THE INTERRELATION OF MENTAL FUNCTIONS

by

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CHAPTER I

INTRODUCTION

That branch of science which measures, or attempts to measure, mental functions and their interrelations is of quite recent origin and development. A few men considered the problem of mental measurement, and conducted some investigations, during the last two decades of the nineteenth century, but the methods used and results obtained were almost hopelessly confused, so that the findings of different investigators could not be satisfactorily compared.

In 1901, some pioneers in this field published results of investigations conducted in a manner somewhat similar to present day methods, though both methods and results were very indefinite. Since that time several other men have made investigations in this new branch of science, sweeping statements have been made and disputed, radical theories have been advanced and attacked. Some experimenters have believed that a solution of all, or at least most, of the problems had been discovered, but further investigations have not justified their extreme optimism.

Perhaps it is still too early to predict the final outcome, but progress is being made, and as methods of procedure become more definite and uniform, results may also become more consistent. The aim of this dissertation is to review the most important results published up to the present time, and to add a statement and discussion of results obtained in the laboratory of educational psychology at the University of Missouri.

CHAPTER II

PREVIOUS INVESTIGATIONS

In 1901, W. C. Bagley completed a study of the correlation of mental and motor ability in school children.[1] The scores in motor ability were based on teachers' ratings, and on tests of strength, rapidity, accuracy, control and involuntary movement. The classification of mental ability was based on class standing, and on tests of reaction time. The subjects were 110 pupils.

The author gives the following summary of results: "Under the conditions of the investigation, and with the children that were tested, there is a general inverse relation between motor and mental ability; those who are the 'brighter' pupils and those who have the quickest reaction time being, as a rule, deficient in motor ability, while those who are best developed physically, who are the strongest, who have developed motor 'control' to the greatest extent, are generally deficient in mental ability. This rule, however, was found, with the children tested, to have numerous individual exceptions, and a varying validity at different periods of development.

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1 - Bagley, American Journal of Psychology, 1901, pages 193 - 205.

There seems to be little direct relation between mental ability as represented by reaction times, and mental ability as represented by class standings, except that excellence in either of these directions is apt to be accompanied by a deficiency in motor ability.

There is a gradual increase of motor ability with age. The increase in mental ability is not so well marked.

In general, the boys slightly surpass the girls in motor ability, while the reverse obtains in mental ability.

Regarding cranial capacity as indicated by the head girths, we notice a significant trend toward an inverse relation between mental ability and head girth."

In 1901, Clark Wissler published the results of an investigation.[2] He had tested over 200 college students, using simple mental tests, and had correlated the results of these tests with one another and with the students' marks in the various subjects of the college curriculum. The correlation coefficients obtained were small.

In 1902 Aikens and Thorndike published the results of tests given to 240 boys and girls of the fifth and eighth grades.[3] Although the functions which they studied

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2 - Wissler, Psychological Review, Monograph Supplement, June 1901, Vol. 3, No. 16, pages 62ff.

3 - Aikens and Thorndike, Psychological Review, 1902, Vol. 9, pages 374 - 382.

were more similar to one another than those studied by Wissler, the correlations were again low. The tests were the following: marking misspelled words, marking r and e, hard opposites, easy opposites, alphabet test (writing beside each of a list of letters the letter that comes before it in the alphabet), and examples in addition.

The correlation method was based on rank, and distance from average. The results varied widely, the correlations ranging from 0 to .60, though only one (alphabet and easy opposites) exceeded .50. Hard opposites and easy opposites gave .40. Hard opposites and alphabet gave .22. Addition correlated with the amount done in the three combined association tests gave an average coefficient of .51.

The author's conclusions are as follows: "The results reinforce the evidence showing that functions apparently closely similar may really be to a large extent independent specializations. For instance, the ability to call up quickly the opposites of good, rich, heavy, etc., is by no means identical with ability to call up quickly the letters coming before c, k, t, and e, or with the ability to call up quickly the answers to 7 + 4, 11 + 9, 20 + 6, etc. 'Quickness of association' as an ability determining the speed of all one's associations is a myth. Quickness in noticing words containing the two letters r and e does not to any appreciable extent involve quickness in noticing words grossly misspelled, nor does accuracy in the one involve anything like equal accuracy in the other. The 'attention' and 'discrimination' required in the two cases must therefore be different things.

"Our results also suggest the possibility of clearly defining the classes of functions which we may expect to find closely related. For in the tests involving quickness and accuracy in purposive associations there is much closer dependence than in the tests involving quickness and accuracy of perception, though to the speculative psychologist the latter would seem to be cases of the same function." (p 375)

The importance to general psychological theory of measures of the relationship of different mental functions is obvious. Where introspective analysis fails to discover the exact structure of a mental process, the study of its relationships with other better known functions may succeed. Moreover the whole question of the influences of heredity, maturity and training will be illuminated by a knowledge of the necessary bonds and interactions of the different mental processes."

In 1904, C. Spearman published the results of five series of tests, dealing with simple forms of psychical activity in connection with hearing, sight, and touch.[4] His purpose was to measure sensory discrimination by these tests, and compare the results with general intelligence as estima-

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4 - Spearman, American Journal of Psychology, 1904, Vol. 15, pages 201 - 293.

ted from school standing, with allowance made for age, impression produced upon other people, and common sense. Most of the subjects were school children.

All important correlations were worked out by Pearson's product moments formula. Two sorts of corrections were used, aimed at eliminating irrelevant factors and observational errors, respectively. By this means, some rather high correlations were obtained.

The author concludes that "There really exists a something that we may provisionally term 'General Sensory Discrimination' and similarly a 'General Intelligence', and further that the functional correspondence between these two is not appreciably less than absolute. Whenever branches of intellectual activity are at all dissimilar, then their correlations with one another appear wholly due to their all being variously saturated with some common fundamental function (or group of functions)."

He gives the following summary of conclusions indicated by the foregoing experiments:

1. The results hitherto obtained in respect of psychic correlation would, if true, be almost fatal to experimental psychology as a profitable branch of science. But none of these results, as at present standing, can be considered to possess any value other than suggestive only; this fact is not so much due to individual shortcomings of the investigators, as to the general non-existence of any adequate sys-

tem of investigation .

2. On making good this methodological deficiency, there is found to actually occur a correspondence -- continually varying in size according to the experimental conditions -- between all the forms of Sensory Discrimination and the more complicated Intellectual Activities of practical life.

3. By this same new system of methodics, there is also shown to exist a correspondence between what may provisionally be called 'General Discrimination' and 'General Intelligence' which works out with great approximation to one or absoluteness. Unlike the result quoted in the preceding paragraph , this phenomenon appears independent of the particular experimental circumstances; it has nothing to do with the procedure selected for testing either Discrimination or Intelligence, nor with the true representativeness of the values obtained by these tests, nor even with the homogeneousness of the experimental reagents; if the thesis be correct, its proof should be producible at all times, places, and manners -- on the sole condition of adequate methodics.

4. The above and other analogous observed facts indicate that all branches of intellectual activity have in common one fundamental function (or group of functions), whereas the remaining or specific elements of the activity seem in every case to be wholly different from that in all the others. The relative influence of the general to the specific function varies in the ten departments here investigated

from 15.1 to 1.4.

5. As an important practical consequence of this universal Unity of the Intellectual Function, the various actual forms of mental activity constitute a stably inter-connected Hierarchy according to their different degrees of intellective saturation. Hence, the value of any method of examination as to intellectual fitness for any given post is capable of being precisely ascertained, since it depends upon: a. the accuracy with which it can be conducted; b. the hierarchical intellective rank of the test; c. the hierarchical intellective rank of the duties invovled in the post.

Methods have been given whereby all these three points can be sufficiently ascertained.

6. Discussion as to the psychical nature of this fundamental Function has been reserved until a more complete acquaintance has been gained concerning its objective relations. Among the latter, the principal and determining one is its unique position as indicated in paragraph 4. The chief further evidence is to the following effect:

The function appears to become fully developed in children by about their ninth year, and possibly even much earlier. From this moment, there normally occurs no further change, even into extreme old age.

In adult life, there would seem no appreciable difference between the two sexes.

The Function almost entirely controls the relative position of children at school (after making due allowance for differance of age), and is nine parts out of ten responsible for success in such a simple act as Discrimination of Pitch.

Its relation to the intellectual activity does not appear to be of any loosely connected or auxiliary character (such as willingness to make an effort, readiness in adaptation to unfamiliar tests, or dexterity in the fashion of executing them) but rather to be intimately bound up in the very essence of the process."

In 1909, Thorndike, Lay and Dean published results of experiments to determine the relation between accuracy in sensory discrimination and general intelligence.[5]

There were two groups of subjects; consisting of 37 young women students in a normal school, and 25 boys in the third year of a high school. Tests of sensory discrimination consisted in matching lines of standard lengths and matching standard weights. General intelligence was measured by estimates of teachers and fellow students, also by scholastic records.

Combining the results of tests in sensory discrimination, and combining the measures of general intelligence, the two sets of measures were compared with each other. The resulting correlations in the two groups give an average of about .23 instead of 1.00 as asserted by Spearman. The different measures of sensory discrimination show an intercor-

5 - Thorndike, Lay and Dean, American Journal of Psychology, 1909, Vol. 20, pages 364 - 369.

relation with one another of .25 to .69. Intercorrelations between measures of general intelligence were higher.

Thorndike sums up the conclusions as follows: "In general there is evidence of a complex set of bonds between the psychological equivalents of both what we call the formal side of thought and what we call its content, so that one is almost tempted to replace Spearman's statement by the equally extravagant one that there is nothing whatever common to all mental functions, or to any half of them."

In 1909, Cyril Burt published a detailed account of some experiments on children, which he had begun with a view to making a practical test of Spearman's mathematical methods, also to verify Spearman's and Meumann's experimental results.[6]

He tested two groups of subjects, age limits 12.6 to 13.6. The first was a group of 30 boys from an elementary school, the second was a group of 13 boys from a preparatory school. The tests were classified as follows: Sensory; discrimination of weights, pitch, and length of lines, and measurement of spatial threshold. Motor; rate of tapping, and carddealing. Sensori-motor; cardsorting and alphabet finding. Association; immediate memory, mirror test, and spot pattern test. Voluntary attention; dotting test. Burt also obtained a measure of imputed intelligence, from judg-

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6 - Burt, British Journal of Psychology, 1909, Vol. 3, Parts i and 2, pages 94 ff.

ments of teachers and school fellows.

The tests were given individually, and repeated at least once. The reliability coefficients were rather high, only seven out of the twelve falling below .6, and only two of these falling below .5.

The author draws the following conclusions:

Simple Sensory Tests

"There appears to be no general connection between Intelligence and capacity to discriminate Weights; any general connection between Intelligence and Tactile Discrimination, if it exists, is of the slightest; there is considerable general connection between Intelligence and Pitch Discrimination; and an undoubted general connection between Intelligence and Visual Discrimination of lengths, though not to such an extent as in the case of Pitch Discrimination."

The correlations obtained by Dr. Spearman follow the same increasing order, namely, Weight, Vision and Sound.

Simple Motor Tests

Of the two forms of simple motor test, Tapping seems a more satisfactory method than Dealing, especially as its defects could largely be remedied by improved apparatus, while those of Dealing cannot. Motor tests seem to have a higher correlation with Intelligence than Sensory tests. Here the correlation between the tests and Intelligence seems more direct, and more likely to be the outcome of a central factor, than in the case of the Sensory tests.

Compound Sensori-Motor Tests

Depending as they do for their performance upon processes of a more complex nature and a higher mental level, tests combining perception with motor reaction seem to involve intelligence to a still higher degree than relatively simple sensory or motor tests. Of the two above discussed, the Alphabet seems to be in practice far the more efficient.

Association and Attention Tests

According to the corrected coefficients, these last four tests - Memory, Mirror, Spots and Dotting - have pure correlation with intelligence, on the whole, the highest of all. In general purpose, as well as in results, these last four tests seem to fall together. The Dotting test was devised specifically to test attention. The three other tests have been classed as tests of Association, but Attention is also a particularly essential factor.

General Conclusions

Diagnosis of Intelligence

Of the twelve tests correlated with imputed intelligence, six (simple sensory and motor) furnish coefficients below .50 and six (compound sensori-motor, association, and voluntary attention) above .50. On making a grand average of the second six gradings and arranging the boys accordingly, we obtain a list corresponding with the Headmaster's order to the extent of .85 at the Elementary School and .91

at the Preparatory School. By means, then, of some half dozen tests, we can arrange a group of boys in an order of intelligence, which shall be decidedly more accurate than the order given by scholastic examinations, and probably more accurate than the order given by the master.

The Analysis of Intelligence

High Intelligence seems to mean high capacity for continually systematizing mental behavior by forming new psychophysical coordinations, older coordinations being retained, so that newer coordinations bring with them increased complexity and incessant change. In such progressively integrative actions of the mind the efficient and directive agent is attentive consciousness. And in this sense we may agree that so called 'Voluntary' Attention is, of all recognized psychological processes, the essential factor in General Intelligence." (See Tables VIII and IX for results)

In 1911, Cyril Burt published the results of another investigation[7] From the results of a previous series of mental tests, conducted at Oxford, the author had found seeming indications that all the mental activities tested were prevaded, more or less, by a single fundamental capacity, forming, as it were, their greatest common measure. This universal ingredient has been identified with "general in-

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7 - Burt, Journal of Experimental Pedagogy, 1911, Vol. 1, pages 93 - 112.

telligence", and seems to be inherited and innate, rather than acquired. The correlations showed that, roughly speaking, the more complex the mental process involved and the higher the mental level tested, the more completely did the experimental results correspond with the empirical estimates of intelligence.

In 1910 the author began a further investigation at Liverpool, the primary object being to elaborate tests of an even higher and more complex order than those previously used, which should yield yet larger correlation with intelligence than the largest yielded by the Oxford tests. About 100 school children served as subjects.

The names of the tests used, and the correlation of each with intelligence, are as follows: Pearson coefficients being calcuted from Spearman's formula for R; Alphabet .42; Division of lines, cutting off one half .08, cutting off one third .19, cutting off one fourth .25, cutting off two fifths .21; Erasure of letters .39; Addition .25; Multiplication .41; Speed of reading, aloud .26; silently .21; Speed of writing .42; Association of words, .13; Answering questions .35; Formation of sentences .62; Completion of analogies, group .52, individual .50; Completion of sense, story, .48, argument .53; Reconstruction of pictures, group .72, individual .46; Apprehension of number .64; Syllogisms, group, .45, individual .51

The author's final conclusion is as follows: "Of all the tests proposed, those involving higher mental processes, such as Reasoning, vary most closely with Intelligence, and are least vitiated by variations with irrelevant conditions, such as Sex, Social Status, Training of the experimenter, and Mass-measurement of numbers of children at once."

In 1911, William Brown published the results of experiments with six groups of subjects, of various grades from elementary pupils to university men and women.[8] The numbers of subjects in the different groups ranged from 23 - 66.

In all, 14 tests were given, as follows: (1) Crossing e and r in a page of print; (2) Crossing a,n,o, and s in a page of print; (3) Crossing every letter in a page of print; (4) Adding up single digits in groups of ten, measuring speed and accuracy; (5) Bisecting ten printed lines (80 mm long) and putting in one of the points of trisection in each of ten other lines (90 mm long); (6)Müller-Lyer Illusion, measuring size and mean variation; (7) Vertical-horizontal Illusion, measuring size and mean variation; (8) Mechanical Memory (permanent), tested by means of nonsense syllables; (9) Memory for poetry; (10) Combination test (Ebbinghaus). In two groups, the following tests were also used: (11) Marks for drawing; (12) Total school marks; (13) Grading for

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8 - Brown, Essentials of Mental Measurement, Cambridge University Press, 1911.

general intelligence (two independent measures). In the case of other two groups, the following test was also employed: (14) Association-time (uncontrolled), measuring rate of sequence of ideas called up by a stimulus-word. Most of the tests were applied twice, at intervals of about two weeks.

The author states his conclusions as follows: (See Tables I and II).

"1. The correlation between different psychical abilities is not very close. Few coefficients are greater than .6.

2. The size of the correlation coefficient varies greatly from one group of subjects to another. This shows how great is the danger of spurious correlation due to heterogeneity of material, in psychical measurements.

3. The Combinations-Methode of Ebbinghaus is a good measure of intellectual ability. It correlates with "general intelligence" almost as closely as "scholastic intelligence" (school marks) does.

4. Mechanical memory correlates fairly closely with intelligence.

5. Drawing also correlates closely with intelligence in the case of higher grade school boys. On the other hand, for girls of the same age the correlation is nil.

6. The susceptibility to the Müller-Lyer Illusion is not at all closely correlated with that to the Vertical-Horizontal Illusion. This indicates that the factors involved are for the most part different in the two cases.

TABLE I

Brown's Results. Pearson Coefficients of Correlation

(Top line, Group I; 2nd line, Group II;

3rd line, Group III)

	Marking er	Marking anos	Ebbinghaus Test	Mechanical Memory	Memory of Poetry	Addition -Speed-	Addition -Accuracy-	Motor All Letters	Bisection	School Marks	General Intelligence
Marking e r.		78 80 74	45 -15 00	40 00 00	27 23	59 13 35	30 00 00	53 49 25	00	 00 30	 00 28
Marking a n o s. . .	78 80 74		48 00 10	29 20 00	28 14	51 00 20	24 00 -11	21 21 00	00	 27 17	 13 10
Ebbinghaus test. . .	45 -15 00	48 00 10		52 37 28	52 44	40 -13 32	38 -25 00	13 00 28	15	 54 60	 43 69
Mechanical Memory. .	40 00 00	29 20 00	52 37 28		49 -1[illegible] 38	27 -13 00	31 -23 00	14 00 00	10	 59 40	 55 49
Memory of Poetry . .	27 23	28 14	52 44	49 38		41 00	38 -11	12 19	13	 60	 57
Addition (Speed) . .	59 13 35	51 00 20	40 -13 32	27 -13 00	41 00		13 24 33	25 33 20	00	 00 28	 10 24
Addition (Accuracy).	30 00 00	24 00 -11	38 -25 00	31 -23 00	38 -11	13 24 33		00 30 00	41	 00 11	 00 00
Motor (all letters).	53 49 25	21 21 00	13 00 28	14 00 00	12 19	25 33 20	00 30 00		00	 00 23	 13 32
Bisection.	00	00	15	10	13	00	41	00			
School Marks	00 30	27 17	54 60	59 40	 60	00 28	00 11	00 23			64 78
General Intelligence	00 28	13 10	43 69	55 49	 57	10 24	00 00	13 32		64 78	

7. The "mean variation" of the Vertical-Horizontal Illusion is positively related to the size of the illusion (Group I .21 ± .08, Group III .33 ± .10).

8. In the case of the Müller-Lyer Illusion, there is a zero or slightly negative correlation between M. V. and size.

9. The two optical illusions correlate differently with drawing, the Müller-Lyer negatively (Group II -.44 ± .09, Group III -.19 ± .10), the Vertical-Horizontal positively or not at all (Group II .27 ± .10, Group III 0).

10. The mean variation of the illusions show a zero or very slight negative correlation with other measures of mental ability.

11. The correlation between speed and accuracy of mental performance is slightly non-linear.

12. Correlations may be very low even within a set of mental tests which appear to measure closely related mental abilities, and this when the reliability coefficients are high. Thus, the correlation between erasing the letters a, n, o, s and erasing all the letters, is less than three times the probable error in every group tested. For "erasing the letters e, r" constant, the partial correlation is negative and numerically greater than 3 P. E. in each group.

13. In homogeneous groups of subjects there is no positive evidence of the existence of one "central factor" to which the correlation between the individual mental abilities may be regarded as due.

14. There is in several cases a pronounced correlation between ability and variability. This may be either positive or negative. It is, e.g., positive for speed in adding figures, negative for accuracy.

15. There is definite evidence that variability, as measured by the coefficient of variation, is greater in boys than in girls. Differences in correlation, though sometimes appreciable, seem to follow no well defined rule."

TABLE II

Brown's Results

Pearson Coefficients of Correlation

(Top line, Group IV; 2nd line, Group Va)

	Ebbinghaus Test	Addition - Accuracy	Addition - Speed	Mechanical Memory	Marking er	Association Time
Ebbinghaus test		53 -16	34 19	31	[illegible] 19	 33
Addition (accuracy)	53 -16		43 38	20	 -26	 39
Addition (speed)	34 19	43 38		18	 00	 37
Mechanical Memory	31	20	18			
Marking e r	19	-26	00			18
Association time	33	39	37		-18	

In 1912, B. R. Simpson published[9] the results of a series of experiments in which fifteen tests were used, which may be divided into groups as follows: two of perception; marking "a" and marking geometrical forms; three of memory, memory of unrelated words (auditory), memory of passages (auditory), and recognition of 25 forms studied, amongst 50 shown later; four of association, addition, easy opposites, associating words with hieroglyphic forms in pairs, and adding letters to make ba, ca, ...be,ce, etc., into words (referred to as the ba or completing words test); three of selective thinking, hard opposites, Ebbinghaus or mutilated text, and absurdities; two of sense discrimination, drawing lines each equal to a given length, and estimating the comparative lengths of pairs of lines; one of motor control, the scroll test.

There were 37 subjects; 17 in the good group and 20 in the poor group. The good group was made up of professors and advanced students of Columbia University. These 17 men undoubtedly rank high in general intelligence and in management of affairs. Of the poor group of 20, only two were earning comfortable livings for their families, and they were recognized by their associates as being dull. The others were staying at the Salvation Army Industrial Home, or

9 - Simpson, Teachers College, Columbia University, Contributions to Education, No 53, 1912.

in a mission on the Bowery, until they could find employment.

The tests were all given individually in the same order and as nearly as possible in the same way.

The method of scoring finally adopted was that which seemed fairest on grounds of common sense, and that which seemed to vary as little as possible from the results secured by other reasonable methods of scoring. The author gives a detailed discription of the method of scoring in each test.

The reliability of the tests was determined by finding the Pearson coefficient of correlation of the first, or first few, with other trials, in each test. In the accompanying table, the first figure in each case is the reliability for all 37 subjects taken together; the second figure is for the good group alone, and the third figure is for the poor group alone. (See Table III).

Another table (IV) shows the extent to which the poor group overlaps the good group. This table indicates the significance of the tests, also an analysis of general intelligence as shown by the differences between the good group and the poor group.

The easy opposites test is the only one that separates the two groups completely, while in the two tests of sense discrimination the two groups overlap to such an extent that there is little difference between them. The other tests tend

T A B L E III

SIMPSON'S RESULTS

Reliability of the Tests, as Shown by the Pearson Coefficients of Correlation Between First and Second Trials (Raw Coefficients)

In the case of each test the figure given first is for the Good and Poor together, divergences being measured from the median of the 37 individuals. The second figure is for the good group, divergences being measured from its median. The third figure is for the poor group.

Ebbinghaus test	First 4 trials and last 4	92 96 93
Hard Opposites	" 2 " " " 2	97 60 88
Memory of Words	" 2 " " " 2	73 48 49
Easy Opposites	" 2 " " " 2	93 53 89
A test	" trial and second	72 62 60
Memory of Passages	" 2 trials and last 2	90 78 83
Adding	" trial and second	91 76 90
Geometrical Forms	" " " "	90 69 91
Learning Pairs	" 2 trials and last 2	93 79 52

TABLE III (Cont'd)

Recognizing Forms	First trial and second	40 -41 -10
Scroll	" " " "	76 -04 71
Completing Words	" " " "	92 27 89
Drawing Lengths	" 4 trials and last4	72 42 95
Estimating Lengths	" trial and second	48 47 60

TABLE IV

Extent to Which the Poor Group Overlaps the Good Group.

Percentage of Poor Group Surpassing	50% of Good Group	Lowest 4 of Good Group 23½%	Lowest 2 of Good Group 12 %	Lowest 1 of Good Group 6 %
Ebbinghaus Test	0	0	5	5
Hard Opposites	0	0	0	0
Memory of Words	0	5	10	10
Memory of Passages	0	10	15	40
Easy Opposites	0	0	0	0
Adding	10	20	25	30
Completing WordsBa	5	10	15	15
Learning Pairs	0	0	0	30
A test	15	20	25	25
Geometrical Forms	0	20	25	35
Recognizing Forms	0	0	0	10
Scroll	0	10	30	35
Estimating Lengths (100 & 102 mm)	15	80	90	90
Estimating Lengths (100 & 104 mm)	30	40	55	90
Drawing Lengths	55	65	75	85

to separate the two groups more or less completely, the results varying rather widely.

The author classifies the results of this part of the experiment as follows:

Thus the tests reveal very marked differences in the two groups in language tests demanding selective thinking; marked but less difference in certain tests of memory; very decided differences in language tests demanding speed and accuracy in easy association; less difference in the more directly practiced and mechanical associations demanded in adding; in perception tests and in motor control the differences are somewhat less still; and in discrimination of lengths they are least of all. The author believes it can be shown that by far the largest factor in causing these differences is the native capacity of the individual in question, rather than differences in training and education.

The raw Pearson coefficients of correlation are given in Table V. The top line gives the correlations when all the subjects are taken together in one group of 37. The second line gives the correlations for the good group only, and the last line, the correlations for the poor group only. (See also Table VI).

In general, the correlations are considerably higher in the top lines. The correlations of the poor group average somewhat higher than those of the good group. This difference in correlation is due to the different selections of sub-

TABLE V

Pearson Coefficients of Correlation, Raw

In the case of each test the first figure given is for the Good and Poor together, divergences being measured from the median of the 37 individuals. The second figure is for the Good group, divergences being measured from its median. The third figure is for the Poor group.

	Ebbinghaus Test	Hard Opposites	Memory of Words	Easy Opposites	A Test	Memory of Passages	Adding	Geometrical Forms	Learning Pairs	Recognizing Forms	Scroll	Completing Words	Estimating Lengths	Drawing Lengths-Total Error	Drawing Lengths-Variable Error
Ebbinghaus test...		98	94	79	62	91	71	54	78	88	55	42	33	25	
		58	54	42	-16	31	61	-05	09	54	15	47	23	01	-16
		85	66	87	65	56	65	34	55	31	14	44	12	34	00
Hard Oppo-sites..	98		84	80	64	81	79	70	73	74	52	43	26	25	
	58		53	70	12	34	67	07	16	19	32	62	-02	06	-18
	85		63	75	49	58	48	31	49	12	-07	34	00	16	-03
Memory of Words..	94	84		62	55	82	49	56	73	71	53	40	28	21	
	54	53		36	-10	23	21	00	32	37	-17	07	19	-01	-28
	66	63		59	60	73	22	52	23	15	19	29	04	05	-08
Easy Oppo-sites..	79	80	62		57	52	68	53	42	56	45	29	38	48	
	42	70	36		01	-05	45	26	-09	26	00	45	-05	-05	-17
	87	75	59		36	56	46	28	45	32	-02	13	26	47	14
A test	62	64	55	57		55	54	73	39	51	39	59	25	22	
	-16	12	-10	01		-03	57	54	-11	02	13	11	-18	-01	-17
	65	49	60	36		44	31	72	49	07	-02	62	17	03	-30
Memory of Passages..	91	81	82	52	55		53	57	59	66	54	31	28	19	
	31	34	23	-05	-03		20	-17	01	14	15	19	-23	-19	-29
	56	58	73	56	44		10	37	19	06	10	13	32	03	04

TABLE V (cont'd)

	Ebbinghaus Test	Hard Opposites	Memory of Words	Easy Opposites	A Test	Memory of Passages	Adding	Geometrical Forms	Learning Pairs	Recognizing Forms	Scroll	Completing Words	Estimating Lengths	Drawing Lengths-Total Error	Drawing Lengths-Variable Error
Adding....	71 61 65	79 67 48	49 21 22	68 45 46	54 57 31	53 20 10		45 16 16	39 14 41	47 15 15	51 61 04	57 63 51	17 -05 -29	25 -39 22	-47 00
Geometrical Forms	54 05 34	70 07 31	56 00 52	53 26 28	73 54 72	57 -17 37	45 16 16		35 -18 23	49 13 18	54 -19 -06	56 07 39	25 -14 01	25 33 15	22 -03
Learning pairs..	78 -09 55	73 16 49	73 32 23	42 09 45	39 -11 49	59 01 19	39 14 41	35 -18 23		69 05 21	36 34 -28	29 55 18	26 31 03	09 -12 23	-07 00
Recognizing forms	88 54 31	74 19 12	71 37 15	56 26 32	51 02 07	66 14 06	47 15 15	49 13 18	69 05 21		44 -27 07	37 48 -03	34 19 26	28 49 24	19 09
Scroll	55 15 14	52 32 -07	53 -17 -19	45 00 02	39 13 -02	54 15 10	51 61 04	34 -19 -06	36 34 -28	44 -27 07		31 10 08	19 25 -27	27 -24 11	-19 03
Completing Words...	42 49 44	43 62 34	40 07 29	29 45 13	59 11 62	31 19 13	57 63 51	56 07 39	29 55 18	37 48 -03	31 10 08	18	21 18 -09	07 -03 03	-08 -09
Estimating Lengths.	33 23 12	26 -02 00	28 19 04	38 -05 26	25 -18 17	28 -23 32	17 -05 -29	25 -14 01	26 31 03	34 19 26	19 25 -27	21 18 -09		24 09 22	06 24
Drawing Lengths. (Tot.Error)	25 01 34	25 06 16	21 -01 05	48 -05 47	22 -01 03	19 -19 02	25 -39 22	25 33 15	09 -12 23	28 49 24	27 -24 11	07 -03 03	24 09 22		73 78
Drawing Lengths (Variable error)	-16 00	-18 -03	-28 -08	-17 14	-17 -30	-29 04	-47 00	22 -03	-07 00	19 09	-19 03	-08 -09	06 24	73 78	

TABLE VI

Pearson Coefficients of Correlation

(Corrected for Attenuation)

In the case of each test the figure given first is for the Good and Poor together, divergences being measured from the median of the 37 individuals. The second figure is for the Good group, divergences being measured from its median. The third figure is for the Poor Group.

	Ebbinghaus Test	Hard Opposites	Memory of Words	Easy Opposites	A Test	Memory of Passages	Adding	Geometrical Forms	Learning Pairs	Completing Words	Drawing Lengths	Estimating Lengths
Ebbinghaus test		92 66 90	92 67 78	75 48 90	68 03 76	91 42 61	71 55 63	54 00 36	72 22 73	50 67 71	26 -17 27	52 28 01
Hard Opposites	92 66 90		92 75 77	81 93 78	76 15 65	86 45 64	74 79 51	64 07 33	72 14 66	70 100 49	25 10 13	55 -08 -02
Memory of Words	92 67 78	92 75 77		68 52 70	70 -13 88	89 41 100	56 20 23	67 06 56	82 53 44	51 100 43	06 -23 -09	59 44 16
Easy Opposites	75 48 90	81 93 78	68 52 70		71 05 51	69 05 58	70 45 50	54 38 34	43 -04 64	50 100 49	53 00 43	56 -02 16
A test	68 03 76	76 15 65	70 -13 88	71 05 51		60 14 48	67 59 39	94 68 91	44 -16 72	84 04 88	27 -10 08	57 -11 13
Memory of Passages	91 42 61	86 45 64	89 41 100	69 05 58	60 14 48		66 20 15	60 -30 41	63 -26 22	38 35 13	12 -24 09	58 -36 35

TABLE VI (Cont'D)

	Ebbinghaus Test	Hard Opposites	Memory of Words	Easy Opposites	A Test	Memory of Passages	Adding	Geometrical Forms	Learning Pairs	Completing Words	Drawing Lengths	Estimating Lengths
Adding	71 55 63	74 79 51	56 20 23	70 45 50	67 59 39	66 20 15		44 13 19	46 12 51	77 86 70	27 -49 05	17 04 -40
Geometrical Forms	54 00 36	64 07 33	67 06 56	54 38 34	94 -68 91	60 -30 41	44 13 19		40 -23 39	61 00 32	30 40 14	35 -14 07
Learning Pairs	72 22 73	72 14 66	82 53 44	43 -04 64	44 -16 72	63 -26 22	46 12 51	40 -23 39		34 74 34	04 -38 20	54 61 36
Completing Words	50 67 71	70 100 49	51 100 43	50 100 49	84 04 88	38 35 13	77 86 70	61 00 32	34 74 34		17 -04 00	22 06 -28
Drawing Lengths	26 -17 27	25 10 13	06 -23 -09	53 00 43	27 -10 08	12 -24 09	27 -49 05	30 40 14	04 -38 20	17 -04 00		55 -41 34
Estimating Lengths	52 28 01	55 -08 -02	59 44 16	56 -02 16	57 -11 13	58 -36 35	17 04 -40	35 -14 07	54 61 36	22 06 -28	55 -41 34	

jects, and the different points from which the deviations are measured. In the amalgamated group, as two extreme grades of ability are represented, and measured by the approximate central tendency of all men, the correlations are high wherever the traits concerned are themselves correlated with general intelligence.

On the basis of relationships shown by the correlation coefficients, the tests may be grouped as follows: (1) Tests of selective thinking; Ebbinghaus and hard opposites; (2) Memory tests, memory of passages and of words, respectively; (3) Association tests, adding and completing words give a fairly high correlation, easy opposites and completing words a little lower, adding and easy opposites still lower, while learning pairs do not correlate closely with adding, easy opposites, or completing words, and so cannot be classed with them as a test of the same kind of thing; (4) Perception tests, "a" test correlates high with geometrical forms; (5) Motor control test, scroll test did not prove very satisfactory; (6) Discrimination of lengths, drawing lengths and estimating lengths seem to involve very different factors.

The author has estimated the true correlations, for people in general, between each test and every other test given. (See Table VII) On this basis, the average correlation of each test with all the others is as follows: hard opposites .60, Ebbinghaus .58, memory of words .56, easy opposites .53, "a" test .50, completing words .47, memory of passages .44; adding .43; learning pairs .41; geometrical forms .40; estimating lengths .26; drawing lines .13.

Grouping the related tests as above, and finding the average correlation of each group with other tests, the results are as follows: selective thinking .59, memory .50, association (exclusive of learning pairs) .48, perception .45, motor control .26, discrimination of lengths .19. Provided only we have appropriately named the abilities above mentioned, all this means that, using the argument from correlation alone, power of selective thinking is more intimately connected with, and more characteristic of , general mental ability than is any of the other abilities tested; that memory is next most highly correlated with general ability; the simpler forms of association next; perception next, motor control considerably less, and discrimination of lengths least of all. This confirms the more direct argument stated above, from the extent of overlapping of the good and poor groups in the different tests.

A combined measure of each individual was taken, obtained by summing up his score in the Ebbinghaus test, hard opposites, easy opposites, learning pairs, and recognizing forms, arranged in such a way as to allow approximately equal weight to each test. Then the scores of the individuals were found, in terms of individual deviation from the median of all. By this arrangement the good group and the poor group are completely separated, leaving a gap of 21 points between the two.

TABLE VII

SIMPSON'S RESULTS

Estimated True Correlation for People in General

(That is, the probable correlations as they would be if the subjects were a very large number of persons representing a random sampling of all people, instead of two small selected groups.

	Ebbinghaus Test	Hard Opposites	Memory of Words	Easy Opposites	A Test	Memory of Passages	Adding	Geometrical Forms	Learning Pairs	Completing Words	Drawing Lengths	Estimating Lengths
Ebbinghaus test	.	85	82	72	54	71	65	36	60	60	15	33
Hard Opposites	85		84	83	58	70	70	42	56	72	18	25
Memory of Words	82	84		65	54	80	39	49	65	61	-05	44
Easy Opposites	72	83	65		50	50	56	45	37	62	37	31
A test	54	58	54	50		46	58	87	36	65	13	29
Memory of passages	71	70	80	50	46		42	33	30	31	02	29
Adding	65	70	39	56	58	42		30	39	77	02	00
Geometrical Forms	36	42	49	45	87	33	30		36	38	28	16
Learning Pairs	60	56	65	37	36	30	39	36		44	-02	51
Completing Words	60	72	61	62	65	31	77	38	44		07	05
Drawing Lengths	15	18	-05	37	13	02	02	28	-02	07		26
Estimating Lengths	33	25	44	31	29	29	00	16	51	05	26	
Totals	633	663	618	588	550	484	478	440	452	522	141	289

The Pearson coefficients of correlation corrected for attenuation were calculated between the estimated intelligence of 12 members of the good group and each of the 11 most reliable tests. The results were as follows: in the case of hard opposites .96, Ebbinghaus test .89, memory of words

.93, memory of passages .35, easy opposites .82, adding .72, learning pairs .34, completing words 1.00 (unreliable), "A" test .21, geometrical forms .07, drawing lengths -.20

Conclusions reached by the author were as follows: As to method - In general, the author found it highly instructive to calculate correlations with two contrasting, selected groups, and also with the groups combined. The results can thus be used to check each other. When this method is used, there appear to be few if any negative correlations. The gain in accuracy secured by correcting Pearson coefficients does not seem proportionate to the amount of time spent. It would be more profitable to spend this time in securing more accurate and reliable individual records of performance in the various tests.

As to facts - The most important results are probably the quantitative ones presented in Tables V, VI, VII, summarizing the correlation of each test with each of the other 13 tests used. (Compare Burt's results, arranged by Simpson, Tables VIII and IX)

We find justification for the common assumption that there is close interrelation among certain mental abilities, and consequently a something that may be called 'general mental intelligence' or 'general ability'; and that on the other hand, certain capacities are relatively specialized, and do not necessarily imply other abilities except to a very limited extent.

TABLE VIII

Burt's Results, arranged by Simpson. See Burt in British Journal of Psychology, 1909, Vol. 3, Parts 1 and 2, pp.94 ff., and Simpson, p 92.

Corrected Coefficients for Elementary School	Imputed Intelligence	Spot Pattern	Dotting	Mirror Tracing	Alphabet	Tapping	Memory	Dealing	Sorting	Sound	Lines	Touch	Weight
Imputed Intelligence		100	75	74	68	65	60	54	53	52	51	17	01
Spot Pattern	100		80	75	96	64	41	66	68	55	50	21	27
Dotting	75	80		84	85	83	22	83	75	68	60	30	07
Mirror Tracing	74	75	84		71	48	13	72	64	40	16	27	-10
Alphabet	68	96	85	71		67	47	83	83	68	37	66	26
Tapping	65	64	83	48	67		01	79	78	53	16	12	11
Memory	60	41	22	13	47	01		18	27	19	05	15	07
Dealing	54	66	83	72	83	79	18		77	41	59	32	05
Sorting	53	68	75	64	83	78	27	77		25	32	20	23
Sound	52	55	68	40	68	53	19	41	25		-05	-01	06
Lines	51	50	60	16	37	16	05	59	32	-05		26	-16
Touch	17	21	30	27	66	12	15	32	30	-01	26		37
Weight	-01	27	07	-10	26	11	07	05	23	06	-16	37	

Of the six varieties of capacity tested, in so far as the tests used are representative of them, we find that those most intimately related to other abilities are (a) selective thinking, (b) memory and association, (c) quickness and accuracy of perception, (d) motor control, (e) sensory discrimination, each in the order named.

This in turn throws light upon the question as to what constitutes 'general intelligence.' This is a broad term,

TABLE IX

Burt's Results, arranged by Simpson. See Burt in British Journal of Psychology, 1909, Vol. 3, Parts 1 and 2, pp 94 ff, and Simpson p 93.

Corrected Coefficients for Preparatory School	Sorting	Dotting	Alphabet	Tapping	Intelligence	Memory	Mirror	Spot Pattern	Dealing	Lines	Touch	Weight	Sound
Sorting		100	100	100	100	90	71	47	32	07	-32	-33	-62
Dotting	100		84	73	96	84	100	62	-17	45	31	25	63
Alphabet	100	84		94	91	100	56	83	37	32	-48	-06	35
Tapping	100	73	94		41	80	100	50	36	57	09	74	44
Imputed Intelligence	100	96	91	41		82	68	66	06	44	-17	-20	41
Memory	90	84	100	80	82		64	84	06	27	27	22	27
Mirror	71	100	56	100	68	64		75	-61	94	40	71	93
Spot Pattern	47	62	83	50	66	84	75		40	85	-29	10	40
Dealing	32	-17	37	36	06	06	-61	40		-07	-51	-40	-06
Lines	07	45	32	57	44	27	94	85	-07		21	15	23
Touch	-32	31	-48	09	-17	27	40	-29	-51	21		61	26
Weight	-33	25	-06	74	-20	22	71	10	-40	15	61		53
Sound	-62	63	35	44	41	27	93	40	-06	23	26	53	

and may be subject to some variation in interpretation. Our good group may not be exactly representative of general intelligence as exhibited in callings and occupations of a different order from that required in leadership in the teaching profession or in an educational career. We must also acknowledge limitations in the number and variety of tests used. However, subject to these limitations, we find that 'general intelligence' implies the different abilities tested in the relative order stated in the above paragraph -- abstract thinking in very high degree, memory and association in less degree, etc.

We find no justification for the view that 'general intelligence' is to be explained on the basis of a hierarchy of mental functions, the amount of correlation in each case being due to the degree of connection with a common central factor.

Finally, we find that 'general intelligence', as commonly understood, can be measured with a high degree of accuracy by the use of certain of the tests. In fact, an hour so spent in testing an individual gives us a very significant indication of his 'general intelligence' as the term is commonly understood and used by well educated people. The time seems not far distant when we shall be able to say to a student:"Such and such is the order of general mental capacity that we may expect of you at the present time. If you do not attain to such and such a standard of efficiency, it will be due to other causes than lack of mental capacity."

The author then proceeds to suggest that some of the tests should be improved, and that norms should be established.

In 1913, W. H. Pyle published an article[10] on standards

10 - Pyle, Journal of Ed. Psychology, 1913, 4, pp 61-70

of mental efficiency. A good mental test must satisfy several conditions. It must test some aspect of mind that is important in learning, either in getting ideas or in forming habits. The test must be simple, easily given, readily understood by the pupils and easily graded.

Perhaps the best test of all is the substitution test for learning capacity. Another of the very best is a test of logical memory, its worth being indicated by the following considerations: its high correlation with permanent retention, $\pm.76$; its high correlation with other tests, an average of .29, its high correlation with school standing, in some grades as high as .69. An accompanying table, showing the intercorrelation of the various mental tests, is pretty good evidence of what the best tests are.

The names of the tests are given in the table. The subjects were several hundred students in the University of Missouri. (See Table X).

In 1914, E. L. Thorndike[11] sums up his study of individual differences as follows: The most important fact is not the commonness of this or that form of distribution of a trait, but the absolute law that the form of distribution is a result of the factors at work to produce the trait's amount. One large factor that is present for some individuals and not for others will always act toward the production of bimodality or distinct types.

There are two ways of discovering sorts or types of minds. The first is by direct measurement of individuals in toto, and of their differences. The difference between the two men means just all those particular differences. No adequate measurements exist of even a single individual.

The second way of discovering the sorts or types into which men as total natures are divided is by discovering what each amount possessed of any one trait implies concerning the individual's condition in other traits. The necessary preliminary to the direct study of differences of total natures is thus the study of the relations of single mental traits.

The correlation between two mental traits means the relation of some amount of one trait (a) to some amount of another trait (b). It also means, for the present purpose, the relation between an amount of "a", characteristic of a given individual and an amount of "b", characteristic of that same individual.

The significance of the relations between mental traits which have been measured in this way is seen most easily and clearly by observing the doctrines about individual psychology which they disprove. First may be mentioned a series of beliefs in mental antagonisms or compensations. Not all such antagonisms have been specifically tested by the calculation of the appropriate r's; but those which have been so tested have been found in gross error. The relations which do seem to be inverse are very instructive. They are mostly cases of the relation of a desirable divergence in one trait

T A B L E X

PYLE'S RESULTS

Showing the Intercorrelation of Mental Tests

	Simultaneous Adding	Complicated Prose	Attention	Association	Learning	Rote Memory	Logical Memory	Fidelity Report	Imagination	Sentence Building	Word Building	Description
Simultaneous adding. . . .		21	00	43	76	25	21	44	24	00	71	21
Complicated prose	.21		21	31	71	41	48	08	-12	24	16	-03
Attention . . .	.00	21		01	47	33	00	07	-19	35	22	37
Association . .	.43	31	01		44	00	39	17	23	25	17	32
Learning. . . .	.76	71	47	44		44	55	03	10	17	44	02
Rote Memory . .	.25	41	33	00	44		36	27	13	29	27	-05
Logical Memory.	.21	48	00	39	55	36		07	40	11	21	-31
Fidelity of report. . . .	.44	08	07	17	-03	27	07		37	12	21	17
Imagination . .	.24	-12	-19	23	-10	-13	-40	37		-42	06	21
Sentence building. . .	.00	24	35	-25	17	29	11	12	-42		01	05
Word building .	.71	16	22	17	44	27	21	21	06	01		05
Description	21	-03	37	32	02	-05	31	17	21	-05	05	

to an undesirable divergence in the other. Thus general intellect seems to be antagonistic to sullenness. It is very, very hard to find any case of a negative correlation between desirable mental functions. Divergence toward what we vaguely call better adaptation to the world in any respect seems to be positively related to better adaptation in all or nearly all respects. And this seems specially true of the relations between original capacities.

There may, however, be cases where some one large environmental agency acts to bring all those individuals subject to it up in one trait but down in another. Finally, there are the notable cases of apparent compensation due to the special practice of one trait to make up for irremediable weakness in some other.

On the whole, negative correlations between different 'efficiencies' or 'adaptabilities' or 'desirable traits' are surely rare, seem almost never to occur as a result of original mental nature, and require as causes peculiar oppositions of influence upon the two traits from the environment.

A second error in opinions about mental relations is in sharp contrast to the one just described. It is the doctrine that some one function is shared by all intellectual traits, and that whatever resemblances or positive correlations the traits show are due to the presence in each of them of this function as a common factor. In so far as they have it, they are identical. In so far as they lack it, they are totally disparate.

This doctrine requires not only that all branches of intellectual activity be positively correlated, which is substantially true, but also that they be bound to each other by one common factor, which is false.

The next error may be roughly described as the supposition that for any one operation that is the same form, such as discrimination of differences, attention, observation, inference or the like, the varieties produced by different data or content are perfectly correlated. On the contrary, measurements reveal a high degree of independence of different mental functions even where to the abstract psychological thinker they have seemed nearly identical.

A table of the known degrees of relationship would abundantly confirm the statement that the mind must be regarded not as a functional unit, nor even as a collection of a few general faculties which work irrespective of particular material, but rather as a multitude of functions each of which involves content as well as form, and so is related closely to only a few of its fellows, and to the others with greater and greater degrees of remoteness.

Correlations seem to be closer within the analytical or abstracting functions than between these and others. So also within the purely mental associative functions like adding, completing words, giving opposites, and naming objects, than between one of them and one of the sensori-motor functions. The sensitivities seem to interrelate only loosely; and any one of them would relate very loosely to the associative or analytical functions, even when the latter was busied with data from that sense.

Certain functions quite diverse from the point of view of the classification into sensory, associative and analytical processes would be found to be related by reason of some instinctive tendency.

The circumstances of training would be seen to sometimes intensify and sometimes weaken original relations. Just what the original relations are will in the progress of research be discovered. It is unlikely that the relations of original capacities and instincts, including interests, are so complicated as the relations amongst adult achievements and abilities. But present knowledge is insufficient to determine even the original relations.

In 1915, L. G. Cogan, A. M. Conklin, and H. L. Hollingworth published the results of an experimental study of self analysis, estimates of associates, and the results of tests.[12] The subjects were 25 juniors and 25 seniors in a college for women. The tests used were as follows: completion, association, hard directions, opposites, supraordinate, whole-part, action-agent, and mixed relations. The series of experiments also included judgments of certain traits of character, but that part of the series is not directly connected with our study of mental functions, except for the one item of intelligence.

The three classes of measures used may be defined as follows: (a) The results of the psychological tests named above; (b) The combined opinion of associates as to the individual's intelligence; (c) The academic records in six

12 - Cogan, Conklin, Hollingworth, Sch.&Soc., 1915, 2, pp. 171 - 179

subjects; German, English, psychology, logic, economics, and history.

By comparing these three classes of measures, the following correlations were obtained: psychological tests with estimated intelligence, for juniors, .70, for seniors .53; psychological tests with average academic record, for juniors .42, for seniors .57, academic records with estimated intelligence, for juniors .22, for seniors .37.

The author's conclusions are as follows: The most striking result here is the rather low correlation of the academic records with the other measures of intelligence. The psychological tests agree closely with the results of the estimates by associates. The correlation of the tests with the records is considerably lower, while the correlation of the records with estimates is exceedingly low. The ultimate value of the mental tests is still to be determined. Inasmuch as the tests and the estimates agree closely, the tests and the records less closely, while the records do not correlate to any marked degree with either of the two other measures, the significance of the academic marks, or their reliability in this instance, must be seriously called into question.

In 1916, D. E. Weglein published the results of an investigation of the abilities of high school pupils.[13] This study deals with the coefficients of correlation between

13 - Weglein, Cor. of Abil. of High School Pupils.

school records of 121 high school girls in Baltimore, also with the relation between the results obtained in several ability tests and the school grades of some of the pupils. The author sums up his conclusions as follows:

1. This study of the coefficients of correlation among high school grades shows a considerable amount of correlation, 71% of all the coefficients being equal to or greater than .3, and 41% being equal to or greater than .5.

2. Drawing ranks lowest among all the subjects, the size of the coefficients being taken as a basis.

3. The correlation, as found, may be due either to a 'spread of ability' or to resemblance of elements among the several school subjects. Since drawing, a subject very unlike the other ones, shows low coefficients, the correlation is probably due to resemblance of elements among the subjects, or at least of those things counting for success in school.

4. If it is desired to use a single subject as the basis of judgment of school progress, English is probably the best one to select for this purpose.

In 1917, W. A. McCall published the results of a study of 63 pupils in a public elementary school in New York City.[14] The following tests were given: initial and final; visual vocabulary, reading, completion, arithmetic, omnibus I (including several tests such as opposites); Special measures, proverb, age, school mark, teacher rank; practice tests; cancellation

14 - McCall, Sch. & Soc., 1917, 5, pp. 24-30

of 2's, of 3's, of A's and of S's, addition, copying addresses, handwriting (speed). Two measures were secured for each individual in each test, except proverb and age. All measures except age, proverb and handwriting were combined in a measure called the Composite, which the writer believes to be the best available measure of the mental ability of these pupils. Results are summed up in the following conclusions:

1. The corrected correlations among the educational and psychological tests and the functions which they measure continuously vary in size from -.63 to +.98

2. Meaning by mental ability a composite of all the measurements, the omnibus and completion tests correlate with it +1.00 and +.96, respectively. That is to say, a perfect measure of an individual by omnibus or completion would be a substantially true index of his mental ability.

3. The seven best measures of mental ability together with their correlations with the composite are; omnibus 1.00, completion .96, school mark .91, teacher rank .86, reading .81, visual vocabulary .80, and arithmetic .72.

4. Ranked in the order of their correlation with mental ability the complex educational and vocational tests come first; the relatively complex practice tests second, and the simple practice tests last.

5. The power tests, or those which measured the upper threshold of ability, showed a higher correlation with mental

ability than the speed tests or those which measured how rapidly a relatively easy task could be accurately performed. The power tests were superior not only as to correlation, but also as to time required and the distribution of that time.

6. The indications are that for a test to show a close correlation with mental ability it should emphasize power rather than speed and test a relatively complex function rather than a narrow mental trait.

7. Improvement at a speed, practice test was on the whole not so good an intellectual index as an average of the practice scores and not nearly so good an index as a single score from a complex, power test.

8. In this particular six B school grade chronological age correlated negatively with mental ability.

9. The cancellation tests correlated negatively not only with the composite, but also with all those tests which proved to be good measures of mental ability. This demonstrates that negative correlation between apparently desirable traits can exist. Heretofore the weight of scientific evidence has been against such a possibility.

10. The correlation between columns of correlational coefficients does not corroborate Spearman's important "Theorem of the Universal Unity of Intellective Function." Some pairs of columns give -.95 instead of +1.00.

11. In no way can a correlational table be so constructed

from our coefficients as to satisfy Burt's "Hierarchy of the Specific Intelligences."

In 1917, I. King published the results of an investigation of the relationship of abilities in certain mental tests to ability as estimated by teachers.[15] Several varieties of tests were given to various groups of subjects. The tests included such features as opposites, addition, cancellation, memory, substitution, maze, completion, etc. The subjects were groups of students at Iowa University. They were ranked according to ability by their instructors, or on a basis of class standing. Correlations between estimated ability and various tests were rather low and in some cases negative. Correlations between initial and final scores in practice tests were in most cases high. Gains in such tests correlate much higher with later scores than with earlier. In most cases, scholastic advancement showed a decided influence on results in completion tests. A decided positive relation between speed and accuracy was observed. Negative correlations were obtained only in the case of the A and the B cancellation tests given the first group and in the "recognition of forms" test given the first and third groups. The writer observes that the ability to cancel A's rapidly may represent a "desirable mental trait," but certainly an ex-

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15 - King, Sch. & Soc., 1917, 5, pp 204 -209.

tremely narrow and abstract one. A probable explanation of the negative correlation in such cases is that the duller students try harder and excel the brighter ones.

CHAPTER III

DISCUSSION OF PREVIOUS INVESTIGATIONS

In studying the methods and results of previous investigations, it is interesting to note the evidences of development in the theory and practice of testing mental functions. Perhaps the most striking feature of the early investigations is their vagueness, vagueness of ideas as to what sorts of mental functions are suitable for testing, and as to what methods or tests are most suitable for measuring those functions. By no means all of this vagueness has disappeared from later studies, but it seems that there are indications of decided improvement along some lines. Needless to say, there is still abundant room for further improvement.

Perhaps it is to be expected that the pioneers in this field, as in any other, should have used methods and expressed opinions which have been more or less discredited by subsequent developments, for no branch of science can be complete in its early stages. For instance, W. C. Bagley in 1901 correlated mental and motor ability in school children. The scores in mental ability included the results of a test of reaction time, and the scores in motor ability were based partly on teachers' estimates, as well as on the results of tests of strength, rapidity, accuracy, etc. At present, reaction time is considered as an important factor in motor ability, and teachers' estimates would hardly be accepted as having any value in a study of motor ability.

The earlier studies vary so widely, both in method and in general conception of the problems of mental measurement, that it is very difficult to find a satisfactory basis of comparison. But as the task became more definite, the various investigators and results began to classify themselves with reference to a few general theories or problems. Then for the first time a few consistencies and many inconsistencies became evident, for in the beginning the results had no common basis of comparison which would show whether they were really consistent or inconsistent.

Probably the question of a central factor has been disputed more than any other feature in the study of mental functions. Spearman and others have believed that they had proof of the existence of such a factor, and have made it the basis of the interrelation between the various functions measured. Spearman says: "There really exists a something that we may provisionally term 'General Sensory Discrimination' and similarly a 'General Intelligence', and the functional correspondence between these two is not appreciably less than absolute." "Whenever branches of intellectual activity are at all dissimilar, then their correlations with one another appear wholly due to their all being variously saturated with some common fundamental function (or group of functions)."

Thorndike, Lay and Dean conducted experiments dealing with sensory discrimination and intelligence. The coefficient of correlation between these two functions they found to be

.23 instead of 1.00 as Spearman had asserted. Thorndike sums up their conclusions in regard to this matter as follows:

"In general there is evidence of a complex set of bonds between the psychological equivalents of both what we call the formal side of thought and what we call its content, so that one is almost tempted to replace Spearman's statement by the equally extravagant one that there is nothing whatever common to all mental functions, or to any half of them."

In 1914, Thorndike said that a table of the known degrees of relationship would abundantly confirm the statement that the mind must be regarded not as a functional unit, nor even as a collection of a few general faculties which work irrespective of particular material, but rather as a multitude of functions each of which involves content as well as form, and so is related closely to only a few of its fellows, and to the others with greater and greater degrees of remoteness. The foregoing statements are fairly representative of opinion on the two sides of this question of a central factor. The theory of a central factor involves the theory of a hierarchy of mental functions due to the influence of said central factor. This idea of a hierarchy has been supported by Burt and others, but strongly opposed by Simpson and others.

In sharp contrast to the central factor theory, some psychologists have held the theory of compensation, that superiority in one mental function is likely to be accompanied by inferiority in others. This theory would of course involve negative coefficients of correlation between various pairs of functions.

Thorndike vigorously attacks the doctrine of compensation, saying that it is very, very hard to find any case of a negative correlation between desirable mental functions; divergence toward what we vaguely call better adaptation to the world in any respect seems to be positively related to better adaptation in all or nearly all respects; and this seems specially true of the relations between original capacities.

On the other hand, McCall and King, working independently, both found that cancellation tests gave negative correlation with other tests which seemed to be good measures of mental ability. King observes that the ability to cancel A's rapidly may represent a "desirable mental trait," but certainly an extremely narrow and abstract one."

Raw coefficients of correlation are generally rather low, in many cases so low as to be disappointing to the investigator. Various methods of correction have been suggested and used, presumably for the purpose of eliminating various types of errors. In the writer's opinion, it is doubtful whether such methods have much practical value except to make the coefficients of correlation appear higher.

In view of such diversity of opinion on so many points at issue, one is almost tempted to concur in Spearman's opinion that the results hitherto obtained in respect of psychic correlation would, if true, be almost fatal to experimental psychology as a profitable branch of science. However, it may be possible to develop a practical working scheme of mental measurements without waiting to reconcile conflicting theories as to the ultimate basis of general mental ability, if we may use this term in its common sense, rather than technical meaning.

After noting the points of disagreement mentioned above, we are glad to find at least one point on which there is a sort of general agreement among many investigators, that is, the relative degree of interrelation existing between various kinds of mental functions. The results of several investigations seem to indicate that the highest coefficients of correlation are found between functions involving the higher or more complex mental processes, such as selective thinking or reasoning. We also find that such functions correlate highest with estimates of general mental ability. Next come functions involving such factors as memory, association, etc., while the simpler processes involving sensory discrimination or motor ability stand lowest.

These facts probably give us a fairly good idea as to what kinds of mental tests afford the best indication of general ability as that term is usually understood. Previous investigations have differed so widely, both in functions tested and in methods used, that it seems impossible to collect the results into a single table, or to find any satisfactory basis of comparison. Several students of the subject have calculated the correlation of estimated intelligence with various functions. The following is an attempt to tabulate some of the results, giving in each case the name of the investigator, the name of the function measured, and its raw Pearson coefficient of correlation with estimated intelligence.

TABLE XI

Correlations with estimated intelligence

Thorndike, Lay, Dean, Discrimination of lengths	.055
" " " " " weights	.205
" " " " of lengths and weights	.165
Brown, Group 2, Combination(Ebbinghaus)	.43
" " " Mechanical memory	.55
" " 3, Combination(Ebbinghaus)	.69
" " " Memory for poetry	.57
Spearman, Discrimination	.38

C H A P T E R IV

PRESENT INVESTIGATION

For some years past, Dr. W. H. Pyle has been giving various kinds of mental tests in his laboratory of educational psychology at the University of Missouri. Careful records of all results have been kept, and are available for study. The present investigation is based on these records, including the results of tests given during the current term. An effort has been made by the writer to collate and organize the available data in such a way as to give a somewhat comprehensive view of the results. The method followed has been mainly that of averaging the results of several years' work, hoping thus to eliminate chance errors, or inaccuracies due to individual variations from year to year.

The tests given have for the most part followed the lines suggested in Whipple's Manual, though Dr. Pyle has also devised some original tests. Since there is considerable difference of opinion as to just what function of mind is tested by each of the various mental tests given, it will perhaps be best to refer to these functions by the names of the tests which measure each one, respectively, instead of trying to define the ultimate nature of the function itself.

With this understanding as to nomenclature, the principal functions tested may be described as those measured by the following tests: Completion, Logical memory, Opposites, Word Building, Rote Memory, Free Association, Substitution, and various tests of learning capacity, such as Card Distributing, Marble Distributing, Mirror Writing, etc., which were used in addition to Substitution. Army tests, Alpha series, were also given. Doubtless most of these tests are familiar to all those interested in mental measurements, so they need not be described in detail. Most of the subjects taking these tests have been students in the department of education as the University of Missouri. The records also include tests of a class at Ann Arbor. In most cases the tests of university men and women have not been kept separate. The classes have been made up largely of women, so that the results should be similar to those obtained by testing women only. Perhaps more than half of the subjects have been juniors at the time of taking the tests, most of the remainder have been sophomores.

The principal purpose of this investigation has been to ascertain the relations existing between the mental functions measured by the various tests used. If any function can be found which gives high correlations with various other functions, then we may suppose that said function is of rather broad application to the varied situations of life.

This brings us to a consideration of general intelligence or general ability. These terms have been variously defined, and there has been a great deal of speculation as to what constitutes the reality denoted by the terms. Some have held that there is one central factor of general intelligence influencing in greater or less degree each of the lesser factors of the mental equipment of the individual. Others have held that there is no such central factor, that high general intelligence merely means that the individual possesses a large number and variety of separate abilities forming a well selected group, some one or other of which will prove sufficient to meet almost any situation. The difference between these views may be illustrated as follows: the former view gives the fortunate individual a master key which will open any door in a certain building, the latter gives him a bunch of individual keys, one for each door in the building. The practical result is much the same in either case.

Whatever may be the ultimate constitution of general intelligence, it is evident that some mental tests measured it more accurately than others. In a general way, we may suppose that the mental test which gives the highest correlations with a great variety of other tests of different functions will also give the best indication of general intelligence or ability. Since the purpose of the present study is to ascertain the correlations between mental functions as measured by different tests, such a study necessarily involves the problem of measuring general intelligence or ability, without necessarily attempting to define the nature of this general function or group of functions, whichever it may be.

Since muscular speed seems to be an important factor in some mental tests, a study has been made of the relation of speed in tapping to various other functions tested.

C H A P T E R V

RESULTS

Accompanying tables show the results obtained in several series of tests, given at different times and to different classes. The most complete series of tests which have been given are three series, each involving seven kinds of mental tests as follows:Completion, Logical Memory, Opposites, Word Building, Rote Memory, Free Association and Substitution. In nearly every case, two or more tests were given for each function, and the results were compared in order to obtain a coefficient of reliability, and these coefficients are included in the tables, where practicable. In calculating correlations between two functions, the average scores for the different tests of each function were used.

Table XII shows the correlations obtained between each function and every other function, in each of the three series of tests, also the average of the three series in each case. Though the correlation between any two functions may be quite different in the three series, its ranking with reference to other correlations is fairly consistent throughout the three series. That is the coefficients obtained in some series are considerably higher than those obtained in other series, but the relative standing of coefficients in their respective series does not vary very much from one series to another

The figures in the last row at the bottom of the table show the average of the correlation coefficients between

TABLE XII

Results of Three Series of Tests, Used in Present Investigation

	Completion	Logical Memory	Opposites	Word Building	Rote Memory	Free Association	Substitution
Completion	.455 .241 .45	.439 .734 .466	.561 .496 .508	.445 .316 .098	.255 .660 .155	.144 .263 .125	.229 .565 .030
	.382	.546	.522	.286	.357	.177	.274
Logical Memory		.39 .638 .54	.345 .240 .289	.186 .331 .18	.317 .740 .25	.116 .576 .091	.233 .136 -.004
	.546	.523	.291	.232	.436	.261	.122
Opposites			.73 .683 .26	.378 .732 .205	.262 .104 .097	.339 .141 .015	.113 .580 .028
	.522	.291	.558	.438	.154	.165	.240
Word Building				.62 .681 .661	.022 .038 .005	.263 .265 .073	-.080 .345 -.116
	.286	.232	.438	.654	.022	.200	.050
Rote Memory					.76 .775 .43	.175 .378 .241	.098 .082 -.131
	.357	.436	.154	.022	.655	.265	.016

TABLE XII
(Cont'd)

	Completion	Logical Memory	Opposites	Word Building	Rote Memory	Free Association	Substitution
Free Association						.828 .429 .78	-.023 .025 -.084
	.177	.261	.165	.200	.265	.679	-.027
Substitution							.872 .737
	.274	.122	.240	.050	.016	-.027	(.805
Average	.360	.315	.302	.205	.208	.174	.113)

the function in question and every other function named in the table. Reliability coefficients are not included in these averages.

All figures given in connection with the results of the present investigation are raw Pearson coefficients of correlation.

CHAPTER VI

DISCUSSION OF RESULTS

Completion

Perhaps the results can best be discussed by taking up each function separately, and noting its relation to each other function tested.

As intimated above, the value of a test as an indication of general ability may be judged, to some extent, by its average correlation with other tests representing a wide variety of mental functions. When judged by this standard, completion stands first. Perhaps it measures a larger variety of functions than any of the other tests used. In two series out of the three included in this table, the reliability coefficient of completion is less than its coefficient of correlation with logical memory. Its low coefficient of reliability may be partly due to two sources of possible error. The material used may be more interesting, more familiar or for some reason more intelligible, to some subjects than to others. It is hard to find material which will appeal equally to all members of a class, unless said class is highly homogeneous. The other chance for error is in scoring the papers. Should each blank count equally in the score, or should the more difficult ones count more? Practice varies in this respect, but by using the same method of scoring throughout a series of tests, the resulting errors should be reduced to very small dimensions.

Except for coefficients of reliability in some of the tests, the highest coefficient of correlation in this table is that between completion and logical memory, .546. This would seem to indicate that the function,or group of functions, tested by completion is similar to that tested by logical memory. Probably the following factors are involved: attention, perception, organization of material, etc.

The correlation between completion and rote memory is not so high, only .357. The difference between these two coefficients may be partly due to the fact that rote memory does not involve the factor of organization to so great an extent as logical memory does.

The lowest coefficient of correlation obtained between completion and any other function is that with free association, .177.

Logical Memory

The second highest average of correlations belongs to logical memory. This test seems to measure not merely retentiveness, as in rote memory, but also such factors as understanding, organization, etc. Its correlation with completion is higher than that with rote memory, indicating that logical and rote memory differ considerably, though retentiveness must exert an important influence on logical memory. Logical memory correlates much higher with rote memory than with opposites.

Although the average reliability coefficient of logical memory, as given in this table, is fairly high, the results of this test are subject to several sources of variation. The material used may be of such a nature as to appeal to some subjects more strongly than to others, or it may deal with a topic which is already more or less familiar to some of the subjects. For instance, the material suggested in Whipple's Manual and generally used at the University of Missouri for this test includes a sketch of Cicero, giving a decided advantage to students of the Latin classics. As to the general type of material used, description is much harder to remember in detail than narrative, but does not necessarily give one subject an advantage over others.

Even though the material used may be equally fair to all the subjects, there is still room for the exercise of judgment in scoring the papers. When the subject uses words or sentences implying a meaning more or less similar to that of the original but not exactly the same, question arises as to how much credit should be given.

In the fall of 1918 and in the winter and spring of 1919, four tests of logical memory were given to the classes in educational psychology at the University of Missouri and a careful study of the results has been made. The accompanying table (XIII) shows the correlation obtained between each test and every other test, in both series of experiments, also the average coefficient of correlation between each test and every other test taken separately. The

T A B L E XIII

Intercorrelations of Four Tests

of Logical Memory.

	Costly Temper	Dutch Homestead	Cicero	Marble Statue	
Costly Temper		.524	.568	.556	Fall, '18
		.617	.559	.518	Spring, '19
		.571	.564	.537	Average
Dutch Homestead	.524		.555	.590	
	.617		.545	.476	
	.571		.550	.533	
Cicero	.568	.555		.379	
	.559	.545		.550	
	.564	.550		.465	
Marble Statue	.556	.590	.379		
	.518	.476	.550		
	.537	.533	.465		
Average	.557	.551	.526	.512	

Average of four averages .537

If the coefficients obtained in the two experiments are arranged in the same order, the correlation between the two sets is -.763.
Subjects were students of Educational Psychology.

figures at the bottom of the table show the average correlation of each test with all the others. These average coefficients do not vary very widely from one test to another, the range is only from .512 to .557. The coefficients obtained between the different tests, in either series, vary from .379 in the case of Cicero and Marble Statue to .617 in the case of Costly Temper and Dutch Homestead; but most of them lie between .50 and .59.

If we take the coefficient of correlation between each pair of tests in the one experiment, then take the same coefficients in the other experiment, and arrange the two sets of coefficients in the same order, the correlation between the two lists is -.763, instead of 1.00 as indicated by Spearman's theory. But perhaps our low coefficient is an extreme case, due partly to the uniformity of the coefficients involved.

Two series of tests of logical memory have been given to determine the relation between immediate and delayed recall. The interval elapsing between the two parts of the experiment in each case was more than a month. The scores were based on the absolute amount recalled.

In one group of 39 subjects the coefficient obtained between immediate and delayed recall was .626; in the other group of 54 subjects, the coefficient was .434. These two coefficients combined give an average of .53. This figure is interesting as throwing some light on the much disputed question of the relation between quickness of learning and quickness of forgetting. Although the coefficient of .53 is not high enough to justify any very positive or definite conclusions, it may at least create a presumption in favor of a direct relation between immediate and delayed recall, so far as absolute amounts are concerned.

In the three experiments which have been combined in our table of correlations for seven mental tests, the correlation between logical memory and rote memory varies from .25 to .74, with an average of .436. Two other experiments have been made in the same laboratory, to determine the relation existing between logical memory and rote memory. The resulting correlations were .37 and .42, respectively. If these two coefficients are combined with the three in the table, the average of all five is .419, slightly lower than the average given in the table. As intimated above, these results seem to indicate that logical memory involves some important factors not included in rote memory, or vice versa. It seems reasonable to suppose that logical memory is the broader function of the two.

Opposites

The opposites test presents a peculiar array of correlations with the six other tests of our table. Two tests were given for this function, one series of words being more difficult than the other. These two are sometimes called "easy" and "hard" opposites. The reliability coefficient for opposites is the correlation between the easy and hard tests, and is fairly high, .558.

Looking at the correlations obtained between opposites and the other functions tested, we see at once that the coefficients divide themselves into two groups, one of which averages more than twice as high as the other. The first group includes completion and word building, whose correlations with opposites give an average of .480; while the second group, including logical memory, rote memory, free association, and substitution, gives an average of only .213. The correlations of any one test with every other test tend to vary considerably, but they are seldom so sharply divided into two two groups; and even if they should be so divided, we should expect to find the coefficient with logical memory in the higher group, while here it is distinctly in the lower group, being only two thirds as high as the coefficient with word building.

Another peculiarity of the opposites test is that its coefficients with rote memory and with free association, respectively, are much lower than its coefficient with substitution, contrary to the general tendency of this table of coefficients.

Perhaps some significance may be attached to the fact that the lowest coefficient found under opposites is that with rote memory, .154, and that the coefficient of opposites with logical memory is also low, .291.

In an earlier series of tests by the same experimenter, opposites with logical memory gave a correlation of .35; opposites with rote memory gave .34.

Word Building

Taking the average of the correlations of each test with every other test, we find that the three functions already studied, completion, logical memory, and opposites, form a group having the highest average correlations recorded in this table, ranging from .302 to .360. Coming to word building, the average correlation is only .205, decidedly lower than the three averages mentioned above.

The highest correlation obtained between word building and any other test is that with opposites, .438, all the other coefficients being below .300. Another group includes three correlations, ranging from .200 to .286, being those of word building with completion, logical memory, and free association, respectively. The correlations of word building with rote memory and with substitution form a third group of very low figures, only .022 and .050. In two of the three series of experiments included in this table, word building with substitution gave a small negative correlation, but in the third experiment the correlation was positive, and high enough to bring the average of the three slightly above zero. For practical purposes, such small coefficients as .022 and .050 are perhaps negligible, and we would as well say that there is no significant correlation between the functions measured.

In an earlier series of experiments, made in the summer of 1917, word building was correlated with each of the other tests given, with the following results:

Word building with	nonsense syllables	.51
" " "	free association	.47
" " "	logical memory	.42
" " "	opposites	.285
" " "	substitution	.26
" " "	rote memory	.22

These figures have not been incorporated in our general table, as they are not entirely in the same form, nonsense syllables being included, and completion omitted. If we compare these coefficients with those in the table, we find these much larger, with the single exception of the coefficient of word building with opposites, which is much higher in the table than in this list.

If the correlations in this list are ranked from highest to lowest, their relative standing is quite different from that of the corresponding correlations in the table.

Rote Memory

As might be expected, the correlation of this function with logical memory is considerably higher than with any other function measured. This coefficient, .436, while showing a marked degree of similarity or perhaps interdependence, does not indicate an approach to identity of the two functions. Their interrelation has been mentioned above, under the discussion of logical memory.

The correlation of rote memory with completion stands second highest, being much higher than any of the other correlations of rote memory except that with logical memory. Lowest of all are the correlations with word building and substitution, only .022 and .016, so small as to be practically negligible.

Tests have been given to determine the relation between rote memory and learning nonsense syllables. The scores in rote memory were obtained by combining the results of four tests, two in abstract rote memory and two in concrete rote memory. These scores represent the average span of rote memory. The scores in learning nonsense show quickness in learning a series of ten nonsense syllables. These syllables are exposed to view, one a t a time, one second being allowed for each syllable. Then the subject writes as many of the syllables as he can recall. The syllables are then exposed a second time, after which the subject again writes. The series may be exposed ten times, or until most of the subjects have learned all the syllables. So the function measured by this test is perhaps not exactly the same as that measured by the test for rote memory span, where each series is given only once.

The correlation between the two tests above described was found to be .56 ± .10.

Free Association

This function differs from all the others in that its highest correlation is with rote memory, .265; logical memory giving a close second, .261.

The second group of correlations includes three, those with completion, opposites, and word building, ranging from .165 to .200.

The last group includes only one correlation, that with substitution. Here for the first time in this table we encounter a negative correlation, -.027, but it is not large enough to be significant. Practically, this table indicates no correlation between free association and substitution.

Substitution

Noting the average of the correlations of each test with every other test included in this table, we find that substitution stands lowest of all, having an average of only .113. This low figure probably indicates that the function measured by this test has not very much in common with the other functions measured, or at least with most of them. However, it is interesting to note that the relative standing of the coefficients of substitution with every other test is similar to the relative standing of the average coefficients of the several functions, as shown in the last row of figures at the bottom of the table. In the degree of correspondence between the ranking of its coefficients and the ranking of the average coefficients at the bottom of the table, substitution is surpassed only by completion, though some of the other functions maintain about the same degree of correspondence with the average. This fact would seem to indicate that there is at least some degree of similarity between the results of this test and the general trend of our table.

The coefficients of substitution with the other tests are decidedly separated into three groups, none of them being very high. The first group includes completion and opposites, with coefficients of .274 and .240, respectively. The second group includes only logical memory, .122. The third group includes word building, rote memory, and free association, the coefficients ranging from -.027 to .050, but all of them being so small as to be comparatively insignificant. As noted above, this negative coefficient is the only one found in this table as an average of the coefficients obtained in the three series of tests; though in some other cases one or two negative coefficients have been obtained in the separate series studied, in the relation between substitution and another function. In all, our table shows 18 such separate coefficients for substitution, and six of the 18 are negative. All these negative correlations are numerically small, ranging from -.004 to -.131. When the numerical values of coefficients are so small, possibly it is only chance that makes some of them negative, but we can hardly overlook the fact that no other negative coefficients occur in this table except in connection with substitution.

Further Studies in Correlation

If we take the coefficients of correlation of a given function with every other function, arrange them in the same order as the functions listed in our table, and then correlate this column of coefficients with the average coefficients at the bottom of the table, the following coefficients of correlation will be obtained in the case of the several functions, respectively: completion, .881, logical memory, .784, opposites, .620, word building, .710, rote memory .707, free association .576, substitution .928. When writing the average coefficients for these calculations, the average coefficient corresponding to the function in question was of course omitted, in each case. The coefficients of correlation thus obtained were correlated with the average coefficients at the bottom of the table, giving a coefficient of .027, indicating practically no correlation at all. It is not easy to express clearly the exact significance of the foregoing figures. The coefficient obtained in the case of each test seems to indicate the degree of consistency with which said test ranks the other tests in an order corresponding to their standing as judged by their average coefficients at the bottom of the table. That is, a perfect correlation in the case of any function would mean that if the other functions are correlated with said function, the relative standing of the resulting coefficients would be exactly the same as that of the average coefficients of the several functions, recorded at the bottom of the table. From purely numerical considerations, we might expect that the function having the highest average coefficient would exert the greatest influence in determining the relative standing of the average coefficients of the other functions, respectively; and that its array of coefficients would give the highest correlation with the array of average coefficients. If these considerations prevailed, we might find that the coefficient obtained in the case of each function, as mentioned above, would occupy the same relative position in this array of coefficients that the average coefficient of said function occupies in the array of average coefficients at the bottom of the table. As a matter of fact, we do find some degree of correspondence between the two arrays, completions and logical memory standing high and free association standing low in both cases. Substitution, however, stands at the head of one column and at the bottom of the other. The coefficient of correlation between the two columns is only .027, so small as to be practically negligible. This makes it clear that other considerations are involved, which outweigh the factor of mathematical value of the coefficients.

It seems that one of the other considerations involved is a matter of distribution of coefficients, rather than their absolute or average size. The coefficients obtained for substitution, although much smaller than those of completion and other tests, are distributed in an array which is more highly consistent with that of the average coefficients; so that substitution stands highest in the column of coefficients obtained in this calculation. This consistency of distribution must be due to something in the nature of the function measured by the substitution test, and the same may be said of the other functions measured.

Relation of Each Test to the Average of All.

Our table shows the correlation between each function and every other function, also the average coefficient of each function with every other function.

Another study has been made, showing the relation of the score in each function to the average of all the scores combined. Said average includes the score in the function under consideration, in each case. This study is based on the first of the three series of experiments included in our table. The results are as follows:

Completion with average of all tests	.77
Logical memory with average of all tests	.64
Opposites with average of all tests	.77
Word building with average of all tests	.53
Rote memory with average of all tests	.44
Free association with average of all tests	.41
Substitution with average of all tests	.26

The ranking of the tests in this column of coefficients is much the same as in our table combining the results of three series of tests. Logical memory and opposites have exchanged places, while the latter test gives the same coefficient as that of completion, which stands first in the table.

C H A P T E R VII

RELATION OF SPEED IN TAPPING TO OTHER FUNCTIONS

In order to determine to what extent the several functions measurd are influenced by muscular speed, a study has been made of the correlation of speed in tapping with each of the seven functions treated in this investigation. The results are as follows:

Speed in tapping with	completion	.276
" " " "	logical memory	.445
" " " "	opposites	.132
" " " "	word building	.068
" " " "	rote memory	.421
" " " "	free association	.188
" " " "	substitution	.050

These results are interesting and rather surprising. As these tests are given at the University of Missouri, logical memory and rote memory are the only ones which seem quite independent of the time element. On the other hand, substitution, after the scheme of characters has been mastered, seems almost entirely a matter of speed in writing. The same remark applies to free association and to easy opposites. There is also a time limit in tests of completion and work building. From these considerations, we should expect that substitution would correlate highest of all with speed in tapping, that free association would also correlate high, and that logical memory and rote memory would stand lowest of all.

On studying the list of coefficients, however, we find that the tests which seem most independent of speed or time, logical memory and rote memory, stand highest of all in their relation to speed in tapping, much higher than any of the other tests. We also find that substitution, which seems most dependent on speed, stands lowest of all the tests.

These facts seem at least to indicate that the relations between various mental functions cannot be judged *a priori*. Substitution must involve other factors more influential than muscular speed. On the other hand, there must be some sort of relation between speed and the functions measured by both memory tests, although the nature of that relation is not apparent and may be rather indirect.

CHAPTER VIII

ARMY TESTS.

The army tests, Alpha series, were also given to one of the classes which had taken the seven mental tests described above, during the present term. The total scores of the eight army tests, with the average of the seven mental tests, gave a correlation of .58. It seems probable that the mental tests measure native ability rather than acquired; while in the army tests acquired ability is rather more important than in the mental tests, though of course native ability also influences the results quite strongly. In general, men seem to make better scores than women in the army tests, while in the mental tests the reverse is true.

The various army tests, when compared with the average scores in the seven mental tests, gave the following correlations:

No.	1	gave	.31 ± .10	No.	5	gave	.52 ± .08
"	2	"	.22 ± .05	"	6	"	.57 ± .073
"	3	"	.22 ± .09	"	7	"	.603 ± .070
"	4	"	.324 ± .099	"	8	"	.33 ± .098

These tests may be roughly classified into three groups, on the basis of the correlations which they give with the average scores in the seven mental tests. Nos. 5,6, and 7 give over .50; nos.1,4, and 8 give a little over .30; while nos. 2 and 3 give .22. No. 5 is to rearrange random words into sentences and judge whether the resulting statements are true or false; no. 6 is a test in mathematical series; no. 7 is a test in analogues. Powers of perception and organization seem common to these three, but no.6 also involved mathematical training or ability, which would seem rather special. No. 1 measures attention and memory, no. 4 involves association and vocabulary, while no. 8 is largely a test of information. Perhaps both vocabulary and information are partially dependent on attention and memory. No. 2 measures arithmetical ability, which depends largely on training and practice, while no. 3 measures common sense and also involves information.

On the whole, it seems probable that the army tests which give highest correlation with the average scores in these seven mental tests are the best of the series in their indication of general ability. However, the number of subjects tested in the present experiment, 40, was perhaps too small to form the basis of a decided opinion.

CHAPTER IX

TESTS OF LEARNING.

Several tests of learning have been given, but a more careful study has been made of three of them, substitution, card distributing, and marble distributing. These tests are of a different sort from most of those listed in our table under the head of mental tests, substitution being the only one common to the two series of experiments. Mental tests may readily be compared with mental tests, and learning tests with learning tests; but when we undertake to compare the results of the two sets of experiments, a difficulty at once arises. What shall we consider as the standard score in learning tests?

Various plans have been suggested. We might use the total performance in a given series of learning tests, or we might use the scores in a single trial at a certain stage of the series, for instance, the second or fifth trial. Or we might use the combined results of certain trials, as the first three, or some other combination. Any plan suggested seems open to possible objection. In some learning tests the physiological limit is approached much more quickly than in others. For instance, the third trial in one test might represent a more advanced stage of habituation or learning than the sixth trial in some other more complex test. In the present study, different methods have been used, and different results obtained.

The three tests, cards, marbles, and substitution, were given in a series of nine trials for each test. By combining the results of the nine trials into total scores for each test, and comparing the scores of the three tests, the following correlations were obtained:

Cards with substitution	.168
Marbles with substitution	.142
" " cards	.079
Cards with average of three tests	.783
Substitution with average of three tests.	.649
Marbles with average of three tests . . .	.464

By using the score of a single trial in each test as the standard of performance in said test, namely, third trial in marbles, fifth trial in cards, and second trial in substitution, the following correlations were obtained:

Cards with substitution	.237
Marbles with substitution	-.080
" " cards	.043

Comparing these results with the coefficients of correlation between the total scores of these tests we find the same pair, cards with substitution, giving the highest coefficient in both cases; but the other pairs give quite different results in the two calculations. These results will serve to illustrate the difficulty of finding a satisfactory standard of comparison between learning tests and other mental tests. The detailed study of this problem is not included in the scope of the present investigation.

A comparison has been made between the results of the three learning tests above mentioned and the results of the army tests, Alpha series. For the purposes of this comparison, the scores representing the learning tests were those of the third trial in marbles, fifth trial in cards, and second trial in substitution; the same scores that were used in the second scheme of comparison described above. In the case of the army tests, the figures used were the total scores for the series of eight tests. The correlations obtained were as follows:

Substitution with army tests	.32
Marbles with army tests	.30
Cards with army tests	.25
Average of these three with army tests	.23

These four coefficients show a degree of uniformity which is rather remarkable in view of the widely varying sets of coefficients sometimes obtained in the case of series of apparently similar tests.

Using this same scheme of scores, the results of the three learning tests were also compared with the results of the seven mental tests listed in our table. As noted above, the substitution test is common to the two series of experiments. In this comparison, the score of each individual in the seven mental tests was the average of his performances in all of said tests.

The following correlations were obtained:

Substitution with average of 7 mental tests	.48
Marbles with average of 7 mental tests	.17
Cards with average of 7 mental tests	.09
Average of these 3 with average of 7 mental tests	.42

Comparing these correlations with those of the several learningtests with the army tests, we note that in this case the figures vary much more widely; but that the relative standing of the three learning test is the same in both cases, namely; substitution, marbles, and cards, in descending order. The average of the three learning tests gives nearly twice as high a coefficient of correlation with the average of the mental tests as with the total of the army tests, though two of the individual correlations are much lower.

Calculations have also been made, dealing with the scores obtained in learning tests, at different stages of the learning process. Tests in card distributing and in substitution were compared in this way. There were nine five minute practices in substituting letters for digits, and nine days of practice in card distributing. In these calculations, the first trial in each day of the card test is used, and is compared with the corresponding trial in the substitution test.

The resulting correlations are as follows:

Cards,	first	day,	with substitution,	first	trial	.777 ±.051
"	second	"	"	second	"	.228 ±121
"	third	"	"	third	"	.395 ±108
"	fourth	"	"	fourth	"	.560 ±088
"	fifth	"	"	fifth	"	.396 ±108

Cards,	sixth day,	with	substitution,	sixth	trial	.394 ±.108
"	seventh "	"	"	seventh	"	.319 ±.115
"	eighth "	"	"	eighth	"	.395 ±.108
"	ninth "	"	"	ninth	"	.319 ±.115
Average of nine coefficients,						.4203

The coefficients in this column show some interesting variations. The first is the highest of all, .777, the second drops to the lowest of all, .228, while the third is the most frequent figure in the column, .395. The third, fifth, sixth, and eighth figures are practically identical; the seventh and ninth are also identical, but much lower than the four coefficients just mentioned.

Some of the scores in the card distributing test and in the substitution test were compared with the scores in logical memory. In the card test, the score in the first trial of each day was taken as the score for that day. The results were as follows:

Cards,	first day,	with	logical	memory	.231
"	fourth "	"	"	"	.290
Substitution,	first trial	"		"	.358
"	fourth "	"		"	.316

We note that in the case of card distributing, the correlation of the fourth day's performance with logical memory is higher than that of the first day's performance. But in the case of substitution, the fourth trial gives a lower correlation with logical memory than the first. So these data are not sufficient to justify any conclusion as to what stage of the learning process will give the highest correlation with logical memory.

In addition to the series of three learning tests described above, an earlier experiment had been made with 60 or 70 subjects, to determine the interrelations of four learning tests; substitution, card distributing, marble distributing and learning nonsense syllables. For purposes of comparison, the scores used were those obtained in the second or third trial in each test, except in the case of nonsense syllables.

The resulting correlations were as follows:

Cards with	marbles	.218
" "	substitution.	.559
" "	nonsense	.399
Marbles"	substitution.	.620
" "	nonsense	.342
Substitution with nonsense		.432
Average of above correlations.		.4283

Substitution	with average of other 3 tests	.537
Marbles	" " " " " "	.393
Cards	" " " " " "	.392
Nonsense	" " " " " "	.391
Average of preceding four correlations		.428

The coefficients of correlation between pairs of tests range from .218 in the case of cards with marbles to .620 in the case of marbles with substitution. These coefficients are much higher than those obtained in the experiment described above, using three learning tests.

Perhaps the most remarkable feature of this column of coefficients is the uniformity of the correlations of the several tests with the average of the other three in each case. Three of these coefficients are almost identical, though the fourth differs considerably from them.

In this experiment, as in the later one using three learning tests, as described above, substitution gives the highest average correlation, marbles second, and cards lowest of these three tests. This ranking remains almost unchanged throughout all of our calculations involving results of learning tests.

C H A P T E R X

CONCLUSIONS

1. It seems useless to expect raw Pearson coefficients to be very high. Reliability coefficients of the seven mental tests average .608.

2. We find the highest correlation between functions which seem more complex, such as completion, logical memory, opposites, etc., and the lowest correlation between functions which seem more simple, such as substitution, free association, etc.

3. Through the absolute value of coefficients of correlation may vary widely from one series of experiments to another, their relative standing is fairly consistent.

4. If the various functions are ranked according to their degree of consistency in the distribution of the coefficients of correlation with other functions, their relative standing is quite different from their relative standing based on their average coefficients. In the present study, substitution stands highest in the former list, but lowest in the latter.

5. The intercorrelations between the three learning tests studied range from .079 to .168, or from -.080 to .620, according to the scheme of scores used. The coefficients are much higher in some series of experiments than in others.

6. The correlation of the average of the three learning tests studied, substitution, marble distributing, and card distributing, with the average of the seven mental tests studied is .42

7. The correlation of the average scores in these three learning tests with the total scores in the eight army tests is only .23.

8. The correlation of the total scores in the eight army tests with the average scores in the seven mental tests is .58.

9. The various army tests, when compared with the average scores in the seven mental tests, gave correlations ranging from .22 to .603.

10. There is no positive evidence showing whether general intelligence or ability is based on a single central function, or on a group of more or less specific functions.

11. So far as we now know, it is possible that correlation between two mental functions may be due to the influence of a central factor, to the presence of identical elements, to interdependence of the functions concerned, or to their common dependence upon a third factor, which may be as yet unknown.

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