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SOME FACTORS OF INTELLIGENCE

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I. Introduction

As a result of the analyses and discussions of recent years there is a widespread belief in the existence of a general factor, '*g*', running through all intellectual activity. Interpretations of this factor differ, Spearman accounting for it by quantity of energy, Kelley by heterogeneity, Thomson by the nature of the sampling process; but there is a general agreement that, however it arises, it is a convenient and satisfactory functional unity. The chief dissentient is Thurstone, and in his recent elaborate analysis of fifty-seven tests (3) he finds nine defined factors, none of which is common to all the tests. Thurstone's argument, however, is inconclusive, and Holzinger & Harman have shown, by analysing the same material, that the data do not preclude the existence of a general factor (2).

One of the strongest arguments in favour of the conception of '*g*' is the fact that in many of the standard group intelligence scales the intercorrelations of the tests can be explained in terms of a single common factor. And it seems natural to suppose that when the scale is extended by the addition of other tests which break the hierarchy, the single factor previously identified continues to exist, and should be sought for in the more complex material.

At the same time it must be recognized that the persistent functional unity of '*g*' is a hypothesis which requires confirmation and which may

be subject to modification and even to rejection in the light of further evidence. For instance, when we are dealing with a complex correlation matrix into which '*g*' is presumed to enter, along with other factors, it is not sufficient to extract a general factor which we identify with '*g*' without giving adequate consideration to the effect which this has on the interpretation of the other common factors. All the factors should be considered together, and if the postulation of '*g*' renders difficult a psychologically plausible interpretation of the factors as a whole, then it is necessary to revise the postulate and to modify the conception of '*g*'.

II. Experimental procedure

(1) *Test material*

We have been fortunate in obtaining from Dr M. L. Fick, of the South African National Bureau of Educational and Social Research, permission to use extensive data collected by him (1), which make it possible to approach the problem from this point of view. Fick has extended an existing scale of the Binet type by adding fresh items at the upper levels, and in order to select these items he gave a number of different tests to 1497 school children. Our analysis sets out from the intercorrelations of ten of those tests, most of which are of a well-known character. They are as follows:

1. Formboards. These are the Worcester formboards, II A, III A, II B and III B.
2. Repetition of digits.
3. Repetition of digits backwards.

These two tests consist of the series contained in the Stanford Revision, with additions.

4. Match test. As this test, which was originally devised by Dr E. G. Malherbe, is probably unknown to English readers, a description of it may be given.

The materials required are a set of nine stiff cards, numbered 1–9, each measuring 3 by 12 in., and divided by lines into four equal squares. On these cards match sticks are glued in various patterns, as shown in Fig. 1. The subject is given about twenty additional match sticks with which to operate.

The procedure is as follows: The first card is shown to the subject for 6 sec.; it is then taken away and he is asked to reproduce the pattern with the loose matches supplied. The same procedure is adopted for each of the next five cards, but for the seventh card it is changed. The subject is now told that there ought to be four figures on the card, arranged in the same way as those on card 6. Three of them, however, have been lost, and the subject has to reproduce them with loose matches in the vacant squares on the card itself. Cards 8 and 9 are dealt with in the same way as card 7.

5. Absurdities. This includes items from Terman and Burt.
6. Porteus mazes.

7. Arithmetic reasoning. This is Terman material with additions.
8. Reasoning test, based largely on Burt.
9. Vocabulary test—50 words, given in the Terman fashion.
10. Dissected sentences—an extension of the Terman test of this nature.

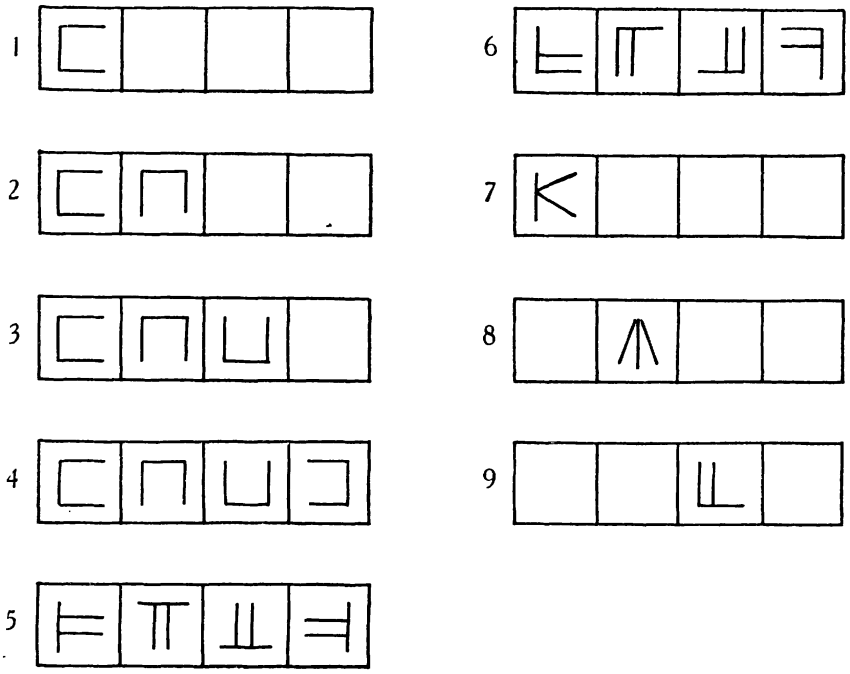

Fig. 1.

(2) *Method and subjects of experiment*

The tests were given individually by Fick himself to 1497 Transvaal school children, 723 of them being English-speaking and 774 Afrikaans-speaking. They were chosen from Standards V–X inclusive, and their age range was from 12 to 18. They were not, however, distributed uniformly over this range, the average age being almost exactly 15 years, and the probable error of the distribution 12 months. Two points call for comment here.

In the first place the children were selected on a definite basis. Fick's main purpose was to obtain age norms, and for this reason he selected and tested only those pupils in each standard whose age did not deviate by more than 6 months from the median age for the standard, calculated for the whole country.

Secondly, there was a language complication. Some of the tests are verbal in nature, particularly 9 and 10, and care had to be taken to

equate these tests in the two languages. For this purpose Fick relied on two considerations. On the one hand he believed that his principle of selection ensured that the two halves of his population were approximately equal to one another in ability and schooling; and on the other hand, when two groups, of English- and Afrikaans-speaking children respectively, obtained equal average scores on performance tests, numbers 1, 4 and 6, he assumed that they were of equal ability and therefore expected them to show equal average scores also on the language tests. Accordingly, the form of the language tests was adjusted until such results were secured. The difference between the tests in the two languages is probably not greater than the difference between two forms of a single test in the same language.

On the whole the results do not seem to us to be vitiated by the use of the two languages, but the method of selecting the subjects introduces an uncertainty. Undoubtedly the correlation with age is enhanced, as the extreme cases at each age are rejected. This does not involve the introduction of any fresh common factors into the analysis, but it must make some difference to the saturation coefficients themselves. The general effect is to limit the variance of each test as compared with an unselected sample of the same size drawn from the total population. But as we are unable to give any measure of the extent of this limitation, all we can do is to treat the given variance as unity, and to recognize that somewhat different saturation coefficients of the final factors might be obtained from an unselected sample. There seems to be no reason to believe, however, that the analysis itself would be fundamentally altered.

III. Treatment of test results

(1) *Factorial analysis*

The intercorrelations of the ten tests, as calculated by Fick, are presented in Table I. This matrix was submitted to factorial analysis by Thurstone's centroid method. Fick himself made a first approximation to the communalities by taking the highest figure in each column. From the factor loadings obtained in this way we made a second approximation, and from the new factor loadings a third approximation was reached. The final centroid matrix, which is presented in Table II, is thus the outcome of three successive applications of the centroid method.

Five factors appear to be necessary. The probable error of the average correlation coefficient is 0·0166, and the average residual does not come down to this value until five factors have been extracted. If only four

factors are extracted, the residuals are too large to be accounted for in terms of random error. Five is therefore the minimum number of common factors by reference to which the correlation table may be explained.

Table I. *Correlation matrix*

Decimal points are omitted

	1	2	3	4	5	6	7	8	9	10
1	—	027	103	231	241	178	254	217	138	109
2	027	—	477	137	164	115	194	169	183	144
3	103	477	—	263	166	266	256	249	338	261
4	231	137	263	—	184	200	249	293	249	217
5	241	164	166	184	—	047	243	303	203	179
6	178	115	266	200	047	—	267	258	263	273
7	254	194	256	249	243	267	—	319	307	130
8	217	169	249	293	303	258	319	—	348	205
9	138	183	338	249	203	263	307	348	—	537
10	109	144	251	217	179	273	130	205	537	—

Note. There is a discrepancy in the table between the two versions of the value r_{310}. We have taken the mean of the two values, viz. 0·256.

Table II. *Centroid matrix*

	I	II	III	IV	V	h^2
1	0·353	0·327	0·058	0·099	0·087	0·252
2	0·441	−0·283	−0·544	0·031	0·028	0·572
3	0·584	−0·269	−0·260	0·154	0·031	0·505
4	0·461	0·131	0·072	0·104	0·110	0·258
5	0·432	0·331	−0·148	−0·315	0·115	0·431
6	0·446	−0·069	0·193	0·266	−0·075	0·317
7	0·516	0·179	−0·019	0·125	−0·173	0·344
8	0·548	0·189	0·035	−0·020	−0·127	0·354
9	0·636	−0·195	0·240	−0·231	−0·143	0·574
10	0·534	−0·341	0·372	−0·229	0·221	0·641

The factors obtained directly by the centroid analysis have of course no immediate psychological significance, and the axes must be rotated. This process cannot be undertaken in a purely mechanical fashion, but must be guided by psychological considerations. Some of the points we have allowed for here are as follows:

(1) All the coefficients in the correlation table are positive, and although there are several possible explanations of this, the simplest one is the existence of a general factor, such as '*g*', with which all the tests are positively loaded. Throughout the process of rotation we tried if possible to preserve such a factor.

(2) The correlation between tests 9 and 10 is unduly high in comparison with the rest of the table, and this suggests the presence of a verbal group factor.

(3) The correlation between tests 2 and 3 is also high, implying the presence of another group factor. *A priori* its precise nature is not clear,

for it may consist either of facility in dealing with numbers or of some wider memorizing or retentive ability.

(4) One further consideration is relevant here. It is highly probable that all the common factors underlying the tests are positive, and hence, when the axes have been rotated to their final position, there should be no significant negative loadings.

There is, however, one value in the correlation table which makes it difficult to reconcile the first and last of these assumptions. The correlation between test 5 (absurdities) and test 6 (mazes) is only 0·047. Both of these tests would commonly be regarded as having a reasonably high saturation with '*g*', and yet if this were so, the resulting correlation ought to be much larger than that experimentally found. The correlation r_{56} is the lowest in both columns in which it appears, and the correlations of these tests with test 2 (repetition of digits), into which presumably '*g*' does not enter in any high measure, are on the average three times as large as their correlation with one another. Of course it may be that the error of r_{56} is unusually big. But if the correlation is augmented by three times its probable error it still falls short of 0·1, and thus leaves little room for a general factor of any magnitude. Moreover, when the correlation between tests 5 and 6 is reconstructed from the factors obtained by the centroid analysis—and these of course are determined by all the data in the table and not only by the correlation between tests 5 and 6 themselves—the figure obtained is 0·046, a result which is hardly compatible with the idea that its original value was seriously in error.

It seems therefore that the first and fourth of the assumptions which we were prepared to adopt may prove inconsistent. If '*g*' is significantly present in all the tests, there must be other factors with negative loadings to account for the low value of r_{56}. If, on the other hand, negative loadings are excluded, there is no general factor in all the tests. This dilemma is a real one, and we had to choose between the first and the fourth of the assumptions. We were prepared to accept '*g*' as commonly understood if we could give a psychological meaning to the negative loadings of the other factors which its retention entailed. But we failed in this endeavour. None of the bi-polar factors which we considered gave any promise of a psychological meaning, and hence in the end we abandoned the first assumption in favour of the fourth.

The method of rotation adopted was primarily graphical. The factors were plotted against one another in pairs, and when an angle of rotation was chosen, the new factor loadings were calculated by the suitable orthogonal transformation. In the end seven rotations were retained, and

the transformation matrices which they involve are shown in Table III. The ideas governing these rotations are (*a*) the avoidance of significant negative loadings, (*b*) the isolation of two factors, one of which is defined mainly by tests 9 and 10 and the other mainly by tests 2 and 3, and (*c*) the possibility of giving a psychological meaning to the remaining three factors.

Table III. *Transformation matrices*

	I	II
	0·84227	0·53905
	−0·53905	0·84227

T_1

	I	III
	0·50387	0·86378
	−0·86378	0·50387

T_2

	III	IV
	0·93881	0·34444
	0·34444	−0·93881

T_3

	I	III
	0·97168	−0·23630
	0·23630	0·97168

T_4

	III	V
	0·82728	0·56180
	−0·56180	0·82728

T_5

	II	III
	0·98058	−0·19612
	0·19612	0·98058

T_6

	IV	V
	0·96153	−0·27472
	0·27472	0·96153

T_7

The final factorial matrix is given in Table IV, and in Table V the percentage of the variances to be attributed to each factor.

Table IV. *Factorial matrix*

	I	II	III	IV	V
1	0·048	0·441	0·168	−0·002	0·165
2	0·755	0·002	−0·016	0·038	0·013
3	0·635	0·040	0·248	0·054	0·189
4	0·173	0·316	0·250	0·080	0·245
5	0·209	0·528	−0·028	0·326	−0·040
6	0·162	0·091	0·477	−0·031	0·233
7	0·254	0·360	0·386	−0·019	0·005
8	0·218	0·390	0·368	0·138	0·002
9	0·244	0·077	0·528	0·478	0·039
10	0·143	−0·071	0·361	0·592	0·368

Table V. *Percentage variance*

		I	II	III	IV	V
1	Formboards	—	19	3	—	3
2	Digits forwards	57	—	—	—	—
3	Digits backwards	40	—	6	—	4
4	Match test	3	10	6	1	6
5	Absurdities	4	28	—	11	—
6	Mazes	3	1	23	—	5
7	Arithmetic	6	13	15	—	—
8	Reasoning	5	15	14	2	—
9	Vocabulary	6	1	28	23	—
10	Dissected sentences	2	1	13	35	14

(2) *Interpretation of the factors*

(*a*) The nearest approach to a general factor is the first one, but it cannot be '*g*'. It looks like a memory factor. It is present in a high degree in the two tests where one would expect such a factor, viz.

2 (digits forwards) and 3 (digits backwards); it is absent in test 1 (formboards); and it is present in a low but almost uniform degree in the other tests. These results appear to be compatible with the interpretation of it as immediate memory span, although of course it may be some more complex memory function.

(*b*) The fourth factor is obviously verbal. Its main loads are in tests 10 (dissected sentences) and 9 (vocabulary). It also enters into test 5 (absurdities), and has a small but presumably significant load in test 8 (reasoning). This factor may also be complex, and the data are hardly sufficient to allow it to be defined more closely.

There is nothing surprising in the appearance of these two factors in the battery, as their presence was suggested beforehand by the correlation table, and we deliberately looked for them. The remainder of the analysis however appears to be new.

(*c*) In the fifth factor the highest load is in test 10 (dissected sentences), and then follow tests 4 (matches), 6 (mazes), 3 (digits backwards) and 1 (formboards), in that order of magnitude. The other loads are negligible. In all the tests in which the factor is significant the tasks involve the arrangement or rearrangement of sensory material, and the interpretation which we suggest is that it consists in some kind of manipulative fluency or elasticity in dealing with perceived sensory data. It is a form of dexterity, but mental and not manual, and, so far as the present tests go, confined to perceived objects.

(*d*) We are now left with the second and third factors. Both are present, in almost equal proportion, in tests 4 (matches), 7 (arithmetic) and 8 (reasoning). Although both are also present in test 1 (formboards) the second factor has much the greater weight. This second factor is present, and the third absent, in test 5 (absurdities). On the other hand the third factor is present and the second absent in tests 9 (vocabulary), 6 (mazes), 10 (dissected sentences) and 3 (digits backwards). Incidentally it may be remarked here that the analysis accounts for the smallness of the correlation between test 5 (absurdities) and test 6 (mazes). Each of them correlates reasonably well with the other tests, but, apart from the memory factor, they do so by virtue of separate factors, and consequently do not correlate with one another.

Neither the second nor the third factor can plausibly be identified with '*g*' in its ordinary interpretation. If the third factor is interpreted as '*g*' the absence of it in test 5 (absurdities) is difficult to explain, and the low saturation of test 1 (formboards) is also a stumbling-block. On the other hand the attempt to identify '*g*' with the second factor is

precluded by the absence of that factor from tests 6 (mazes), 9 (vocabulary) and 10 (dissected sentences).

In point of fact '*g*' seems to be divided here into two separate and independent factors, and the problem is how to describe them. The critical tests are 5 (absurdities), 6 (mazes), 9 (vocabulary) and 10 (dissected sentences). What does test 5 (absurdities) possess that 6 (mazes), 9 (vocabulary) and 10 (dissected sentences) lack, and what does it lack that is present in them? If test 6 (mazes) can be taken as a guide, the third factor conditions the ability to see a path through a maze and to follow it. If we separate this ability from the contributions due to memory and to perceptual dexterity, it may be regarded as the ability to make, or isolate, and follow a plan. It is not a visual factor, and is not confined to sensory material, for it is equally marked in the ability to define words and to perceive the meanings of disarranged sentences. It would thus appear to be a synthetic and constructive ability as well as an analytic one. It is the power to find or make a significant pattern in a mass of irrelevant material.

(*e*) In comparison with this factor the second one appears negative, and the main guide to it is the part it plays in the perception of absurdities. This perception is not immediate, but involves inference and implication and the apprehension of a general idea. For the subject is required to show why the given statements are absurd or how the premises involve contradiction. If he has such an ability he will be in a position, in many tasks, to rule out certain lines of thought or action. He will see that certain paths lead nowhere, and will not require to go to the end of each of them to discover that he is in a cul-de-sac. The ability therefore may be described as one of logical elimination.

If this conception is right, the presence of the second factor in test 1 (formboards) is clearly intelligible. The perception that a particular block cannot fulfil the conditions required for the completion of a pattern, no matter how it is turned, will save endless trial and error and be of the utmost value for the performance of the task. Unless the subject sees that certain general conditions have to be satisfied in a formboard problem he is at the mercy of chance, nor indeed will he have much success unless he can go further and deduce from the conditions which he has grasped the exclusion of all the wrong shapes.

The second factor, as we have seen, is lacking in tests 6 (mazes), 9 (vocabulary), 10 (dissected sentences) and 3 (digits backwards). In none of these cases is it feasible to exclude unnecessary steps and minimize trial and error by means of implications drawn from a principle or general

idea. In the maze a blind alley cannot be actively eliminated unless the eye travels to the end of it. Wrong definitions of words are not excluded by inference from a general idea. In the test of disarranged sentences there are few if any principles to be appealed to, and once the right idea is obtained, the answer is given immediately. And finally, in repeating digits backwards it is fatal to proceed by elimination. The moment alternatives present themselves explicitly to the subject's mind he is confused and lost.

From a comparison of the two factors the following difference emerges. When the third factor is dominant irrelevancies are brushed aside or neglected because the thinker is holding to something which he sees clearly, or, to change the metaphor, he does not take bypaths because he is following a defined road. On the other hand, when the second factor is dominant, irrelevancies are set aside because they are perceived to be irrelevancies. Extensive trial and error is avoided, because attention is given to false procedures and their implications are seen. From this point of view the presence of both factors in the match test, in reasoning and in arithmetic seems completely intelligible. For the second factor by itself does not go far enough. In test 5 (absurdities) it may be adequate, since the test itself requires no more than the perception of the absurdity; but when more than this is needed it fails. Although it excludes mistakes and closes bypaths, by itself it supplies no positive contribution towards finding the true road or providing a solution. It does not lead one through the maze, nor give the proper explanation of a word, nor rearrange a sentence. For these we have to rely on the third factor; and in ordinary reasoning processes, whether dealing with arithmetical or other material, as well as in the match test, both factors are important.

IV. Conclusions and further treatment of results

The results which we have reached are difficult to reconcile with the accepted conception of '*g*' as a unitary character, and since there is a reasonable quantity of evidence in favour of this conception, some comment is called for. Undoubtedly batteries of tests have been applied where the correlation table can be accounted for by a single factor; and the problem is to explain how this can happen if intelligence tests are really as complex as our analysis would suggest.

In the first place, it may be noted that not every grouping of intelligence tests satisfies the tetrad equation criterion. It is well known, for example, that tests of the Binet type involve more than one common factor. Secondly, a verbal factor has been recognized for some time, and

undoubtedly this factor does enter into batteries of tests which satisfy the tetrad criterion. That is to say, these tests, although they appear, when analysed by themselves, to imply only one common factor, are really complex and involve at least two common factors. Moreover, it is difficult to believe that a memory factor, such as we have isolated, does not also enter into them. Thirdly, tests which satisfy the tetrad criterion and are grouped in a battery to measure '*g*' have in many cases been selected under the guidance of this criterion. They are the survivors of larger batteries from which tests which disturb the hierarchy have been ejected. And when this procedure is adopted it is possible to obtain a residuum of tests which, analysed by themselves, are consistent with the assumption of a single common factor but which in reality are complex.

We may illustrate this situation from the battery which we have been considering. Ignoring for a moment the analysis which has just been made, let us adopt the procedure which would be natural on the assumption that there is a single general factor, and that the hierarchy is disturbed only by group factors. Wherever a group factor is suspected to link two or more tests, we shall retain only one of these, and by this method derive a sub-battery which will measure '*g*' as adequately as possible. Obviously tests 9 and 10 cannot both be retained as they have a verbal factor in common; let us omit 10 and retain 9, which has notoriously a high correlation with '*g*'. Again, tests 2 and 3 cannot both remain, but neither has a strong claim, for they would normally be regarded as poor tests of '*g*'. Hence both should probably be omitted. Finally, tests 5 and 6 cannot be incorporated in the battery together because of their low intercorrelation. Let us retain test 6, which has greater scope and has been more widely used. This leaves us with tests 1, 4, 6, 7, 8 and 9. Three of these, it may be noted, are performance tests, and accordingly there is still some risk of a group factor remaining.

Taking these six tests, let us examine their correlation matrix. Assuming a single common factor and applying Spearman's well-known formula,[1] we obtain the following factor loadings:

Tests	1	4	6	7	8	9
Factor loads	0·386	0·483	0·456	0·572	0·592	0·521

Reconstituting the correlations by means of these factor loadings and subtracting them from the original correlations, we obtain a set of residuals, the mean numerical value of which is 0·022. The probable error of the mean correlation coefficient in this reduced table is 0·016,

[1] *Abilities of Man*, Appendix, equation (21).

and the residuals therefore appear to be slightly too large to be accounted for by random error. Presumably there is still a group factor involved in the correlation table. As already suggested, this may be associated with the performance tests, and *a priori* an overlap is likely between tests 1 and 4, both of which involve manipulation. Let us drop test 1.

Applying the same method of analysis to the remaining five tests, we obtain the following factor loadings:

Tests	4	6	7	8	9
Factor loads	0·456	0·455	0·550	0·601	0·566

The average residual is now 0·010, which is less than the probable error of the average correlation coefficient. This reduced battery would obviously satisfy the tetrad equation criterion, and '*g*' might well be postulated as the explanation of the intercorrelations of these five tests.

This result may be compared with the factorial analysis of the same tests based on their examination along with the rest of the original battery. The relevant figures, extracted from Table IV, are reproduced here for convenience, together with the values of h, which enable a direct comparison to be made with the saturation coefficients of '*g*' presented in the preceding paragraph.

Table VI

Test	I	II	III	IV	V	h
4	0·173	0·316	0·250	0·080	0·245	0·508
6	0·162	0·091	0·477	−0·031	0·233	0·563
7	0·254	0·360	0·386	−0·019	0·005	0·586
8	0·218	0·390	0·368	0·138	0·002	0·595
9	0·245	0·077	0·528	0·478	0·039	0·757

If the analysis given in Table IV is sound, it will be observed that there are two factors common to the five tests, together with three group factors. And it may be added that the communalities are significantly higher than those obtained when the five tests are examined in isolation. The unity of '*g*' therefore, in this instance at least, would appear to be spurious in the sense that it does not maintain itself when the tests are made part of the larger battery.

A difficulty remains. The correlation matrix of the five tests which we have just discussed involves two general factors and three group factors; nevertheless these five factors can apparently be replaced by a single factor, and the matrix treated as if it were of rank one. In general a reduction of this kind cannot be made unless (*a*) the group factors are insignificant, and (*b*) the general factors are proportional to one another. Neither of these two conditions is fulfilled in the present case, and it seems a refuge of despair to say that the result is merely accidental.

The situation would be an impossible one if the data were infallible, and a matrix which is genuinely of rank five cannot be reduced to rank one. But the position is changed when the data are fallible, for the two factorial matrices are not equivalent to one another, and hence the problem of reducing one to the other does not arise. Both give approximations to the original correlation matrix, neither of them differing from the data by larger values than can be accounted for by random error. But they do not differ from the original in the same way, and the residuals obtained in the two cases are different. If the correlation matrix constituted from the five factors of Table VI is analysed anew and a single centroid factor extracted from it, the residuals average 0·014, a value which is not incompatible with the assumption that one common factor is sufficient to explain the table. Thus the difference between the two analyses is covered by random error.

A further consideration may be mentioned here. If an artificial correlation matrix is constructed from a number of factors equal or nearly equal in number to the variables, and an attempt is made to analyse it by the centroid method, it will frequently be found, particularly if the number of variables is small, that the first factor extracted in this way accounts for most of the co-variance and that relatively little is left for the others. Accordingly, if allowance has to be made for probable errors, all factors other than the first may easily be swamped. This appears to be what has happened in the case we have been discussing, and we suggest that it is not of infrequent occurrence.

Of course the group of five tests which we have isolated here cannot be regarded as a normal representative of those batteries which are commonly employed to measure '*g*', and the composition of the latter may differ considerably from that of the former. Nevertheless we may claim that our analysis creates a presumption that '*g*' is complex, and obviously the next step is to analyse a more orthodox battery of tests, commonly recognized as measures of '*g*', together with other tests similar to those which we have discussed in this paper.

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