AN EXPERIMENTAL ANALYSIS OF THE THEORY OF INDEPENDENT ABILITIES*

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The current theories of abilities appear to favor a theory of independent functions. Thurstone,[19] whose theory of primary abilities has superseded the Thorndike[16] multiple factors, subscribes to a theory of independence among the primary group factors. Kelley[5] assumes a position which is close to that of Thurstone by conceiving mental traits as constellations of abilities and related phenomena capable of independent functioning. The theory of "unique traits" posited by the psychologists at the University of Minnesota[12] agrees quite well with the Thurstone primary abilities. Thomson's sampling theory[15] considers the mind as made up of an infinite number of neural bonds which may exist independently, or as "subpools" of the various bonds. Tryon[22] advocates a similar point of view with the gene as the basis.

In contrast to these theories of independent abilities stands the Spearman two-factor theory.[14] Alexander[1] advocates dynamic interrelationship among the different abilities in a modification of Spearman's theory. He insists, however, that the interrelationships are the resultant of more than one factor. Garrett[4] analyzed the group factors found in several investigations and reported that in all cases these group factors are interrelated instead of existing independently as had been thought.

THE PROBLEM

The purpose of the present study, therefore, is to determine whether human abilities as measured by special tests are independent or interdependent and the extent of such relationship. More specifically, the problem is to find by means of correlational analysis and the factorial analysis technique the degrees of relationship among certain tests of intelligence, musical ability, artistic judgment, clerical ability, mechanical ability, and manipulative ability.

THE EXPERIMENT

Subjects.—Eighty male students from the undergraduate course in general psychology at Brooklyn College and at New York University were given the complete battery of tests used in this study. The age range of these subjects was from fifteen years, nine months to twenty-four years, two months, with the median age at eighteen years, four months. The socio-economic status of the vast majority of the subjects was essentially the same, since most of them came from the upper working class and lower middle class type of home environment. All were born in the United States. They usually had one or both parents who were born in this country, and they were mainly of the Hebrew cultural background.

Procedure.—Eight presumably different tests of ability were given in a random manner to the subjects. Because of the fact that many of the tests could be administered to groups as well as in the individual form, and also because of the fact that a conscious effort was made to avoid adherence to a particular sequence of administration, the testing procedure varied and was very different for various subjects. Whether the tests were taken individually or in groups depended upon conditions, such as the number of subjects available at a particular time. The groups never exceeded six, and were usually two or three in number. Some subjects took all the pencil-paper tests in group form; others took some of these tests in group and individual form; while most took all the tests individually.

The testing program was approximately six hours long. Depending upon the subjects' convenience, the program was administered in three sessions, two sessions, or six sessions. The procedure most often followed, however, was a two-hour session, repeated three times. The pattern of administration of the test battery depended upon factors which helped create maximum motivation or facilitated the testing program. For instance, if the interest of the subject could be maintained by withholding the music or intelligence test until the end, this procedure would be used. In many cases it became necessary to administer these tests first in order to arouse the curiosity and interest of the subject. Most of the so-called mechanical ability tests were individual tests and were administered mainly at the end of the procedure.

Tests.—Many factors entered into the selection of the specific testing materials used in this experiment. Among the outstanding bases for selection of the material were the extent to which the tests

were considered to be distinct and separate measures of the specific abilities, the validity and reliability of the tests, the length and difficulty of administration of the tests, the reputation which these tests had among various psychologists,* the use of the tests in previous research, and the personal experiences of the experimenter with these and other tests.

The test of intelligence used was the 1938 edition of the American Council on Education Psychological Examination for College Freshmen by Thurstone and Thurstone.[21] This test consists of six separate tests, two subscores and a general score. The Q-score comprises the three allegedly quantitative tests—the arithmetic, analogies and number series tests; the L-score is the total of the three linguistic tests—the completion, artificial language and same-opposite vocabulary tests. The general or gross score is the total of the six separate tests.

The Seashore Measures of Musical Talent[13] containing tests of pitch, intensity, time, consonance, memory and rhythm were used to indicate musical ability. As a test of artistic appreciation the Meier-Seashore Art Judgment Test[7] was used. The Minnesota Vocational Test for Clerical Workers,[3] containing number checking and name checking tests, was used to measure clerical ability.

Three tests were used to measure the different aspects of mechanical ability. The Likert and Quasha Revised Minnesota Paper Form Board[6] was used to measure the ability to perceive and analyze spatial or geometrical patterns in two dimensions. The short form (Boards A and B) of the Minnesota Spatial Relations test[12] was used as an apparatus test for the measurement of two dimensional spatial relations. The short form (Set I and II) of the Minnesota Mechanical Assembly Box[12] was used to measure mechanical analysis and assembling ability.

The O'Connor Finger and Tweezer Dexterity Tests[10] were used as measures of manipulative ability. The O'Connor manipulative tests and the Minnesota Spatial Relations and Assembly Boxes were given in the individual form in all instances.

THE RESULTS

The Intercorrelations among the Tests.—The correlational analysis has been almost indispensable as an aid in studying "mental" abilities.

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* Pallister[11] conducted a study in which thirty-eight applied psychologists were asked their opinions on fifty-three well-known tests. Almost all of the tests used in the present study received highly "efficient" ratings.

TABLE I.—INTERCORRELATIONS AMONG THE TESTS OF INTELLIGENCE, MUSICAL ABILITY, ARTISTIC JUDGMENT, CLERICAL ABILITY, MECHANICAL ABILITY, AND MANUAL ABILITY

N = 80

Variable	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	.29	.56	.76	.88	.35	.29	.43	.60	.19	.19	.16	.11	.16	.09	.17	.08	.20	.17	.29	.04	.11	.16
2		.44	.75	.34	.40	.29	.47	.64	.18	.04	.23	.02	.17	.07	.11	.22	.23	.30	.18	.02	.03	.01
3			.84	.29	.48	.20	.57	.66	.21	.24	.31	.08	.43	.13	.08	.36	.33	.19	.08	.14	.05	.02
4				.42	.52	.27	.70	.82	.24	.14	.31	.06	.08	.06	.15	.08	.05	.25	.28	.03	.07	.06
5					.41	.30	.82	.68	.03	.13	.11	.08	.08	.18	.16	.40	.57	.23	.08	.16	.14	.03
6						.27	.69	.70	.12	.17	.25	.05	.22	.07	.20	.07	.23	.24	.13	.08	.10	.17
7							.64	.64	.12	.04	.29	.04	.31	.18	.31	.26	.51	.00	.18	.15	.15	.10
8								.69	.18	.15	.31	.04	.31	.18	.31	.29	.37	.27	.26	.14	.12	.16
9									.18	.12	.19	.34	.52	.33	.28	.12	.15	.20	.26	.07	.18	.12
10										.38	.30	.06	.37	.13	.16	.02	.13	.22	.02	.11	.05	.18
11												.13	.26	.25	.15	.01	.18	.18	.11	.07	.06	.02
12														.61	.17	.04	.35	.22	.07	.29	.29	.06
13														.51	.04	.30	.14	.18	.07	.28	.15	.05
14															.12	.21	.63	.22	.25	.23	.03	.08
15																.07	.01	.06	.02	.45	.28	.14
16																		.13	.33		.38	.27
17																		.18				.39
18																						.35

No. 1. Thurstone Arithmetic
No. 2. Thurstone Analogies
No. 3. Thurstone Number Series
No. 4. Thurstone Q-score
No. 5. Thurstone Completion
No. 6. Thurstone Artificial Language
No. 7. Thurstone Same-Opposite
No. 8. Thurstone L-score
No. 9. Thurstone Gross Score

No. 10. Seashore Pitch
No. 11. Seashore Intensity
No. 12. Seashore Time
No. 13. Seashore Consonance
No. 14. Seashore Tonal Memory
No. 15. Seashore Rhythm
No. 16. Meier-Seashore Art
No. 17. Minnesota Number Checking
No. 18. Minnesota Name Checking

No. 19. Minnesota Paper Form Board Revised
No. 20. Minnesota Spatial Relations
No. 21. Minnesota Assembly Box
No. 22. O'Connor Finger Dexterity
No. 23. O'Connor Tweeser Dexterity

The degree of relationships among the abilities is revealed through this technique. Hierarchies of relationships indicate the possible presence of common or group factors.

The intercorrelations among all the variables are shown in Table I. The coefficients of correlation range from —.275 between the Minnesota Clerical Name Checking and the Minnesota Assembling Tests to .944 between the Thurstone L-score and the Thurstone Gross Score. However, if the Q-, L- and Gross Scores are eliminated from the table of intercorrelations, as seen in Table II, the highest correlation coefficient then becomes .625 between the Number Checking and Name Checking tests of the Minnesota Clerical. In view of the fact that the Q-, L- and Gross Scores have a somewhat dubious character, it appeared more feasible to do the computations with them included as well as without them. The presence or absence of the Q-, L- and Gross Scores seemed to have little effect on the general results.

It will be observed from Table II that the correlations are mainly positive, although rather low, thereby indicating slight degrees of interrelationships among the abilities tested. The highest intercorrelations appear to be among the tests which are components of the same ability. There is, however, considerable overlapping throughout.

The mean of the correlational matrix, that is, the mean of all the correlation coefficients in Table II, is .148. The mean of the correlation coefficients of the six intelligence sub-tests, as seen in Table III, is .339. The mean of the music sub-tests is .275. The mean of the mechanical battery, which is composed of the two spatial tests and the assembling box is .336; the mean of the three mechanical and the two manipulative tests taken together is .296. The coefficient of correlation between the number and name checking tests is .625, and the coefficient of correlation between finger and tweezer dexterity is .349.

That the correlation coefficients are higher for the tests which measure the same ability than with tests measuring the different abilities may be seen in Table III. In this table are presented the mean coefficients of correlation of the tests of the same ability taken together as well as the mean correlation coefficients for different combinations of relationship.

Certain hierarchies stand forth prominently in Table III. The relationships between intelligence and clerical number and name checking, art judgment and mechanical ability, and mechanical and manipulative ability are most outstanding. In a similar way certain negative relationships are manifested. For instance, the manipulative tests

TABLE II.—INTERCORRELATIONS AMONG THE TESTS OF INTELLIGENCE, MUSICAL ABILITY, ARTISTIC JUDGMENT, CLERICAL ABILITY, MECHANICAL ABILITY, AND MANUAL ABILITY
(With Thurstone Q-, L-, and Gross Scores Omitted)
N = 80

No.	2	3	5	6	7	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	.290	.556	.376	.252	.197	.188	.187	.165	-.110	.165	.094	.167	.079	.200	.168	.293	.040	.107	.162
2		.438	.339	.401	.286	.183	-.039	.234	.021	.165	.067	.107	.217	.228	.303	.183	.024	-.028	.005
3			.287	.476	.202	.209	.241	.312	-.085	.407	.133	.077	.361	.361	.193	.048	-.143	-.053	-.016
5				.414	.300	.098	.126	.254	-.064	.094	.132	.094	.157	.290	.236	.198	-.013	-.052	-.032
6					.269	.123	.165	.286	.050	.361	.065	.195	.400	.570	.000	.081	-.106	-.142	.132
7						.043	.035	.187	.337	.217	.334	.313	.074	.230	.365	.264	.096	-.122	.157
10							.381	.302	.080	.519	.126	.159	.123	.149	.198	.198	.145	-.172	.212
11									.132	.319	.153	.168	.023	-.025	-.115	-.118	.136	-.054	.157
12										.366	.049	.036	-.037	-.011	.025	.069	-.056	-.034	-.021
13										.258		.122	.228	.351	.056	.065	.106	.058	.017
14											.506	.066	.210	.298	.195	.253	-.223	.003	-.058
15													.012	.625	.125	.015	.253	-.293	.033
16															.180	.028	.108	-.147	.084
17																.332	.275	.029	-.033
18																	.228	.058	.231
19																	.449	.278	.360
20																		.378	.390
21																			.349

No. 1. Thurstone Arithmetic
No. 2. Thurstone Analogies
No. 3. Thurstone Number Series
No. 5. Thurstone Completion
No. 6. Thurstone Artificial Language
No. 7. Thurstone Same-Opposite
No. 4. Thurstone Q-score (omitted)
No. 8. Thurstone L-score (omitted)
No. 9. Thurstone Gross Score (omitted)

10. Seashore Pitch
11. Seashore Intensity
12. Seashore Time
13. Seashore Consonance
14. Seashore Tonal Memory
15. Seashore Rhythm
16. Meier-Seashore Art Judgment

17. Minnesota Number Checking
18. Minnesota Name Checking
19. Minnesota Paper Form Board Revised
20. Minnesota Spatial Relations
21. Minnesota Assembly Box
22. O'Connor Finger Dexterity
23. O'Connor Tweezer Dexterity

show no relationships with any of the abilities, save mechanical ability, and, to some extent, art judgment.

Factor Analysis of the Correlations.—Factor analysis represents a highly useful technique for studying organization of abilities. According to this technique, test performances in a wide variety of situations, as in the present experiment, can be reduced to a relatively small

TABLE III.—MEAN COEFFICIENTS OF CORRELATION OF TESTS MEASURING ASPECTS OF SAME ABILITY AND OF DIFFERENT ABILITIES
(Based on the Intercorrelations of Table II)

Intercorrelations	Range of r's	Mean r
Intelligence tests alone	.197-.476	.339
Music tests alone	.049-.519	.275
Mechanical tests alone	.228-.449	.336
(Mechanical-manipulative tests combined)	.058-.449	.296
Intelligence and music	-.110-.407	.125
Intelligence and art	.077-.313	.168
Intelligence and clerical	.063-.570	.257
Intelligence and mechanical	-.156-.303	.090
Intelligence and manipulative	-.171-.162	-.025
Intelligence and (mechanical-manipulative combined)	-.171-.303	.044
Music and art	.036-.168	.117
Music and clerical	-.025-.351	.134
Music and mechanical	-.223-.365	.107
Music and manipulative	-.058-.212	.034
Music and (mechanical-manipulative combined)	-.223-.365	.078
Art and clerical	-.012-.142	.065
Art and mechanical	.195-.290	.246
Art and manipulative	.033-.293	.163
Art and (mechanical-manipulative combined)	.033-.293	.213
Clerical and mechanical	-.275-.180	-.015
Clerical and manipulative	-.147-.029	-.099
Clerical and (mechanical-manipulative combined)	-.275-.180	-.049
Mechanical and manipulative	.058-.390	.267

number of experimentally determined reference abilities, such as verbal ability, numerical ability, and the like. It is particularly useful in cases such as the present where there is considerable overlap among the correlations. In the factor analysis technique the vast number of correlations are reduced to a relatively small number of fundamental abilities.

The Thurstone centroid multiple factorial analysis[17] was used to determine the loadings for the four extracted factors in Table IV. The

Thurstone method of factor analysis is applicable to a large number of variables and factors, and is not dependent upon the absence of group factors for its application. Moreover, it aims to give a more comprehensive analysis than tetrad analysis of the factors involved since the first factor loadings are supposed to give the same information as tetrad analysis.

The symbol h^2 stands for the communality of the test, which represents the sum of the square of the factor loadings for each variable. If the communality is equal to unity there are no specific factors present. The variance, or what Thurstone calls the "uniqueness" of a test equals $1 - h^2$. This indicates the extent to which specific factors (including the sampling errors) are present. The factor loadings squared indicate the percentages of variance in each test attributable to each factor. The sum of the factor loadings squared for each factor divided by the number of variables ($\Sigma K^2/N$) indicates the total variance for each factor. This corresponds with the sum of the communality (h^2) divided by the number of variables.

The factor loadings in both tables remain relatively unmodified whether or not the Q-, L- and Gross Scores are included. Since these variables were determined through previous factor analysis, they are consequently omitted in this one.

Factor I appears to be a general factor. It is present in all the variables, although in varying degrees. Factor I accounts for eighteen per cent of the total variance of the tests; Factor II for approximately eleven per cent variance; Factors III and IV for seven and four per cent, respectively. In all, the four factors account for about 40 per cent of the variance. The communalities indicate that from twenty-one per cent to sixty-two per cent of the variance of the individual variables is accounted for by the four factors. It could, therefore, be stated with much certainty that specific factors are present.

Although all of the variables are positively loaded with Factor I, it can be seen that there are large differences in some of the weightings. There seems to be no definite hierarchy of high loadings, thereby indicating that Factor I is a general integrating factor. There are some considerably low loadings in this factor. These are for the manipulative tests, including the Mechanical Assembly Box, which involves work with the hands. The Consonance test and the Same-Opposite test also reveal low factor loadings. The latter are extremely unreliable tests.

TABLE IV.—FACTOR LOADINGS FOR VARIABLES WITH THURSTONE Q- AND L- AND GROSS SCORES OMITTED

(Four Factors, Determined by Thurstone Centroid Method)

$N = 80$

Test	Factors								
	I	II	III	IV	I²	II²	III²	IV²	h^2
1	.486	.089	.441	−.263	.236	.008	.194	.069	.507
2	.485	.231	.260	.172	.235	.053	.068	.030	.386
3	.566	.426	.159	−.281	.320	.181	.025	.079	.605
5	.445	.188	.280	.072	.198	.035	.078	.005	.316
6	.559	.433	−.011	.252	.312	.187	.000	.064	.563
7	.299	.312	.221	.201	.089	.097	.049	.040	.275
10	.566	−.260	−.333	−.226	.320	.068	.111	.051	.550
11	.438	−.194	−.170	−.208	.192	.038	.029	.043	.302
12	.430	.102	−.096	.049	.185	.010	.009	.002	.206
13	.157	−.180	−.374	.172	.025	.032	.140	.030	.227
14	.583	.194	−.453	−.202	.340	.038	.205	.041	.624
15	.304	.199	−.376	−.190	.092	.040	.141	.036	.309
16	.400	−.174	.186	.185	.160	.030	.035	.034	.259
17	.361	.367	−.208	.119	.130	.135	.043	.014	.322
18	.485	.489	−.171	.161	.235	.239	.029	.026	.529
19	.505	−.204	−.066	.199	.255	.042	.004	.040	.341
20	.429	−.459	.209	.121	.184	.211	.044	.015	.454
21	.190	−.631	.233	.163	.036	.398	.054	.027	.515
22	.199	−.459	.239	−.162	.040	.211	.057	.026	.334
23	.186	−.473	.106	−.184	.035	.224	.011	.034	.304
ΣK^2					3.619	2.277	1.326	.706	7.927
$\Sigma K^2/N$					.181	.114	.066	.035	.396

1. Thurstone Arithmetic
2. Thurstone Analogies
3. Thurstone Number Series
5. Thurstone Completion
6. Thurstone Artificial Language
7. Thurstone Same-Opposite
10. Seashore Pitch
11. Seashore Intensity
12. Seashore Time
13. Seashore Consonance
14. Seashore Tonal Memory
15. Seashore Rhythm

16. Meier-Seashore Art
17. Minnesota No. Checking
18. Minnesota Name Checking
19. Minnesota Paper Form Board (Revised)
20. Minnesota Spatial Relations
21. Minnesota Assembly Box
22. O'Connor Finger Dexterity
23. O'Connor Tweezer Dexterity

Factor II has very high negative loadings for all the mechanical and manipulative variables. The highest positive loadings are for the Clerical Number and Name Checking tests, and the Thurstone Number Series, Artificial Language, and Same-Opposite tests. In a centroid factor analysis negative and positive signs may be changed arbitrarily
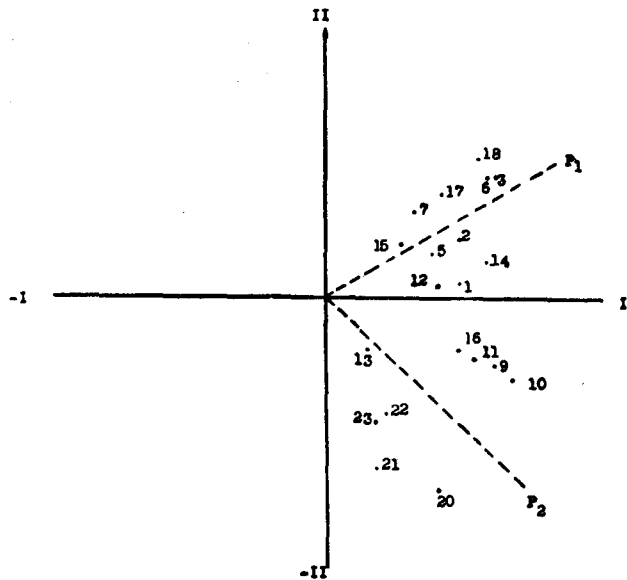
Fig. I.—Correlation between Factors I and II. (Variables Q-, L-, and Gross Scores omitted.)

without altering the results. Factor II would, therefore, appear to be a factor related to mechanical and manipulative ability. The previously indicated hierarchy between Clerical Number and Name Checking as well as the relationship between these abilities and some of the intelligence sub-tests appears to be verified. It would seem then that Factor II is comprised of two subfactors. One combines the group factors of mechanical and manipulative abilities and the other embraces to an appreciable extent the intelligence and clerical group factors.

Factor III apparently has its highest correlations, on the whole, with the tests of musical ability if the signs are interchanged. There seems to be a slight correspondence between musical ability and clerical ability, as well as between intelligence and mechanical-manipulative ability.
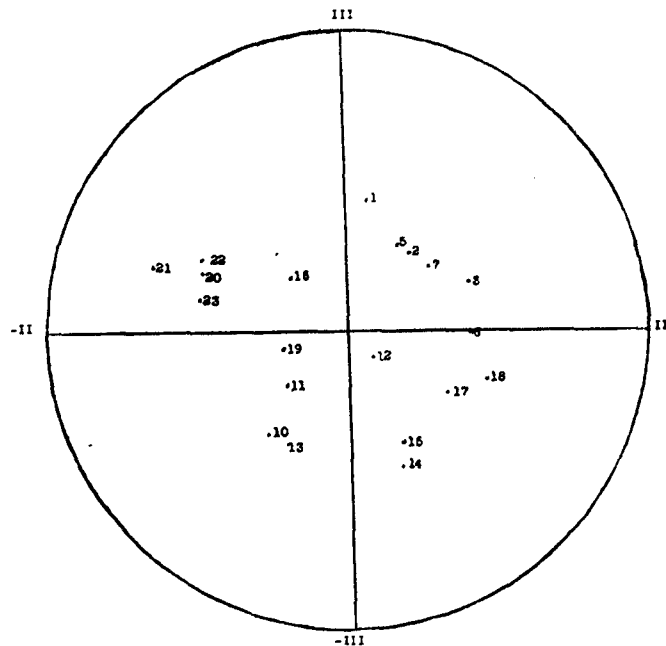

Fig. II.—The relations among Factors I, II, and III. (Axis I considered as being perpendicular to the surface of the chart.)

Factor IV shows few high loadings. Some of the facts revealed in this factor, nevertheless, are that the Analogies test may be considered as much verbal as it is quantitative. Also revealed is the consistent relationship between the Art Judgment test and the mechanical and manipulative tests. Also, the relationships, albeit low, between clerical and art judgment, and clerical and mechanical abilities are disclosed.

The degree of relationship between factors can be determined by finding the cosines of the angles between the vectors which are the expressions of the factor loadings. Figure I represents a two-dimensional relationship between Factors I and II, with complete disregard as to the remaining factors. The variables from Table IV are plotted with respect to these two factors. Line P_1 is the average of the positive coördinates and P_2 the average of the negative coördinates. The angle (ϕ) between the two vectors is approximately 76 degrees. The correlation between Factors I and II, which is the cosine of a 76-degree angle, is .242.

With respect to a three-factor relationship it is necessary to describe the variables in a tri-dimensional structure. That is, the factor loadings are plotted on the surface of a sphere. Factor IV appears to be relatively insignificant and is, therefore, omitted. Figure II gives a bird's-eye view of the pattern of the augmented factor loadings plotted on the surface of a sphere, axis I being considered as perpendicular to the surface of the paper. From this figure it can be seen that simple structure is not obtained because of the difficulty in confining the loadings within a right spherical triangle. Distinct and clearcut clusters are absent, revealing minor ones only. The lack of simple structure makes it difficult to measure the relations among the three factors. It is apparent, however, that the factors are not orthogonal. Therefore, Factors I, II, and III are apparently interrelated.

DISCUSSION OF RESULTS

The positive correlations among the abilities tested, the tendency toward hierarchical formation, the overlapping among the correlations and the factor loadings, and the correlations among the factors which are present in these abilities, tend to demonstrate that abilities instead of existing independently are in dynamic relationship with one another. Positive correlations are reported in almost all biometrical and psychological studies. However, no further consideration is given to this fact other than to submit as an explanation the rather vague hypothesis that natural selection favors positive correlations or that "desirable qualities in mankind tend to be positively correlated." Even if Thomson were correct in this Lamarckian hypothesis, it ought not to preclude the concept of functional relations of the abilities. Yet his sampling theory seems to exist in total disregard of this fact. The

consistent appearance of positive correlations between abilities, even though the correlations are often extremely low, indicates that the explanation must extend beyond the simple realm of chance relationship.

In a study involving clerical number and name checking, Andrew[2] reported all correlations as positive among the tests of various abilities. This indicated "the existence of a general factor, while relatively high correlations indicate the presence of group factors, or in other words overlapping." She stated also that multiple factor analysis " . . . indicates that a common factor runs through all the tests and in addition there are minor group factors." Despite these statements Andrew's general conclusion was that the Minnesota Clerical Test "is measuring a specific ability which is relatively independent of spatial, academic, and dexterity abilities." The existence of hierarchies among the abilities was given little consideration except by Spearman and his colleagues.

The correlations among the factors found in the present investigation seem to be confirmed in other studies. Garrett[4] found in multiple factor analyses of the results involving different abilities that positive correlations existed between the group factors which had been isolated. Thus, in one analysis, he found a correlation of .225 between the numerical and verbal factors. In analyzing a second group of data he reported respective correlations of .825 between the verbal and numerical factors, .273 between the verbal and non-language (performance) factors, and .296 between the numerical and non-language factors. He found in analyzing the Anastasi studies, however, that the memory factor was independent of both the verbal and numerical factors. The angles were orthogonal, the correlations being .00 and −.085 between the memory factor and the numerical and verbal factors, respectively.

Murphy[9] found that the primary traits, in the investigation of the relation between mechanical ability and intelligence, were "oblique rather than orthogonal," while Morris,[8] in contrast, reported that the "mental traits . . . are orthogonal, or in other words, they are independent mental traits."

The results obtained here indicate the presence of specific and group factors which are coördinated through the presence of a common factor. In this respect, these findings seem to be analogous to those of Spearman. The specific factors are revealed in the rather low communalities while the group factors are shown in the isolated factors. Factor I,

the configurational or coördinating factor, integrates the abilities into ordered activity.

It is not at all clear whether the *g*-factor of Spearman is similar to this configurational factor, since Spearman has never committed himself specifically on this point. It does appear, however, that the *g*-factor is the sum of all the factors instead of one which integrates the mental functions.

On the basis of this, therefore, the specific factors are separate and independent. They are related only through the additive process, the *g*-factor, which is present to some degree in all the specific and group factors but does not coördinate them. Thus, the Spearman two-factor theory represents a static system and is apparently incomplete for explaining the results obtained here. More adequate agreement with the results, however, is found if one accepts Alexander's modification of the theory whereby he emphasizes the inseparable quality of the group factors as well as the interrelationship among these factors.

The "primary abilities" of Thurstone and the "unique traits" of the University of Minnesota group are representative of a mechanical and atomistic explanation. The independent existence of abilities according to these explanations is indicative of a behavioral anarchism whereby each ability is isolated and specific. That abilities are by no means absolutely specific and diverse is apparent in the existence of considerable overlapping of function. Thurstone contradicts the concept of independent functions by reporting oblique rather than orthogonal relations among the factors in several studies.[19]

If what is commonly called mental activity is regarded as the ordered and integrated expressions of the total personality, then these expressions as a consequence must be considered as in functional relationship instead of static and isolated phenomena. Modern psychological knowledge indicates that the behavior of the organism is not a congeries of disparate faculties but rather an organismic unity in which there is a dynamic relationship between functional and structural aspects. The performance of an act by an individual involves the total personality. Thus excellence in a single ability can not be attributed to a specific faculty of some kind. Such an explanation represents an evasion. An explanation more in keeping with most recent experimentation would attribute such behavior to circumstances which favor the appropriate combination of environmental and hereditary factors expressed through the total organization of the personality.

Insight into the organization of abilities is offered by the factor analysis technique. Practically all of the experimental analyses contradict the conception of independence among human abilities. Thurstone asserts, "The cosine of the angular separation of each pair of primary trait vectors is the correlation between the corresponding primary traits in the experimental population. It will probably be found that these correlations are positive." In *The Vectors of Mind* he indicates several studies with positive correlations among the "traits." In a separate study of vocational interests, after having factored out eight primary interests, Thurstone states, "These reference factors are not all uncorrelated. Several of them have intercorrelations of .25 or .30 in the experimental population but most of them have zero correlations."[18]

Although the theory of primary mental abilities seems to have been founded upon the idea that abilities are independent (orthogonal), Thurstone has of late given definite indications of deviating from this belief. He says, "Among statisticians and psychologists there is a rather general belief that if human traits are to be accounted for by any kind of factors, then these factors must be uncorrelated. The geometrical representation of uncorrelated factors is a set of orthogonal reference vectors. This belief has its origin in the statistical and mathematical convenience of uncorrelated factors and also in our ignorance of the nature of the underlying structure of mental traits. Since we know so little about them and since it is statistically convenient to use uncorrelated reference traits, the insistence on orthogonality can be understood, but it cannot be justified." He states at various times that factor analysis " . . . assumes that a variety of phenomena within the (mental) domain are related and that they are determined, at least in part, by a relatively small number of functional unities, or factors"; or that " . . . mind is not a patternless mosaic of an infinite number of elements without functional groupings"; or "The factors are probably functional groupings, and it is a distortion to assume that they must be elemental"; and finally, " . . . the results point to the conclusion that mind is not a structureless mass, but that it is structured into constellations or groupings of processes that can be identified as distinct functions in the test performances. These are what I have called primary mental abilities or traits."

That these primary abilities are independent at least in part still remains the thesis of Thurstone. In opposition to this, however, it is

recognized that human abilities do not follow the so-called all-or-none hypothesis. Instead, the presence of these abilities is shown to exist in all cases in varying degrees, depending upon different hereditary and environmental factors. These abilities are dynamic expressions of the total personality; hence they exist in functional relationship to each other. This appears to have been shown in the present investigation.

SUMMARY AND CONCLUSIONS

Eighty relatively homogeneous male college students were given in a random manner the Thurstone American Council on Education Psychological Examination for College Freshmen, the Seashore Measures of Musical Talent, the Meier-Seashore Art Judgment Test, the Minnesota Vocational Test for Clerical Workers, the Likert-Quasha revision of the Minnesota Paper Form Board, the short form of the Minnesota Spatial Relations Test, the short form of the Minnesota Assembly Test, and the O'Connor Finger and Tweezer Dexterity Tests. In summary the salient findings of the present experiment seem to be the following:

(1) The intercorrelations among the variables are on the whole positive but low. There is considerable overlapping throughout the intercorrelations. The highest intercorrelations appear among the tests which bear the name of the same ability (*i.e.*, the intelligence tests). Hierarchies among certain of the abilities are apparent.

(2) Four factors are found by means of the Thurstone "center of gravity" technique, of which three seem to be important. Factor I seems to be a general, integrating factor. Factor II seems to be made up of two "subfactors," one combining the group factors of the mechanical and manipulative abilities and the other combining the intelligence and clerical group factors. Factor III indicates relationships between musical ability and clerical ability as well as between intelligence and mechanical ability. Consistent relationship between art judgment ability and mechanical ability appears in the factors. There is considerable overlapping among the factors. They seem to be interrelated instead of completely independent of each other.

By virtue of these findings, it would appear that the Spearman and Thurstone theories are inadequate for explaining the relationships expressed in this study. Rather must one conclude with the hypothesis that the abilities here tested are not disparate and static abilities, but t' at they are, instead, functional and dynamic relationships within

the total personality. This organismic conception seems to be in closer conformity to modern psychological theory than the previously reported atomistic hypotheses.

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