Left		Right	Left		Right	Left		Right	Left	
11111	11114	1	12221	22222	1	15222	21121	1	22221	21421	1
11111	13311	1	12222	12221	1	21111	11211	1	22222	12121	1
11111	14144	1	12411	13111	1	21111	21221	1	23111	21112	1
11111	21411	1	12421	15411	1	21111	21411	1	23111	22111	1
11111	22411	1	12521	12111	1	21111	23222	1	23111	23411	1
11111	51121	1	13111	11411	1	21121	12121	1	23112	14121	1
11121	11122	2	13111	13411	1	21121	14411	1	23121	12111	1
11121	12122	1	13111	14111	2	21121	21112	1	23121	13111	1
11121	12321	1	13111	31111	1	21121	22111	1	23121	23121	2
11121	13111	1	13121	11111	4	21121	23121	1	23121	43111	1
11121	14111	1	13211	13111	1	21221	11111	1	23122	11121	1
11121	23122	1	13221	13222	1	21222	13111	1	23122	12121	1
11121	41111	1	13311	12211	1	21321	11111	1	23221	12221	1
11131	11121	1	13311	13411	1	22111	12121	1	23222	22122	1
11222	11121	1	13321	11111	1	22111	12211	1	23411	11111	2
11222	13121	1	13411	13111	1	22111	21121	1	23411	14444	1
11234	11121	1	13422	12121	1	22111	22211	1	23414	44414	1
11411	13411	1	14111	13211	1	22111	23111	3	24111	14444	1
12111	14321	1	14111	13411	1	22111	53411	1	24111	22111	1
12111	22211	1	14111	21111	1	22112	22112	1	24111	51112	1
12111	23112	1	14111	23111	1	22121	11121	2	24112	21111	1
12111	51111	1	14111	24111	2	22121	12221	1	24121	13111	1
12112	11112	1	14121	14111	1	22121	15121	1	24221	14221	1
12112	22121	1	14124	14121	1	22121	22111	3	24321	11311	1
12121	22122	1	14141	23441	1	22121	22121	6	24411	24411	1
12121	23221	1	14141	41111	1	22121	22122	1	24441	24444	1
12121	42111	1	14144	14444	1	22121	23121	1	25111	23111	1
12121	43121	1	14222	11221	1	22122	13121	1	25121	23122	1
12122	12122	1	14411	11111	1	22122	22111	1	25411	13111	1
12122	12222	1	14444	14444	2	22131	11111	1	25511	12111	1
12122	42122	1	14444	24411	1	22211	11111	1	44111	44121	1
12131	12122	1	15121	11111	1	22211	21222	1	44111	44444	1
12211	23111	1	15121	11121	1	22211	22111	1	44411	44411	1
12221	12221	1	15121	11221	1	22212	22211	1	44444	14444	1
12221	22121	1	15222	13122	1	22221	21121	1			

GROUP 4. FOUND IN MONGOLS AND RETARDATES

PATTERN		NUMBER	
Right	Left	Mongols	Retardates
11111	11121	8	1
11111	21111	12	1
11111	24111	2	1
21122	21122	5	1

GROUP 5. FOUND IN MONGOLS AND RETARDATES

PATTERN		NUMBER	
Right	Left	Mongols	Retardates
11111	11411	1	1
11122	11222	1	1
12111	12111	1	1
21111	13111	1	1
22121	21111	1	1
22122	21122	1	1
41111	41111	1	1

GROUP 6. FOUND IN RETARDATES AND NORMALS

PATTERN		NUMBER		PATTERN		NUMBER	
Right	Left	Retardates	Normals	Right	Left	Retardates	Normals
11111	14311	1	1	21122	11121	1	1
11222	11122	1	1	22111	11111	1	2
12111	11111	4	2	22111	21111	2	3
12111	13111	1	2	22121	12111	1	1
12121	12121	2	1	22122	21111	2	1
12122	12121	1	1	22122	22222	1	2
13111	12111	2	2	22221	22111	1	1
13111	13111	7	4	22221	22211	2	1
13111	22111	1	1	22222	22122	1	1
13111	23111	1	1	23111	11111	1	1
14111	11111	2	3	23111	12111	1	1
14111	14411	1	4	23111	23111	1	1
14411	13111	1	1	23121	11111	1	1
14411	14411	1	2	23121	22121	1	1
21111	21121	1	1	23121	23111	1	2
21111	22111	1	1	23221	22111	2	1
21111	22121	1	1	24111	11111	1	1
21121	13111	1	1	24111	14111	1	1

GROUP 7. FOUND IN MONGOLS AND NORMALS

PATTERN		NUMBER	
Right	Left	Mongols	Normals
11111	11112	2	1
11111	11131	4	1
11111	11141	3	1
11111	41111	5	1
11112	11112	2	1
21121	11111	2	1
21121	21121	3	1

GROUP 8. FOUND IN MONGOLS AND NORMALS

PATTERN		NUMBER	
Right	Left	Mongols	Normals
11411	11111	1	2
13111	11111	1	5

GROUP 9. FOUND IN MONGOLS AND NORMALS

PATTERN		NUMBER	
Right	Left	Mongols	Normals
11111	13111	1	1
11111	14111	1	1
12221	11121	1	1
14444	44444	1	1

GROUP 10. FOUND IN MONGOLS, RETARDATES, AND NORMALS

PATTERN		NUMBER		
Right	Left	Mongols	Retardates	Normals
11111	11111	116	25	12

GROUP 11. FOUND IN MONGOLS, RETARDATES, AND NORMALS

PATTERN		NUMBER		
Right	Left	Mongols	Retardates	Normals
21111	11111	11	3	3
21111	21111	13	4	3

GROUP 12. FOUND IN MONGOLS, RETARDATES, AND NORMALS

PATTERN		NUMBER		
Right	Left	Mongols	Retardates	Normals
11111	13111	1	5	12
14111	13111	1	1	9

GROUP 13. FOUND IN MONGOLS, RETARDATES, AND NORMALS

PATTERN		NUMBER		
Right	Left	Mongols	Retardates	Normals
14111	14111	2	6	4
22222	22222	1	9	2

GROUP 14. FOUND IN MONGOLS, RETARDATES, AND NORMALS

PATTERN		NUMBER		
Right	Left	Mongols	Retardates	Normals
11111	12111	2	2	1
11111	14111	8	3	8
11121	11111	4	1	2
11121	11121	3	1	6
11121	21121	2	1	1
12111	21111	1	1	1
22111	22111	2	3	1
22121	21121	1	2	1
22221	12121	1	1	1
22221	22121	1	2	1
22221	22221	1	5	1
22222	22221	1	3	1

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