THE MEASUREMENT OF MOTOR ABILITY

By
EVELYN GARFIEL, Ph. D.

Archives of Psychology
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The Measurement of Motor Ability

I. INTRODUCTION

The need for some supplement to the general run of intelligence tests, with a view to giving us a measurable account of those aspects of behavior untouched by tests for mental ability, is beginning to be recognized. The Stenquist Mechanical test was one of the earliest responses to this need in one field, the Voelker test for honesty, the Downey will profile, and the Woodworth tests for emotional stability are, each in its field, attempts to "tap" other sources of conduct than the purely intellectual.

Motor ability, roughly so called, has a place in this list. Its practical importance lies chiefly in its immediate usefulness for departments of physical education, and in its more remote, but perhaps more far-reaching significance, in vocational guidance.

In the search for tests of motor ability, much of the preliminary work has been accomplished in the course of mental testing.* The most recent work of Perrin (22)** and Muscio (20) are good attempts toward directly attacking the problems of motor ability, Muscio having had in mind specifically the value of the tests for vocational guidance. But more, naturally enough, needs to be known before we can answer such questions as the following:

(1) What is the intercorrelation of various tests that purport to measure motor ability?

(2) What criterion for motor ability can we use and what is its reliability?

(3) Can we arrange a team of tests that will correlate high with such a criterion?

(4) In the light of these, what is the nature of motor ability, and can we justly speak of *a* motor ability?

(5) What is the relation of this ability to general intelligence?

* See e. g. Abelson (1), Bickersteth (4), Burt (6), and Kirkpatrick (18).
** The numbers in parentheses refer to bibliography references.

With a view to obtaining some material for the answers to these questions the following experiments were undertaken:

Preliminary Experiment A: Investigating the relations of the four standard motor tests (Tapping, Three Hole, Steadiness, Grip) to each other and to the Army Alpha.

Preliminary Experiment B: Feeling the way to an extension of the number of available tests for motor ability and the interrelations and value of these tests in terms of a judgment criterion, as well as certain correlations with Alpha.

Main Experiment: Presenting the results of sixteen different tests for motor ability and one for motor interests on two groups of college students, the distributions of scores, the reliability of the tests, their intercorrelation and final combination into a team of tests for motor ability in relation to a judgment criterion; with a discussion of motor ability as such and its relation to mental ability.

II. PRELIMINARY EXPERIMENT A

Subjects: 25 students (13 men and 12 women) in a graduate class in Experimental Psychology. Ages 18 to 60.

Tests: Mental: Army Alpha.

Motor: *1.* Tapping: metal plate 4 by 5½ inches, wired through two batteries and a recorder. Metal stylus. Score equals number of taps in one minute. Time by stop watch.

2. Coordination: Three hole test. Three holes arranged in triangular form, wired as tapping, metal stylus. Score equals time for a hundred contacts.

3. Steadiness: Brass plate, set at 45°. Holes of 10/64 inch; wired as tapping, metal stylus. Score equals contacts in 60 seconds.

4. Hand Dynamometer: Small hand dynamometer. Score equals highest of three attempts. (Only 19 subjects took this.)

Average motor rank equals average of ranks in 1, 2, 3 above, reranked.

Correlations: Spearman Foot Rule follow:

Tapping with { Three hole equals .07 / Stead. equals .20 / Average Motor equals .66

Three Hole with Stead. equals —.02

Alpha with { Average motor equals .09 / Average motor equals .10 (with grip)

Remarks: 1. The three motor tests correlate low amongst themselves, so that if they do measure motor ability, they measure different aspects of it.

2. The correlation of any test with the average score in the three has no real meaning, for a self correlation forms one-third of the average motor score, and therefore raises the correlation of each with the group. The validity of the tests as a measure of motor ability would not be demonstrated by a high relation of any one test to the three as a group, for one argues here quite within a circle. Yet this mode of determining the value of tests has been used.

3. The correlation of these motor tests with alpha is very low, but positive.

III. PRELIMINARY EXPERIMENT B

Realizing that further experiment along this line would be fruitless unless a more varied series of motor tests could be devised, we desired to reach as many aspects of motor ability as we could. With this in view, we catalogued the aspects of motor ability under five heads:

1. Speed of voluntary movement.
2. Accuracy of voluntary movement, i. e., coordination.
3. Control of involuntary movement or steadiness.
4. Strength.
5. Motor Adaptability, i. e., capacity to "solve" motor situations, to make a new coordinated movement accurately.

We then proceeded to seek tests for each of these aspects. The final group used was:

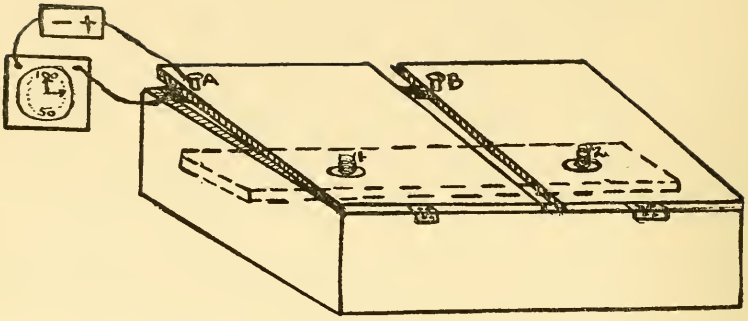

Figure 1.

I. Speed.

A. (Hand) Tapping: Described above (Preliminary Exp. A.)

B. (Legs) Foot-speed: See Fig. 1 above.
By "running in place" contact is made alternately at A and B, the board under each foot being released as soon as the foot is raised, by the stout springs (1 and 2) which rest on a board inside the box and support each foot-board.

Score equals number of contacts in thirty seconds. The experimenter demonstrated the working of the apparatus and allowed the subject a two second preliminary trial.

II. Coordination.

A. (Hand) Three hole test, described above (Preliminary Exp. A)

B. (Arm) Target Test: Three concentric circles, thirty, twenty, eleven inches in diameter respectively and a Bull's eye one inch in diameter were drawn on a blackboard. Subject stood 12 feet away and hit at bull's eye with a rubber ball (tennis ball size). Score equals number of points in five throws, when scoring is:

Bull's eye equals ten points.
Innermost circle equals five points.
Middle circle equals three points.
Outermost circle equals one point.

Other coordination tests were included in the list of "tricks," under adaptability.

III. Steadiness.

A. (Hand) Regular Hand Steadiness described above (Preliminary Exp. A).

IV. Strength: had to be omitted in this series.

V. Adaptability:

It is easy, in a regular gymnasium class, to see that the students differ not only in speed and strength of movement, but also in their ability to see through a motor situation; I mean merely to make quickly a difficult new reaction. Whether the superior student can do the "ladder" or "horse" stunt correctly the first time because she has more complex systems of coordinated movement habits at her command, or whether she can do this because she has some more general ability to quickly form and use such coordinated movement remains to be seen. But whatever the factor determining this ability may be, it is obvious that properly to differentiate between people with good and with poor motor ability we must try to allow for this factor ot speed of motor learning. A clumsy first attempt in that direction has been made here by using the following stunts. The score has been arbitrarily chosen as the number right.

1. A Puzzle: The experimenter slowly took the puzzle apart while the subject looked on. The subject was then required to solve it herself. This method minimized intelligence relative to manipulation as factors in learning to do a puzzle.
   Score equals correct if done in 20 seconds.
2. Another Puzzle: Same method.
3. Experimenter said: "Now see if you can do this; move this finger this way." (Moved right index finger clock-wise fashion in a vertical plane at right angles to the ventral surface of her body.) "And this finger this way." (Moved left index finger similarly but counter clock-wise, both at the same time.) Correct if accomplished at once.
4. "Now see if you can rub your stomach with you right hand and pat your head with your left hand both at once."
5. Experimenter said: "Now see if you can do this." Does the following: clap both hands, strike right knee with right hand, clap both hands, strike left knee with left hand, clap both hands, repeat twice.
6. Experimenter said: "Now see if you can do this." Claps

both hands, touches left ear with right hand and nose with left hand. Claps both hands, touches right ear with left hand, and nose with right hand. Repeat.

7. "Now see if you can do this." Charge right, left arm out horizontally; charge left, right arm out horizontally; back to original position.
8. "Now see if you can do this." Experimenter moved five feet in eight seconds by a movement which raises left toe and right heel and shoves to right toe and left heel, feet being always placed either toe to toe or heel to heel.
9. "Now see if you can do this." A complicated dance step, two hops, a slide and a crossing of the feet.
10. A piece of writing paper eleven inches long was folded down the middle and made to stand on the floor. Experimenter standing in front of the open part of the paper says, "Now hold your right toe in your left hand (crossing the foot behind the body) and pick up the paper with your mouth. You will be allowed enough time to do it, but speed counts. If you lose your balance or throw over the paper stand up, right the paper, and begin over again." Score equals correct if accomplished in sixty seconds or less with two falls or less.

The Alpha test was given to all the students.

Only ten subjects, Barnard Sophomores, were given these tests, just to see how they would work out. All tests were taken in gymnasium clothes: middy, bloomers, no corsets. All the students had had one year of regular gymnasium work at Barnard. (Twice a week.)

The teachers' estimate of motor ability, to be used as a criterion for the tests, was obtained by requesting the three gymnasium instructors in charge of all sophomore classes to rank the ten students in order of motor ability, motor ability to be understood as strength, speed and accuracy of movement, the ability best shown in the gymnasium and in sports. An independent ranking by each teacher could not be obtained because no one instructor knew all ten students. (Ream's method for combined ranking had not yet been published in January, 1920). The three instructors met therefore "in committee" and decided upon a ranking of which they all approved.

The resulting correlations ($p = 1 - \frac{6\Sigma d^2}{n(n^2-1)}$) follow: (p transmuted into r).

TABLE I

	Tapp.	Ft. Speed	3 Hole	Target	Stead.	Tricks	Av. Motor	Teach. Est.	Alpha
Tapp.		.42	.13	.66	.55	.00	.78	.60	–.22
Ft. Speed	.42		.35	.52	–.32	.39	.74	.45	.09
Three Hole	.13	.35		.32	–.08	.07	.59	.59	–.04
Target	.66	.52	.32		–.08	.30	.77	.54	.37
Stead.	.55	–.32	–.08	–.08		–.14	.26	.17	–.49
Tricks	.00	.39	.07	.30	–.14		.45	–.31	.19
Motor Av.	.78	.74	.51	.77	.26	.45		.49	–.08
Teachers' Estimate	.60	.45	.59	.54	.17	–.31	.49		–.19

Tapping and three hee hole with alpha equal –.29

TABLE II

Teachers' Estimate correlated with

A. All tests*	.49	
B. All but one test		
1. Tapping out	.52	almost no effect.
2. Foot speed out	.50	
3. Target out	.50	
4. Three hole out	.48	
5. Steadiness out	.43	lowers
6. Tricks out	.70	raises
C. Combinations:		
1. The four good tests (Three Hole, Foot Speed, Tapping, Target)*	.78	
2. Tapping and Three Hole*	.79	
3. Foot Speed and Target*	.50	
4. The three standard tests (Tapping, Three Hole, Steadiness)*	.73	
5. Steadiness and Tricks*	.04	

A consideration of Tables I and II brings out some interesting relations.

Table I: Concerning the Tests:

1. That Tapping, Foot-Speed, Three Hole and Target,

* Average Motor Scores for any number of the tests represent the sum of the ranks obtained in each of those tests, reranked for the purposes of correlation.

the tests of speed and coordination, correlated fairly high amongst themselves (.13 to .66) and may be supposed, therefore, to be reaching approximately the same or related abilities.

2. That Tricks and Steadiness (except Steadiness with Tapping .55, and Tricks with Foot Speed .39) tend to a very low or negative relation with the other tests, and may therefore be assumed to test different factors from those reached by any of the other tests.

Table II: Concerning the Validity of the tests as tests of motor ability:

1. That the tests (Tapping, Three Hole, Foot Speed, Target) correlate high with the Teachers' Estimate (.60 to .45) and the two tests (Steadiness and Tricks) correlate .17 and —.31 with the Teachers' average. This strengthens the supposition that the first four tests are reaching the factors we are after.

2. That the omission of any one of the four tests seems to leave the correlation substantially the same (See Table II, B). This further corroborates the conclusion that they are reaching more or less the same factors of motor ability, albeit fairly well. Another indication comes from the fact that while the four tests together correlate .78 with the Teachers' Estimate, the omission of Target and Foot Speed does not change the relation, i. e., they add no new factors. However, Target and Foot Speed alone, while they detract nothing from the value of the group, are themselves inferior as a group to Tapping and Three Hole, for they alone (Target and Foot Speed) correlate only .50 with the criterion.

Tapping and Three Hole achieve the .78 by supplementing each other, for each alone correlates only .60 and .59 respectively with the Teachers' Estimate.

The outcome of all this would indicate that in spite of the theory that other factors than those usually measured in the attempt to measure Motor ability as a whole should be added to the group to make it more effective, the two old tests, Tapping and Three Hole together, give the best* combination so far for measuring motor ability (to the extent of a .79 correlation with the cri-

* Best here means the best correlation with the criterion.

terion) and that while some of the other tests which detract nothing from the value of these tests, are alone not as good, others suggested have proven to be unrelated to the ability under consideration.

However, correlation based on tests of ten people with no measure of reliability of either tests or criterion and no evidence from other sources cannot be accepted with too much faith. For this reason, tests with a larger group, under standardized conditions and with a larger variety of individual tests were later undertaken and will be reported in this paper.

One more factor needs to be discussed before we leave this experiment, the relation of the motor tests to Intelligence as measured by the Army Alpha. The individual tests correlated from .19 (Tricks) to —.49 (Steadiness) with Alpha* indicating that they undoubtedly measure a factor not measured in Alpha. The average score** of all the motor tests correlates —.08 with Alpha. The Teachers' Estimate correlates —.19 with Alpha. The two best motor tests (Tapping and Three Hole) correlated —.29 with Alpha. This seems to point to a consistent low negative relation with Intelligence and is borne out by some investigators.*** It is contrary, however, to the low positive relation obtained in the previous experiment and in the one following.

IV. MAIN EXPERIMENT

The object here was again twofold: to obtain a series of tests that should adequately† measure motor ability, and to discover the relation of this ability to mental ability as shown in an intelligence test. Of course this statement involves us immediately in several discussions, the most important of which, "Is there a motor ability, and how shall it be conceived?" will be discussed in the next section.

The subjects were fifty Barnard girls, Sophomores, every fourth name on the class register being chosen. All the students had had one year of Physical Education at Barnard but varying amounts, of course, at their High Schools. The correlations and general conclusions were obtained from this group, but in order to check these results, three Physical Education instructors, who among them had all the Sophomore gymnasium classes, were asked

* The target test correlates .37 with Alpha. The unreliability of the target test (.07 as shown below in the main experiment) must be taken into account in the evaluation of any correlation in which it takes part.

** Average score equals Sum of the ranks in all the tests, reranked.

*** See Chart A, after Main Experiment.

† "Adequately" being understood to mean agreeing with the opinion of competent judges.

to select the ten best students and the ten worst students in the whole class; "best" to mean best in motor ability, in speed, accuracy, and strength of movement, in those abilities shown in the gymnasium, irrespective of interest or intelligence or personal bias. We should have expected five persons from the extremes of the curve to be members of a chance sampling of the total group. This is true because there were two hundred students in the Sophomore class; 50, or 25%, were chosen by chance for the general group. Of the best ten in the class, therefore, 25% or 2.5 persons should already have been included in the sampling of fifty; of the ten worst, 2.5 should likewise have been included. But *seven* of the twenty (ten best and ten worst) chosen proved to be members of the general group of fifty. This was two more, obviously, than would have been found had the general group been a perfect sampling, the general distribution a perfect curve of frequency, and the choice of the ten best and the ten worst a perfect choice of the upper and lower ends of the curve.

The difference between the averages of these best and worst groups in all the tests and the P. E.'s of the averages and the differences were computed and used as a check on the correlations.

Tests

I. Mental: As a general test of intelligence the Army Alpha was chosen. Only 32 subjects took this test. Therefore all correlations with Alpha are based on only thirty-two cases.

II. Motor: The tests were a revised form of those used in the second preliminary experiment with a few additions, but the complete list will be repeated here.

A. Speed.

1. Tapping as in Preliminary Experiment B. But score equals number of taps in 30 sec.
2. Foot Speed as in Preliminary Experiment B.
3. Running: 100 yards on the gymnasium track. Time by stop watch in seconds to tenths of a second.

B. Control, Coordination and Motor Adaptability.

4. Steadiness: as in Preliminary Experiment B.
5. Three Hole: as in Preliminary Experiment B.
6. Target: as in Preliminary Experiment B.
7. Picking up Paper Test: this was one of the

"Tricks" in the preliminary experiment, but it seemed to the experimenter so diagnostic of ability to gain control of the body quickly that it was made a separate test. Score was time to pick up paper with maximum of 65 seconds.

8. Tricks: Experimenter does each and then says, "Now you do it."

Right if done at once, except where time is specified.

First time:* I. Anchor Puzzle: Fifteen seconds.

II. Finger Ladder: (*1*) Touch right index finger to left thumb. Hold position while you; (*2*) touch left index finger to right thumb; (*3*) hold (2), drop (1) and raise the two fingers in (1) over (2), assuming there position (1); (*4*) Drop (2), hold (1), raise fingers of (2) over (1) and touch there; (*5*) repeat.

III. Trick No. 5** of Preliminary Experiment B.

IV. Rub stomach, pat head at same time.

V. Dance step; slide, hop, cross, close.

Second Time:

I′. Nail Puzzle; fifteen seconds.

II′. Meeting of fingers: close eyes, hold arms out horizontally and away from body. Bring index fingers together so fingers touch at nail. Correct if done in three trials or less (the three determined by the number of trials most people who do get it at all usually need.)

III′. A variety of III above. Instead of hitting knee, hit opposite ankle, raising leg to meet hand.

IV′. Same as Trick No. 6*** of Experiment B.

V′. Dance step, almost same as V above.

When results for this test were to be scored, the question arose of weighting the separate tricks, inasmuch as some were done correctly by almost everybody, while one or two very few did correctly. We realized that some of the tricks must be better than others for our purpose and that without further knowledge we could not

* All tests were given twice, but obviously new Tricks had to be devised for the second giving.

** Striking knee, clapping hands, etc.

*** Clap hands, touch nose and ear, etc.

assume that Series II was as good a substitute for Series I as a second trial of other tests for their own first trial. The following table shows the frequency in fifty with which each trick was correctly done, and the weight assigned accordingly.

TABLE III

Showing the Weights of the Tricks According to Frequency in 50.

	FIRST TIME			SECOND TIME	
Trick	No. who got it right	Weight	Trick	No. who got it right	Weight
I	13	3	I′	15	3
II	32	2	II′	40	1
III	35	1	III′	40	1
IV	22	2	IV′	31	2
V	10	3	V′	15	3

The two Series of tricks are found to be similar, but the individual tricks have different difficulty values.

Another weighting method was tried by using the results from the ten best and the ten worst group. The number in each group who had each trick correct was computed and that test considered best which best differentiated between the good and poor groups.

TABLE IV

Showing the weights of tricks according to the degree to which they differentiate the good from the poor group.

Trick	No. of ten best who had it right	Same for ten worst	Difference / Larger No.	Weight
I	2	1	50%	1
II	8	5	37%	1
III	9	9	0%	1
IV	9	3	67%	2
V	3	2	33%	1
I′	3	2	34%	1
II′	9	6	34%	1
III′	9	8	11%	½
IV′	8	2	75%	2
V′	5	3	40%	1

This second series of weights when applied to the actual scores was found to better differentiate the good from the bad group than the first series had done. Tests II, IV, and II′, IV′ and V′ were therefore used with the weights here indicated as one general test "Tricks" for both the general and the ten best and ten worst groups.

C. Strength Tests.

9. Hand Dynamometer: as in Experiment B.

10. Back Dynamometer: see Whipple: Best of three trials used.

11. Leg Dynamometer: see Whipple: best of three trials used.
12. Lung Capacity: see Whipple (wet Spirometer). Record of Barnard Medical office made four months previous to present testing series. One record only.
13. Chest Strength: Record of Medical Office: made same time as 12: special adjustment to hand grip apparatus.

D. Physical Tests.

14. Height } medical office records: made same time as
14. Weight } 12 and 13.

E. Tests of Interest.

16. Preferences: Some indication was sought of the influence of interest in gymnasium and sport activities upon scores in motor ability tests. With this in view the following list was submitted to each subject:

Dear Sophomore:

Suppose you had a perfectly free afternoon, and you were told you might spend it in any one of the 12 following ways. In general, which would you most prefer; call that Number 1. Which would you make your second choice? Call that Number 2, and so on down the list to 12.

1. Playing tennis.
2. Going to a tea.
3. Practising for Greek games.
4. Writing—poetry, a story or a play.
5. Reading a book.
6. Going ice skating.
7. Going to a football, baseball or basketball game.
8. Going to the theatre.
9. Going walking.
10. Going to a lecture.
11. Going swimming.
12. Playing whist or other card games.

Note: 1, 3, 6, 11, indicate motor interest.
4, 5, 8, 10, indicate mental interest.

The justifiability of including 8 as of "mental interest" may be doubted. We do not wish to enter the ranks of dramatic criticism, but we had "highbrow" plays in mind—the kind many Barnard girls attend. A better choice, as a substitute, could however be found for a revised form of this test.

Scores: The sum of the positions (equivalent to the average posi-

tion) assigned to the four motor "interests" was subtracted from the sum of the positions assigned to the four mental interests, the difference being called negative if the mental interests received a higher place, i. e., a smaller sum. This difference was the score. Naturally those most interested in sports showed the largest difference between their motor position and their mental position. It is surprising that so crude an instrument for detecting interests should correlate .31 with the criterion. If the list were longer and included more specific activities, it might yield more valuable results.

The number of hours spent in the gymnasium and in sports per week during the school year was also obtained, but the results were not indicative except in the case of the "good" and "poor" groups.

III. Criterion:

Several varieties of tests (to be discussed below) have been used by experimenters as tests of motor ability. Even the most recent work* is an attempt to analyze motor ability by tests "selected on a priori grounds—[to] test each of the possible (assumed) motor functions—."** But no attempt has been made to discover whether ability in any of these tests corresponds at all to motor ability as determined by competent judges. This means that though on the face of it a test may seem to be measuring some function or aspect of a function, the actual abilities sought are often so complex that the common sense guess at the means of reaching them is not always right. We must therefore use as a standard, a criterion of the "hit-it-rightness" of our tests, either some objective measuring rod, or where that is impossible, the combined judgment of several people.

For this reason we obtained a ranking of the fifty subjects in the general group in order of motor ability in the following way:

Judges: Three of the faculty of the gymnasium department and five students, three of whom were exceedingly interested in athletics, and two of whom were prominent students well acquainted with the other girls.

Material: Each judge received a letter explaining the value of the tests and the necessity of relying on judgment as a criterion for their value. Fifty slips (each containing the name of one student) arranged in alphabetical order, were enclosed. The judge

* (a) Perrin (1921) see bibliography; (b) Muscio (1922) see bibliography.
** Perrin.

was requested to pick out the slips containing the names of the people she knew and to arrange these in order of merit for motor ability, which was described as ability to make strong, accurate and quick movements, the general ability shown in gymnasium and sports. Certain precautions (which need not be repeated here) were given to help in careful ranking. No mention was made of a second grading. Six weeks later copies of the original letter, directions and slips were sent again to the same eight judges and a second grading obtained from two faculty instructors (the third had known only six students) and four students. The correlation between the first and second rankings of the six judges gave a reliability coefficient of .92. The scattered judgments of the eight judges were combined into a single judgment for each subject according to the method of Ream.*

All the tests, except the Alpha and the scores of the Medical Records, were given twice (two weeks between trials), individually and all in one period of thirty minutes.

The following was found to be the most convenient and time saving order in which to give the tests: Tapping, Three Hole, Steadiness, Hand Dynamometer, Back Dynamometer, Leg Dynamometer, Foot Speed, Tricks, Target, Paper, Running. The specific reasons for this order are these: Tapping is always of interest to students; it is a new apparatus and not hard to master; Steadiness and Three Hole are both given at the tapping board, the apparatus for the three tests being wired through the same counter and batteries. Before leaving the table, the Hand Dynamometer is presented to the students and directly after, the two other strength tests, because, while they require effort, they do not seem to leave the student tired or out of breath. The most tiring tests are Foot Speed and Running. The object was therefore to separate them by less strenuous stunts. After Foot Speed, therefore, Tricks was given, for the first two tricks require only leisurely finger movements and none of them is particularly fatiguing. The Target, which also requires little effort, was given next. The interlude afforded by these two tests gave the subject an opportunity to relax thoroughly. The Paper Test, which required complicated control and coordination was presented, and after one minute (consumed in walking across the hall to the track and in giving directions) the subject ran 100 yards and was released.

* M. J. Ream: See Bibliography.

Results

In Table V are presented the Highest, Lowest and Average Scores, as well as the S. D.'s for the group of fifty. This table gives an idea of the distribution meaning of specific scores.

Table VI gives the reliability of the tests. For Alpha and Preferences no second record was taken, nor was a second record available for those tests given by the medical office.

TABLE V

Test	Highest Score	Average	S. D.	Lowest Score
Running	15″	21.05	2.25	28″
Paper	3″	39.46	24.24	65″
Back	240.0	168.52	30.69	88
Tricks	7.5	4.15	2.23	0
Steadiness	8.0	84.98	34.65	198
Tapping	245.0	199.30	18.25	172
Leg	232.0	162.24	28.43	83
Hand	42.0	32.18	4.50	21
Total Wt'd Scale	3889*	2932.6*	62.40	1698*
3 Hole	59.0	40.18	6.16	28
Foot Speed	130.0	96.60	18.85	54
Target	40.0	21.06	7.32	6
Lung Capacity	230.0	169.20	20.93	106
Chest Strength	57.0	42.30	8.04	22
Height	67.0	63.83	1.70	60
Weight	177.5	123.50	19.70	95
Alpha	195.0	163.25	20.40	115
Preferences	25.0	4.84	8.04	–20

TABLE VI

Reliability of Individual Tests

Correlation of Trial I with Trial II is:

Running	.85	
Paper	.48**	
Back Dyn.	.81	
Steadiness	.61	the final team ***
Tapping	.69	
Leg Dyn.	.71	
Hand Dyn.	.70	
3 Hole	.60	
Foot Speed	.76	
Target	.07	

* Last place may be dropped in actual use.

** Part of the unreliability of the Paper Test may be explained by the fact that several of the subjects practised the test as a "stunt" between the first and second trials and so altered their scores materially. In a group of fifty a few big changes can affect the correlation by ten or even twenty points. The .48 reliability of the Paper Test makes the reliability of the scale .77, lower probably, than it really should be. (See Table X.)

*** There is no reliability for tricks because, as explained above, several tricks from each trial were used as one test "Tricks."

Table VII * gives the intercorrelations of each test with all the others, and with the criterion; the P. E.'s are given separately in Table VIII.

TABLE VII

Showing the Intercorrelations of Each Test with Every Other Test.

	Criterion	Running	Paper	Back Dyn.	Preferences	Tricks	Lung Capac.	Hand Dyn.	Foot Speed	Tapping	Chest Str.	Leg Dyn.	Three Hole	Height	Steadiness	Target	Weight	Height	Weight	Alpha
Criterion		.63	.44	.40	.31	.29	.28	.25	.23	.22	.22	.20	.19	−.02	−.19	−.20	−.20	−.23	.02	
Running	.63		.23	.26	.31	.17	.18	.16	.23	.14	.26	.28	.15	.00	−.02	−.11	−.28	−.29	−.17	
Paper	.44	.23		.04	.22	.11	−.13	.13	.09	−.08	.08	.17	−.11	−.24	−.17	−.13	−.39	−.46	−.33	
Back Dyn.	.40	.26	.04		.11	.15	.51	.36	.25	.32	.44	.50	.16	.18	−.04	−.04	.26	.28	.23	
Preferences	.31	.31	.22	.11		.09	.22	−.03	.19	.12	.08	.05	−.04	.17	−.12	−.02		−.03	−.08	
Tricks	.29	.17	.11	.15	.09		.35	−.07	.33	−.02	.04	−.05	−.11	.11	−.12	−.27	−.04	−.07	.32	
Lung Cap.	.28	.18	−.13	.51	.22	.35		.28	.36	.33	.31	.44	−.02	.39	−.16	−.03	.13	.22	.27	
Hand Dyn.	.25	.16	.13	.36	−.03	−.07	.28		.14	.20	.26	.34	.26	.20	.02	.01	.02	.07	.06	
Foot Speed	.23	.23	.09	.25	.19	.33	.36	.14		.20	.15	.21	.03	.06	.06	−.03		−.03	.06	
Tapping	.22	.14	−.08	.32	.12	−.02	.33	.20	.20		.14	.19	.31	−.09	.08	.00		.18	−.12	
Chest Str.	.22	.26	−.08	.44	.08	.04	−.31	.26	.15	.14		.34	.01	.04	.09	.02		.43	.11	
Leg Dyn.	.20	.28	.17	.50	.05	−.05	.44	.34	.21	.19	.34		.26	.06	.01	−.21	.09	.07	−.01	
Three Hole	.19	.15	.11	.16	−.04	−.11	−.02	.26	.03	.31	.01	.26		−.16	−.09	.01	.03	−.01	−.25	
Height	−.02	.00	−.24	.18	.17	−.11	.39	.20	−.06	−.09	.04	.06	−.16		−.20	.05		.16	.22	
Steadiness	−.19	−.02	−.17	−.04	−.12	.12	−.16	.02	.06	.08	.09	.01	−.09	−.20		.09	.18	.14	.27	
Target	−.20	−.11	−.13	−.04	−.02	−.27	−.03	.01	−.03	.00	.02	−.21	.01	.05	.09			.10	.08	
Weight	−.20	−.28	−.39	.26		−.04	.13	.02				.09	.03		.18					
Height																				
Weight	−.23	−.29	−.46	.28	−.03	−.07	.22	.07	−.03	.18	.43	.07	−.01	.16	.14	.10			.03	
Alpha	−.02	−.17	−.33	.23	−.08	.32	.27	.06	.06	−.12	.11	−.01	−.25	.22	.27	.08		.03		

TABLE VIII

Showing P. E.'s of correlation coefficients according to the formula

$$\text{P. E.}_{t\,-\,\text{obt r}} = .6745\ \frac{(1-r^2)}{\sqrt{N}}$$

P. E. r	Coefficients of Correlation	P.E. r
.01	.95.....1.00	.01
.02	.89..... .94	.02
.03	.84..... .88	.03
.04	.76..... .83	.04
.05	.69..... .75	.05
.06	.61..... .68	.06
.07	.52..... .60	.07
.08	.40..... .51	.08
.09	.24..... .39	.09
.10	.00..... .23	.10

* Pearson Correlations were used throughout, but the labor involved in calculating over 100 correlations was considerably shortened by the use of Toops' method for which see his articles, No. 29 in this bibliography.

The major problem was, however, to combine a number of these tests in such fashion that their combined correlation with the criterion would be as high as possible. The usual method of multiple correlation is to find the partial correlations of each test with all the other combinations and by this method to discover both the weights according to which the tests are to be used, and those tests which are most effective. But H. A. Toops, of the Bureau of Educational Research of Teachers College, has devised a method by which one may obtain an approximation (to within .01) of the multiple correlation coefficient. By means of a job analysis the whole series can be solved through in several hours. The final cumulative correlation is checked by assigning the weights obtained to the individual scores of the subjects and recalculating the correlation of their combined weighted scores with their scores on the criterion. This correlation was .02 lower than that statistically obtained, .77 as against .79. This is a permissible degree of error. It occurs because the actual weightings used are only approximations to those obtained from the formula (see Table IX, columns 2 and 3). Since this method is hitherto unpublished, Dr. Toops has been kind enough to write the following paragraphs explaining his method.

"The problem of securing the *maximum* predictive value from a *minimum* number of tests resolves itself into the problem of determining that test, U, of a number of available tests, which will yield by the technique below presented a maximum multiple ratio correlation coefficient when combined at the proper weight with an already existing weighted test composite, C, which already has a maximum correlation with the criterion. This involves the determination of the correlation of test U with the composite, C; the determination of the weight β, of the test U, such that when the deviations in terms of standard deviations in Test U are weighted by that amount (β), the multiple ratio correlation coefficient r_{Ic} (I being the criterion) of the new test composite at that point shall be a maximum by this method of computation.

"At the outset, that test of the n available tests which correlates highest with the criterion, is taken as the "backbone" test, and is named Test C (in this series: Running); the correlation coefficient r_{Ic} (in this series .63) is a maximum at this point of building up a scale. If the gross scores in Test C are now given a weight of 1.000, there is for any test, U, a weight ($\beta_{u/c}$) such that when

σ_c

the gross scores in Test U are multiplied by $\beta_{u/c}/\sigma u$ the multiple correlation coefficient, $r_{IC'}$ of the two-test scale correlated with the criterion shall be a maximum. But some of the tests, when weighted at their own individual $\beta_{u/c}$ weights, will yield higher multiple correlation coefficients than others. Hence, the ordinary formula for multiple correlation is solved for each of the remaining (n-1) tests in turn:

$$r_{IC'} = \sqrt{\frac{r_{IC}^2 + r_{IU}^2 - 2r_{IC} \cdot r_{IU} \cdot r_{UC}}{1 - r_{UC}^2}} \qquad (1)$$

That test which yields the maximum multiple correlation coefficient is now called Test U. The weight of Test U with respect to Test C weighted 1.000 is

$$\beta_{u/c} = \frac{r_{IU} - r_{IC} \cdot r_{UC}}{r_{IC} - r_{IU} \cdot r_{UC}} \qquad (2)$$

We now consider that theoretically the gross scores on Test U have been added at the proper weight to the gross scores of Test C; our problem is then to find by formula the weight of a new Test, U′, such that when its gross scores are added to the now existing test composite, C′, (the gross scores of which are considered as now being weighted 1.000) the multiple ratio correlation coefficient shall be a maximum for all the possible remaining (n-2) tests. It is not necessary actually to combine the gross scores and compute the necessary correlation coefficients, $r_{U'C'}$ since a formula obtains the same result:

$$r_{U'C'} = \frac{\Sigma\, r_{U'y} \cdot W_y}{\sqrt{\Sigma W_y^2 + 2\Sigma r_{xy} \cdot W_x \cdot W_y}} \qquad (3)$$

in which, $r_{U'y} \cdot W_y$ is the sum of the single-products of all the correlations of Test U′ that occur in a column U′, each respectively multiplied by the weight of the Test W_y of the row for all the rows of the test composite C′ which enter into a double symmetrical intercorrelation table, which is being built up as the test composite is being built up. This test composite at this point consists of Tests C and U, whence the two correlation-products are $r_{U'C'}(1.000)$ and $r_{U'U} \cdot \beta_{u/c}$

"ΣW_y^2 is the sum of the squares of the weights in the test composite at this time; namely, here $(1.000)^2 + (\beta_{U/c})^2$.

"$\Sigma r._{xy} W._x W_y$ is the sum of all the double-products when each of the intercorrelations of tests in the test composite at this time are respectively multiplied by the weight of the row and column in which they are found in an intercorrelation table, namely, here, $r_{UC} \cdot (1.000) \cdot \beta_{U/c}$

"With this equation solved for all the remaining (n-2) variables, resort to formula (1) determines which test will yield the maximum multiple ratio correlation coefficient, $r_{IC''}$ This test, when determined, is called U". The weight of U" in the multiple ratio regression equation is given by the formula:—

$$\beta' = \sqrt{\Sigma W_y^2 + 2\Sigma r_{xy} \cdot W_x \cdot W_y} \times \frac{r_{IU'} - r_{IC'} \cdot r_{U'C'}}{r_{IC'} - r_{IU'} \cdot r_{U'C'}} \qquad (4)$$

"The quantity under the radical does not enter into formula (2) for the reason that the standard deviation of the original test C is 1.000, when measured in terms of its own standard deviation. When adding on Test U' the composite C' has a standard deviation of its own which must be considered, and which this radical expression takes full account of. Equation (4) is the perfectly general expression of the weight at which a new test U" is added to an already existing test composite C'. By repetitions of the procedure involved in adding Test U" as above outlined, one may determine in succession the fourth, fifth, sixth tests, and so on. The multiple ratio correlation coefficient at each point is an index of the efficiency of the scale. Soon a point of diminishing returns is reached, where the addition of a test adds but little to the value of the multiple ratio correlation coefficient at that point, and the value available will approach the value which we would receive from the inclusion of the entire *n* tests. At this point the test can be considered complete.

"Any two or more of the tests can be used for the scale by cutting off from the composite any number of tests which are added last.

"The multiple ratio correlation coefficient is not a true multiple correlation coefficient but is a very close approximation to it."

See Table IX for the final weights, scoring Formulæ and cumulative correlations with criterion, derived from Toops Multiple Ratio Correlation Method.

The weight β' is the weight derived from the formula (4) above. This is divided by the Sigma to give the actual comparative gross score weight. This is necessary because while a variation of 1 in the case of Tricks represents about 1/7 of the total range of scores possible, a variation of 1 in the case of Back Dynamometer represents only less than 1/200 of the total range of scores. And it is degree of variability, not magnitude of gross score, which actually affects the amount of correlation. The scores therefore must be used in terms of their variability in order to be comparable.

See Table X for reliabilities of the scale and of the criterion, the relationship of Alpha to the two final motor scores, and the relationship of Preferences to the two final motor scores, as well as the cumulative correlation of the team with the criterion.

TABLE IX

Weights, Scoring Formulæ, Cumulative Correlations.

Tests	Weight β' / Sigma	Gross Score Weight	Final Gross Score Weight (equals actual weight x $\frac{1000}{4}$ Approx.)	Scoring Formula	Cumulative Correlation	Cumulative time to give (Minutes)
Running	1.000 / 2.25	.4444	100	100(28-T)*	.63	1
Paper	.5591 / 24.24	.0230	5	5(65-T)**	.699 ††	4
Back	.4985 / 30.69	.0162	4	4(score)	.742	7
Tricks	.2832 / 2.23	.1270	30	30(score)	.754	12
Stead.	—.2985 / 34.65	—.0086	—2	2(score)***	.768	13
Tapping	.2376 / 18.25	.0130	3	3(score)	.776	14
Leg	—.2576 / 29.43	—.0087	—2	2(235-Score) †	.785	16
(can be given at same apparatus and right after Back Dynamometer)						
Hand	.1587 / 4.5	.0353	8	8(score)	.794	17

* 28 seconds equals highest time. Scores inverted to give highest time least credit. T equals time score of subject.

** 65 seconds equals highest time. Scores inverted for same reason as in *.

*** The score here has been inverted twice, once because the higher number score equals poorer score (i. e., more contacts equal poorer score) and again because the weight is negative, (i. e., this score is in a sense to be subtracted from the total score).

† Although the correlation of Leg with the Criterion is positive, the weight assigned was negative, so that this score had to be inverted.

†† This number (and each below it) equals the combined correlation with the Criterion of all the previous tests, including this test.

TABLE X

Reliability and Validity of Scale, Relation to Alpha, etc.

First giving* with	
A. Second giving i. e. Reliability equals	.77
B. Same, excluding Tricks' reliability equals	.75**
C. First criterion equals	.77
D. Second criterion equals	.73
Second giving with	
A. First criterion	.64
B. Second criterion	.58
Criterion (first) with Criterion (second)***	.92
Alpha with	
A. First giving	.09
B. Criterion (first)	.02
Preferences with	
A. First giving	.30
B. Criterion (first)	.31

We shall present here also three tables which tell the whole story for the good and poor groups. The results obtained from these tables are to be compared with the final results from the general group as shown in Table X.

The subjects, good and poor, were given all the tests in the same way and under the same conditions as the subjects in the general group. (They did not know, of course, that they had been chosen as the especially good or poor ones.) Everyone was told that the selection was a chance one. The reliability of the choices of good and poor people proved to be probably good in all cases but one, a member of the "poorest" group. Her attitude and her scores seemed so different from those of the other members of the poor group, judged by her general attack and sheer observation of her scores, that we questioned her and discovered that she is a transfer from another college, new to Barnard, and to Barnard gymnasium methods, that she had missed a few lessons, then had been bored and then not done well, but that she really liked sports and played tennis well. By the

* First giving equals final weighted scores in the first eight tests listed in Table V. Second giving equals same gross score weights, but for scores in second trials, Tricks included, with reliability of 1.00.

** Because the two sets of Tricks (for the first and second trials) were combined into one score, we had no second measure for Tricks. The reliability of the series was therefore computed both with Tricks in (assuming a 1.00 reliability) and with Tricks omitted.

*** Criterion (first) equals score given each person by combning the first judgments of the six judges who gave later a second judgment. Criterion (second) equals score given each person by the same six judges six weeks later. (Same method of computation.)

tests, instead of being chosen as among the worst ten of the class, she would have rated 284, *i.e.,* 9 points below average. One student in the general group, on the other hand, who was not placed in the "poorest" group was lowest in the motor scale and lower also than any one in the "poorest group." All the judges later rated her lowest of the fifty in the general group; she should probably have been placed in the "poorest group." These points indicate that though the choice of the judges is probably in general a correct one*, the tests have been able to detect two "errors" in this judgment.

Nevertheless, in spite of the fact that one person placed by the judges in the poor group is much better than the average of that group, the differences between the test scores of the two groups are large enough to make the tests, especially when weighted and used as a scale, of diagnostic value for motor ability, in this way corroborating the results for the team as obtained from the general group. ** See Table XI page 24 for scores, etc., in the first and second trials; see Table XII below for scores, differences, etc., in Scale as a whole (weighted according to weights obtained from the correlations of the general group) and for scores, differences, etc., in Alpha and in Interests.

TABLE XII

Results from Good and Poor Group for

	Average Motor Unweighted Running, Paper & Stead. Scores† Inverted	All tests Average Motor Regular Weights	Average Motor Weighted Leg Dyn. not inverted; Stead. inverted‡	Alpha	Preferences	Hours of Gymnasium per week
Av. High	814.40	2969.30	326.20	160.00	13.50	5.00
P. E. Av.	73.63	238.60	319.95	12.09	5.92	1.17
P. E. Dis.	23.30	75.52	101.25	4.56	1.87	.41
Av. Low	640.12	2197.00	2237.00	160.60	–6.10	4.00
P. E. Av.	41.00	224.85	174.98	12.17	10.90	.85
P. E. Dis.	12.97	71.16	55.37	4.59	2.91	.30
Difference	174.28	772.30	1025.00	.60	19.60	1.00
P. E. Diff.	26.67	103.76	115.40	6.47	3.46	.51
P. E. Diff. Diff.	6.54	7.44	8.88	.09	5.66	1.96

* One had best say that correct here means "near the actual ability as it would be determined if one had an absolute objective method for discovering it."

** The range of the worst is from 184 to 284 (last place dropped). The range of the best is from 272 (the next is 287) to 401 (last place dropped); i.e., only one person in the best group is below the highest person in the worst group.

† Because Running and Paper are in terms of time, the higher numbers being poorer scores, and Steadiness is in terms of contacts, the higher numbers, i.e., more contacts, being poorer scores.

‡ Ignoring the negative sign of the weights assigned by the multiple ratio Correlation Method.

TABLE XI

Results: All tests for Ten Best and Ten Worst (First and Second time)

	Running	Paper	Back Dyn.	Tricks*	Steadiness	Tapping	Leg Dyn.	Hand Dyn.	Three hole	Target	Foot Speed	Lung* Capacity	Chest* Strength	Height*	Weight*	Weight* / Height
Av. High	17.00	19.50	201.00	6.00	62.70	219.60	198.40	36.70	43.80	20.50	188.00	194.40	51.90	64.01	119.48	1.860
	17.30	13.40	197.40		66.50	217.00	209.60	38.30	46.30	19.50	124.60					
P. E. Dis.	1.06	10.31	31.36	1.18	16.58	17.08	26.61	4.04	2.70	6.26	8.79	15.96	6.14	1.28	8.14	.096
	.97	7.72	30.00		9.47	21.39	31.34	4.82	2.96	5.66	10.55					
P. E. Av.	.34	3.26	9.92	.37	5.25	5.41	8.42	1.28	.85	1.98	2.78	5.05	1.94	.41	2.58	.027
	.31	2.76	9.49		3.00	6.77	9.92	1.53	.94	1.79	3.34					
Av. Low	20.60	41.40	155.80	2.50	78.60	190.50	151.20	28.70	40.40	19.70	92.70	167.00	35.60	63.02	125.75	1.990
	21.10	34.40	162.80		68.50	193.20	155.40	29.30	41.50	18.00	98.40					
P. E. Dis.	.75	21.95	12.65	1.52	29.18	13.19	13.19	3.08	5.82	2.79	18.17	11.83	7.61	1.17	7.52	.109
	1.34	20.68	21.22		14.62	8.11	28.74	2.63	2.28	5.58	13.42					
P. E. Av.	.24	6.95	4.00	.48	9.23	4.17	3.64	.97	1.84	.88	5.75	3.74	2.41	.37	2.38	.031
	.42	6.54	6.72		4.63	2.57	9.09	.83	.72	1.76	4.25					
Diff.	3.60	21.90	45.20	3.50	15.90	29.10	47.20	8.00	3.40	.80	25.30	27.40	16.30	.99	6.27	.130
	3.80	21.00	34.60		2.00	23.80	54.20	9.10	4.80	1.50	26.20					
P. E. Diff.	.42	7.68	10.69	.61	10.62	6.83	9.17	1.61	2.03	2.17	6.39	6.28	3.09	.56	3.51	.040
	.42	7.10	11.63		5.25	7.24	13.45	1.74	1.18	2.51	5.41					
Diff. / P. E. Diff.	8.57	2.85	4.23	5.73	1.50	4.26	5.15	4.96	1.67	.37	3.96	4.36	5.28	1.77	1.79	3.250
	9.00	2.96	2.98		.36	3.29	4.03	5.17	4.07	.60	4.84					

* No second trial.

V. DISCUSSION OF RESULTS

A. MOTOR ABILITY

The results will be more intelligible if discussed in terms of the work of previous investigators.

The best and most exhaustive account of the various tests that have been used to measure motor ability is to be found in a monograph by M. Buyse.* A short classified list of the tests mentioned follows:

I. Reflexes: Measurement of Inhibition.
Reflexomotor (page 76 Buyse) (Quantitative study of Reflexes)
Inhibit patellar reflex
Inhibit eye wink
Stare into another's eyes: time
Stare at an object: time

II. Strength: Hand Dynamometer
Lung Capacity (Gilbert)
Graphic Record of Hand Dynamometer (Binet)
Back Dynamometer
Leg Dynamometer
Arm strength: Pull apart two sticks tied with a cord

III. Endurance: (Fatigue)
Ergograph (Neumann)
Hang by your hands: Time
Hold heavy weight: Time
Carry heavy weight: Time
Hold hands out laterally: Time
Hold leg out horizontally: Time (sitting, no support)
Keep one eyelid lowered: Time

IV. Muscle Sense, etc.:
Least perceptible difference in weight

V. Physical:
Weight and Height

VI. Reaction Time:
To auditory and visual stimuli

* Buyse: See bibliography.

VII. Speed:

Reading aloud as fast as possible (Münsterberg)

Tapping

Card Sorting

Speed of turning a handle; compressing a spring, etc.

(Apparatus described in Toulouse, Vaschide and Pieron: "Technique de Psychologie Experimentale" T. I. p. 160. 2nd Edition, Paris 1911.)

Speed of pouring shot from a bottle into a narrow vase.

VIII. Steadiness and Control:

Metal holes: put stylus in each of a series (Neumann)

Tracing

Maintain imposed attitude: Time

IX. Coordinated Movements:

Divide 50 cm. line into two parts.

Draw an equilateral triangle and a square, one line given (Hugo)

Reproduce line after five seconds.

Aiming tests:

1. Throwing ten balls into a hole (Binet)
2. Pierce points of intersection of lines in 100 squares graph paper: Time
3. Whipple's target test
4. Metal Three hole
5. Three holes, printed, strike with pencil in clockwise order to beat of metronome. Average distance from hole in 10 rounds equals score.

Ten puzzles of Rossalimo:

Undo a knot: Time

Roll a cigarette: Time

Peel an apple or potato in one piece: Time

Take apart a simple machine

Move each finger separately

Rub stomach, pat head

Tracing:

1. Metal groove with stylus or printed lines with pencil.
2. 3° angle, sides 25 cm. long. Bisect from open end towards angle. Score equals distance between apex and first point of contact of sides with bisecting line.

Courtier's Dexterometer: An ingenious device for measuring various skilled and complicated movements. See pages 109-116 Buyse.

The variety of tests that have been used is so great, that as we discuss results, we shall have occasion to mention a few other tests not included by Buyse.

It is necessary now to make good the promise to discuss the nature of motor ability and the degree to which we can with justice speak of *a* motor ability. One of the main criteria of a general ability is the degree to which different tests of that ability correlate with each other. It was the strong general tendency of all tests of memory, attention, association, etc., to show fair positive correlations, that led to the 'general factor theory' of intelligence. The meaning of correlations as such is involved, as well as the amount of correlation that is necessary before a real interdependence of functions can be assumed. We had best therefore examine the evidence in the case of motor tests to see how far the results justify the use, either theoretically or in practice, of the term motor ability.

The first work that bears definitely on the problem was done by Abelson* in 1912.

Subjects: 88 girls, 43 boys, in a school for mental defectives. These, though, are only "backward."

Tests: Motor: 1. Tapping (pricking holes in paper: 10 seconds)
2. Crossing out dots (used as perception test) Groups of three, four and five dots. Subject required to cross out groups of five.
3. Rings: crossing out rows of small rings irregularly arranged within the row.

Non-Motor: (Mental Tests)

* Abelson: See bibliography (1). For reports of work following no special reference to the bibliography will be made. All authors mentioned are listed there.

1. Memory for Sentences.
2. Memory for Names.
3. Memory for Commissions.
4. Discrimination of Lengths.
5. Interpretation of Pictures.
6. Geometrical Figures (same principle as Alpha, test I)

Results:

A. Intercorrelations of the Motor Test

	Girls	Boys
Tapping with Rings	.42	.46
Tapping with Dots	.21	.32
Rings with Dots	.47	.65

B. Intercorrelations of Memory for Sentences with the other non-motor tests: (boys and girls) varies from .17 to .50 except .66 with Memory for Names. Intercorrelations of Geometrical Figures vary from .21 to .56.
Intercorrelations with Interpretation of Pictures from .21 to .50

C. One may also note that the average intercorrelations of each test with all the others are:

		Boys	Girls
Mental Tests	Memory for Sentences	.39	.36
	Memory for Names and Objects	.23	.26
	Memory for Commissions	.27	.33
	Geometrical Figures	.29	.32
	Interpretation of Pictures	.26	.36
	Discrimination of Length	.28	.31
Motor Tests	Tapping	.25	.33
	Crossing out Rings	.18	.32
	Crossing out Dots	.26	.29

From these results one may note: that the individual intercorrelations of the non-motor tests are no higher than those of the motor tests; that the average intercorrelation of the motor tests with all the others is slightly lower than the intercorrelation of the mental tests with all the others. This difference is smaller than one would expect. For there are only three motor tests but six mental tests, and since these latter tend to be slightly more similar to each other than to the motor tests, they would weight the average correlation in their own favor. Abelson, moreover, argues for a common factor in all these tests on the ground that the average intercorrelations

of each test with all the others are absolutely similar, any differences being due to chance.

Bickersteth was interested in working out the value of various tests; he used the Tapping test as an endurance or fatigue test (Score equals number of taps in first 30 seconds minus number of taps in second 30 seconds).

Plunger: 24 sockets arranged in a circle to be plunged into in order, with a stylus.

The correlation between these two tests varies from .44 at nine years to .13 at 13 years, with no break in the slow descent.

He used also Dr. Shuster's spiral dotting machine,* a form of aiming test in which the subject strikes at small moving circles. This dotting correlates at thirteen years .45 with Tapping. The only negative correlations were between the mental and motor tests. The general tendency to a fair amount of positive correlation among tests for motor functions appears here too.

English used card sorting in addition to the above tests, and used the whole number of taps in 60 seconds as a straight speed test.

The correlations are:

Dotting with Tapping .58 (A) and .22 (B)

Dotting with disc Sorting .12 (A) and .54 (B)

A and B represent respectively a higher and lower social group. Further mention will be made below in the discussion of the relation of mental to motor ability of Glenn's work, but we may say in passing that she obtains the intercorrelations between sewing, bookbinding and woodworking ability (judged by teachers) on the one hand, and five motor tests** on the other hand, for from three to five classes, with an average of 38 children each. The correlations range from .11 between Sewing and Star test to .67 between Sewing and the Paper Folding Test (there is also —.03 between Sewing and the Lane Test).

The most recent work has been done by Perrin in Texas and by Muscio in England. They were concerned with an analysis of motor capacity. Perrin studied the relation to Intelligence (Alpha and School Grades) and to Character Traits (Estimates); but Muscio was particularly interested in the vocational implications. Both conclude that we cannot speak of motor ability as we speak of Intelligence because of the low intercorrelations of the motor

* Described p. 39 of Bickersteth's paper.

** Tapping, Star test, Well's Peg Test, Paper Folding test, Lane Test (a form of tracing).

tests. Perrin's tests are "selected on a priori grounds—[to] test each of the possible (assumed) motor functions—." There are, for complex abilities, the Bogardus, Card Sorting and a tracing test in which both hands work at once. The tests of "elementary motor functions" are: Reaction Time to a visual stimulus, Inhibition of Eye Wink, Maze Memory, Weight discrimination Test, Whipple's Target Test, Aiming at a point drawn by subject on a Whipple Aiming Board, Five Balancing tests (walking forward, backward, turning, on twelve foot board, ½ inch wide and balancing on small platform at the end of this board) two tests for sense of Rhythm, Tapping, Steadiness and Tracing (as in Whipple), Strength tests: Hand, Back, Leg and Lung Capacity.

This is a beautiful, inclusive list of motor tests and worthy of being tried out in further experiments. One may say, however, that the division into simple and complex tests seems entirely arbitrary, for any one of the balancing tests is probably as complex according to any definition, as card sorting.

Perrin gives only the correlations of each test with the three Complex tests. Of the 54 correlations given, 3 are between .30 and .40, 10 are between .20 and .30, 28 between .00 and .20 and 13 negative (to — .22). That places the median somewhere between .00 and .20, which is rather low but of course, positive. The scatter charts however would incline one to place the general correlation nearer .20 than .00.

We have, however, considered the results for all the tests with no knowledge of the relative merit of the tests as indications of motor ability. No one would doubt that ability to draw a maze from memory and Reaction Time are poorer tests of Motor ability (if it exists) than the Bogardus or one of the Balancing tests. And it is interesting to note that the three highest correlations obtain between:

Hand Dynamometer and Coordination	.39
Bogardus and Balancing	.38
Card Sorting and Coordination	.36

Muscio used ten tests: Whipple's Tapping and Steadiness; Tracing; Simple Form Board; Aiming; three forms of Match Stick, stunts (e. g. put thirty matches, one at a time, into a match box; score equals time); Auditory Reaction Time; Total Strength; Pursuit Pendulum and Wrist Movements. Only two or three tests were given to each of five groups ranging in age from 13½ years to

adults, both men and women. He also emphasizes the low correlations and the fact that these correlations do not increase with practice.

In group B (16 girls, average age 13½ years): tests: Tapping, Aiming and Match Stick Insertion (15 trials); the correlations vary from —.04 to .32 (four negative). The average intercorrelation of the averages of each test with all the others during progressive stages of practice is .14.

In group C (12 undergraduates, six men, six women), Tests: The three above, also: Wrist Movement and Pursuit Pendulum. (6 trials). Intercorrelations vary from —.04 (the only negative, the next highest correlation being .11) to .51. The average intercorrelation of the averages of each test with all the others during practice is .35.

In Group D (20 girls, average age 13) (24 trials): Tests: Three of Group B. Average correlation of each test with all the others, all trials, is .22. But great variability in the individual correlations is the rule. For example:

	Highest Correlation	Lowest Correlation
Tapping and Aiming	.72 (4th trial)	—.34 (22nd trial)
Aiming and Match Stick	.29 (11th trial)	—.34 (22nd trial)
Tapping and Match Stick	.62 (4th trial)	.04 (10th trial)

The tables presented in the present paper can help us estimate the average intercorrelation of various tests for motor ability, without which it is futile to discuss the relationship of the various factors to motor ability.

The distribution of sixty-six correlations (Table VII) excluding Alpha, the Criterion, Height, Weight and $\frac{\text{Height}}{\text{Weight}}$ (Physical Tests) and Steadiness (which peculiarly seems to have a consistent negative relation to the criterion and to motor tests*) is found to be;

There are Negative		11 correlations
" "	.00 to .10	7 "
" "	.10 to .20	18 "
" "	.20 to .30	15 "
" "	.30 to .40	11 "
" "	.40 to .50	2 "
" "	.50 to .60	2 "

* An expert marksman had a bad tremor, but "caught it on the fly" when his aim was right.

The median is .17. Including Steadiness, the median is .15. Thus, taking the results of all investigators into account, we may safely say that various tests assumed to be measuring motor ability or some aspect of it tend on an average to correlate somewhere between .15 and .25. What exactly does this mean?

It is hard to tell how this figure compares with a similar one for mental tests, but an examination of many intercorrelations of individual mental tests (not organized teams of tests like the Alpha or Otis or Binet) leads one to believe that they probably average between .30 and .40, i. e., a little higher than these motor tests. Yet it has become evident that a well established positive correlation between measurements even when small is sufficient basis for recognizing an element common to the abilities tested, i. e., the extent to which two variables vary together is an indication of some factor operating in one which is also effective in the other.

It is also true, however, that inasmuch as the correlation is .20 or .25, and not .90 or .95, there are disparate independent factors in the two abilities so correlated. For example, if ability to cross out "A's" correlates .90 with the ability to cross out "E's" (after practice) we know that similarity of content, mode of application, eye-hand coordination, general mental set and perhaps still other factors are all common to the two tests and together produce the .90. However, it is not a correlation of 1.00 because there are "E's" not "A's" to cross out, and also because there are uncontrollable factors that act differently at each testing.

Now if ability in Tapping correlates to the extent of .30 with Three hole, we can also assume some common factors, e. g., control of the muscles of the right hand and right arm, perhaps ability to move "as fast as possible," etc., but on the other hand the number of disparate factors is large, for a different coordination is required, the movement needs to be more accurate in one case than in the other, and so on. To the extent, then, that we speak of ability in arithmetic (though unrelated factors certainly exist, e. g., between ability to add two place numbers and ability to multiply fractions) or general intelligence or motor ability, we imply a classification of abilities that can, for practical purposes, be placed together, because they are more or less alike either in the content with which they deal, or in the manner in which the organism reacts to them.

We have then a group of tests which are enough alike in con-

tent or process or both to produce an intercorrelation of about .20. If we can demonstrate in addition

(a) that they can be combined as a group to correlate .60 or more with an acceptable criterion (a judgment) of the group of abilities we are after, namely, muscle control abilities;

(b) that they are a group independent of the more generally known mental abilities or intelligence, or at least, less related to that ability than they are to each other,

we shall have justified the use of the term motor ability and have given it a comprehensible meaning

On page 14 above the method of obtaining the criterion was described. It is important of course to know just what the judges were actually estimating. In the letter sent to them motor ability was described to them as "that ability best shown in swimming, tennis and athletic activities; that ability which can be described as strength, speed, accuracy and adaptability of movement." None of the judges seemed to have the least doubt about what was meant. This was borne out by their self-consistency. The correlation of the average positions assigned by the six judges to each subject on each of two occasions, six weeks apart, was .92.

The team of tests correlated .77 with the criterion. This means that the factors which are unrelated to those measured correlate to the extent of .64 with the criterion justifying the conclusion that over 50% of the factors affecting the judgment of the teachers have been measured by the tests. This assertion needs explanation:

Since by definition the measured and unmeasured factors together correlate 1.00 with the criterion, then when the measured and unmeasured factors are equally related to the criterion, i. e., 50% of the factors are measured, the correlation of each set of factors with the criterion is expressed in the formula:—

$1.00 = \sqrt{r_{IC}^2 + r_{IU}^2}$ (derived from Toops' formula (1) page 19); when $r_{IC} = r_{IU}$, $r_{IU} = .707$.

As the correlation of the measured factors rises above .707, we know that more than 50% of the factors are measured. A correlation of .77 is high enough to warrant the conclusion that this team of tests does measure motor ability, as understood by the judges.

The Thorndike Entrance Examination, for example, correlates about .65 with grades in college and is considered a good indicator of college ability, and the Alpha scale probably does not correlate in general over .60 with estimates of mental ability.

Further indication that the tests do measure motor ability is to be obtained from a consideration of the differences in scores obtained from the ten best and ten worst groups. Tables XI and XII show that of the tests included in the team only Steadiness does not reach the required quotient of three* when the difference between the average of the good and poor groups is divided by the P. E. of that difference. This is due to the great variability of the scores. The reliability of the steadiness test in the larger group was, however, .61 so that it was finally included in the team.

The Paper test almost reaches 3 (2.96) but its high correlation with the criterion outbalanced the slight shortcoming here.

The team as a whole, however, when weighted according to the weights derived from the multiple ratio correlation technique, gives the unexpectedly high ratio of 8.88, and leaves no room for doubt that the tests differentiate between people with and without motor ability.

The team of tests has thus justified itself as a measure of motor ability, by its high correlation with the criterion in both the general and the selected groups.

The reliability of the tests is important and not as good as it should be: namely .77. The Paper test has by far the lowest reliability (.48) and this naturally pulls down the reliability of the team. The validity of the Paper test was decreased, as explained above, by the fact that about ten or fifteen subjects practised the stunt between trials, not knowing that a second series of tests was to be given.** There is no reliability coefficient for "Tricks" because stunts from both series were used in the final score.

The last point to consider is the light thrown by these experiments on the subject of the relation of motor to mental ability. The team of tests correlates .09 with Alpha (32 cases) ; the correlation of Alpha with the Criterion is even lower, .02.

In Preliminary Experiment A, the correlation of the motor tests with Alpha was also .09, including grip it was .10. Preliminary Experiment B shows a —.08 correlation between Alpha and average motor rank.

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* When the difference equals three times the P. E. of the difference, the difference has 13.5 chances out of 5000 of being due to chance and is usually considered sufficiently clear evidence of indicating a real difference (less than 3 chances in 1000).

** One may note that the negative correlation with height indicates a real factor which introduced an unnecessary variant since the tall girls naturally had further to bend and therefore found the trick more difficult. For every increase of one inch in height over five feet, a proportionately high platform should be placed under the paper to make the test equally easy for all subjects.

This independence of the two abilities is further borne out by the results from the ten best and ten worst group. There, while the $\frac{\text{Difference}}{\text{P. E. difference}}$ ranged, for the motor tests from 1.50 (Steadiness) and 2.96 (Paper), (all others being over 3) to 8.88 for the weighted team, the average Alpha score of the good group was 160 and of the poor group 161, making the $\frac{\text{Difference}}{\text{P. E. Difference}}$ equal to .09. This, if established, would indicate that in the motor tests we are dealing with a group of abilities quite unrelated* to the kind of ability measured by a good intelligence test.

The evidence from the literature is very varied. See Chart A pg. 37 for an outline of the results of other investigators.

Several points must be borne in mind in order that one may properly evaluate the results. The opinions differ all the way from the conclusion that there is a strong negative relation between mental and motor ability (Terman, Bagley, etc.) to the conclusion that they are so closely related that motor tests may be used as tests of mental ability (Bolton). This variation is due to two major causes. The firsts that individual tests, often not more than two or three, have been used as final indices of motor ability and that the value of these tests as tests for motor ability is nearly always unknown. Column 18 of Table VII of this paper shows a similar variation, the correlations of the individual tests with Alpha ranging from .32 (Tricks) to —.33 (Paper). It is impossible at the present state of our knowledge of motor ability to unravel the factors which produce such different relations between mental ability and two tests of motor ability which the judgment of common sense would pronounce to be so similar. Therefore the results of different investigators with different tests are incomparable and not to be balanced one against the other to give a general picture of the results.

The second cause for the disparity in results is due to the differences in range of ability measured. A correlation is not a raw number with an absolute significance like two tables or five apples. It must be understood in terms of the groups measured, because of the immediate effect upon the correlation of any restriction in range or degree of variability in the group. In the results presented in

* Of course, inasmuch as .09 (i. e., the correlation between Alpha and the weighted team of tests) means some degree of positive relationship, we must recognize that there is at least as much common ground as would be expected to result from at least the same organism, the same nervous system acting in both cases.

Chart A an attempt has been made to help the reader to interpret the results by giving the range of ability wherever possible. The subjects include twenty men picked from the entire population for high and twenty picked for low mental ability (Simpson); seven boys picked from five hundred elementary school pupils for superior brightness and seven for exceptional dullness (Terman); four thousand elementary school pupils, all grades (no ages given) (Gesell); fifty-one undergraduates (Perrin); fourteen and fifteen year old applicants for working papers (Wooley and Fischer), etc.

No general conclusion concerning the verdict of the literature on the subject of the relation of mental to motor ability can be drawn from such polyglot results.

Teams of standardized tests applied to specifically defined sections of the population will give more comparable and therefore more intelligible results.

For the present I should venture the guess that mental and motor ability are different groups of abilities which tend to a very low positive relation, say around .10 to .12 for (adult) people in general.

This constitutes the second point in the further proof that motor ability may be meaningfully understood, namely, that it represents a group of abilities in the main, independent of, or at least different from mental ability.

CHART SHOWING RESULTS FROM THE LITERATURE ON THE RELATION OF MENTAL TO MOTOR ABILITY.

A. RESULTS SHOWING ABOUT ZERO CORRELATION

1. McCALL in an unpublished paper finds with
   Mental tests: Number concepts, opposites, sentence completion
   Motor test: Form board
   Result: A "practically zero" correlation
2. CLARK WISSLER (32)* finds with
   Mental tests: Class standing, Association, Crossing out A's, Logical Memory
   Motor tests: Reaction Time, Strength, Fatigue, Accuracy of movement
   Results: (a) Class standing with
   (1.) Reaction Time = .02
   (2) Strength = .08
   (3.) Fatigue = .23
   (b) Association with
   (1.) Reaction Time = .08
   (2.) Accuracy of Movement } too low to be computed
   (c) Crossing out A's with Accur. of Mov't = Ibid.
   (d) Logical Memory with
   (1.) Reaction Time = .19
   Author concludes there is no real relationship
3. McDONALD (19)
   Mental test: Class standing
   Motor test: Grip
   Result: Zero correlation
4. BINET & VASCHIDE (3)
   "Mental ability": Methods of measurement not indicated
   Motor tests: Tapping, Running and simple reaction time
   Result: "No correlation."

* Number in parenthesis is bibliography reference.

5. Glenn (13) tests elementary school pupils with:
   Mental tests: Marks in English, History and Arithmetic
   Motor tests: Healy Psychomotor (Tapping), Star test, Well's peg test, Paper-folding test, Lane test.
   Results: 15 correlations varying from —.10 to .11

6. Perrin (22) with 51 undergraduates, men and women found:
   Alpha with (1) Bogardus = .03
   (2) Card Sorting = .02
   (3) Coordination = .10

7. Gilbert (12) had two series of experiments:
   I. School children, all grades
      Mental test: Grading by school teachers as Bright, Average, Dull
      (a) *Motor tests:* Weight, Height, Lung Capacity
      Result: No relation found except plus with Lung Capacity at 13 and 14 year levels
      (b) *Further Motor tests:* Tapping, Fatigue in Tapping, Reaction Time
      Results: Marked positive relation with Tapping and Reaction Time
   II. College Students
      Mental test: Same as above
      Motor: Same as (a) and (b) above, also wrist lift
      Results: Inverse relation with Fatigue
      Positive relation with Tapping except at 17 years
   Gilbert says "In a good many of the tests, all indication of any relation between physical development and mental precocity seem to be wanting."
   Real positive relation established only between tapping and intelligence as judged by teachers

B. Results showing positive correlation

1. Gesel (11) tested over 4,000 pupils in Grades 1 to 9 in the elementary school
   Mental tests:
   (a) School Intelligence (5 classes according to marks)
   (b) General Intelligence (Judgment of teachers) Bright, Average, Dull

Motor tests:

(a) Handwriting Accuracy, i. e., amount of variation from a copy

(b) Teachers' Judgment of Motor Ability, Clever, Average, Clumsy, to be based on pupil's muscular dexterity as shown in Drawing, Sewing, Manual Training and general aptness in using fingers, hands and arms

Results: distribution tables (no correlations)

(a) Handwriting varies regularly with school intelligence

Of 180 very best specimens, 125 belong to best class of school intelligence

Of 134 very worst specimens, 103 belong to worst class of school intelligence

(b) Handwriting varies directly with (judgment of) Motor Ability

(c) Motor Ability varies with school intelligence

Of 315 (3 with highest marks in each class chosen) only 17 are rated clumsy

But note that Penmanship is stressed so much in the schools that it probably forms a large factor in determining the school grade. This may in part account for the high positive relationship

2. Bolton (5) used elementary school children, ages 8 and 9 years, from 2 schools with children of respectively high and low social status

Mental Criterion: On ground that children of higher social status are, age for age, 2 grades ahead, this division was used as an indication of mental ability

Motor tests:

(a) Tapping, 5 trials, 5 seconds each

(b) Tracing, number of contacts

Results:

(a) Tapping

	8 year group	9 year group
Good Group:	142 taps	151 taps
Poor Group :	136 "	137 "
Diff.	6 "	14 "

(b) Tracing

Good Group:	18 contacts	....	16 contacts
Poor Group :	22 "	....	25 "
Diff.	4 "		9 "

But P. E. s of the Differences not given; criterion of mental ability inadequate and arbitrary.

Author concludes there is a strong positive relation between mental and motor ability.

3. Wooley & Fischer (35) tested 700 school children, 14 and 15 years old when they apply for working papers.

Mental Tests: Standard memory, association, etc.

Motor Tests: Height, Weight, Vital Capacity, Hand Grip, Steadiness, Tapping, Card Sorting.

Results: Average Correlation between ranks in mental and in motor tests = .21 at 14 years
.15 " 15 "

Correlations are Pearson Coefficients "estimated by E. S. Jones, assistant director."

4. Kirkpatrick (18) tested 500 elementary school children

Mental Criterion: Teachers' Judgment, division into 3 classes

Motor Tests:

(a) Counting aloud; speed

(b) Making vertical marks on paper; speed

(c) Sorting 25 cards into 4 piles

Author divides all children into 3 classes according to combined scores in (a), (b) and (c)

Results:

57% pupils placed in same group for mental and motor ability

2% pupils placed in 2 classes away in mental from that obtained in motor grading

(a) and (b) alone give about same degree of correlation

Note that a fourth test, naming 4 ink spots, was included among the motor tests and influenced the degree of correlation.

5. Abelson (1) tested 88 girls and 43 boys of London County School for Mental Defectives "Backward not defective children" used.

Mental Tests: Teacher's judgments of "practical intelligence." Teacher's judgments of reading and arithmetic ability.

Motor Tests: Tapping, crossing out rings, irregularly distributed on the page, crossing out groups of dots.

Results: Correlation with intelligence:

	Girls	Boys
Tapping	.42	.28
Rings	.43	.04
Dots	.32	.28

Correlations with Reading:

	Girls	Boys
Tapping	.26	.37
Rings	.27	.41
Dots	.15	.40

Correlations with Arithmetic:

	Girls	Boys
Tapping	.29	—.11
Rings	.34	—.02
Dots	.30	.39

Note: Correlation between mental tests and teacher's estimate of intelligence about same magnitude.

6. Burt, Cyril (6) tested Elementary School boys and Preparatory School boys.

Mental Tests: Memory, attention, etc.

Motor Tests: (a) Tapping, (b) Card dealing, (c) Mirror tracing, (d) Dotting (a moving target test)

Results: Average mental-motor correlation (Elementary School pupils) = .62

Same for preparatory school = .527

7. Bagley (2) tested Elementary School pupils.

Mental tests:

(a) Teacher's judgment of intelligence
(b) Class standing in relation to age

Motor tests:

(a) Tapping (Morse Key)
(b) Target
(c) Steadiness (Jastrow's automatograph)

Results: 1. Class Standing with

(a) Tapping: indifferent

(b) Target: "Predominant inverse relation." (Only 2 out of 5 cases show this)

(c) Steadiness: indifferent

(d) General Motor Index: "Very marked inverse relation."

2. Teacher's Judgment with

(a) General Motor Index; Inverse relation indicated.

Note: E. L. Thorndike corrected the data for age differences and found the net result to be a low positive relation.

8. Simpson (26) tested 20 college faculty members and graduate students and 20 men always out of a job.

Mental tests: Completion, Memory span, etc.

Motor test: Scroll test (a form of tracing test)

Result: Average of all mental with Scroll = .26

But note that all these correlations are high due to great selection from upper and lower ends of curve.

C. Results showing negative correlation.

1. Terman (27) tested the 7 brightest and the 7 dullest of 500 Elementary School pupils.

Mental tests: Language, Chess, Mathematics, Logical Processes, Memory, Fables and Invention.

Motor ability tests: the specific tests used not indicated.

Results: Different motor tests correlate from —.14 to —.52 with the different mental tests.

Simpson remarks that the "dull" boys were probably picked by the teachers for too much attention to sports, etc. This would artificially increase the amount of negative correlation.

2. Bickersteth (4) tested boys and girls of the Elementary and Secondary Schools.

Mental tests: Analogies test (only one with which motor correlations are given)

Motor tests: Tapping (score = percent loss in speed of 2nd over 1st half of 60 sec. period)

Plunger: 24 pockets, similar in principle to the 3-hole test.

Results: Analogies (called later in paper—Reasoning) with:

Age	Tapping	Plunger
13	—.01	—.01
12	—.32	.32
11	.20	.50
10	.20	.06

Individual graphs given too. Author says "The graphs show in nearly every case the inverse relationship of the motor tests with those of higher levels."

3. ENGLISH (9) tested 2 groups of children:

(a) 37 from school attended by children of professional and upper class.

(b) 31 from school attended by children of lower middle class and upper class tradesmen.

Mental tests:

(a) Analogies, Perception test, memory tests.

(b) For good group, marks } Imputed
" poor " ranked by headmaster } intelligence

Motor tests: Plunger (see Bickersteth below)
Tapping (" " ")
Dotting (" Burt above)

Results:

		Tapping	Dotting	
Analogies	(a)	—.01	.08	(a) & (b) =
"	(b)	.15	.45	the good and
Intelligence	(a)	—.39	—.23	poor groups
"	(b)	.03	.22	respectively.

"In all [i. e., mental tests] save the tests of rapidity of movement, the children of the better class were strikingly superior."

Author concludes a negative or low correlation of intelligence with Tapping, Dotting and Disc.

PART VI. CONCLUSIONS

The conclusions may be summarized thus: that inasmuch as

1. The central tendency of the intercorrelations of motor tests is positive (.15 to .25) and

2. A group of people (the judges) found the term motor ability intelligible and meaningful, proving this by a self-consistency of .92 and

3. That a team of tests could be found which would agree so closely (.77) with the combined ratings of the judges—

in the light of 1, 2 and 3, we may conclude that the use of the term motor ability is justified and we may begin to investigate the relationship of this group of abilities to intelligence and to various special abilities for vocational guidance. And that we may begin at once to use the tests as a means of classification of students for work in physical education because they so nearly approximate in seventeen minutes the judgment of eight teachers and students after six months or more of acquaintance.

There may also be repeated here the third and fourth paragraphs from page 36.

For the present I should venture the guess that mental and motor ability are different groups of abilities which tend to a very low positive relation, say around .10 to .12 for (adult) people in general.

This constitutes the second point in the further proof that motor ability may be meaningfully understood, namely, that it represents a group of abilities in the main, independent of, or at least different from mental ability.

BIBLOGRAPHY

1. Abelson — Measurement of Mental Ability of Backward Children.
Brit. J. Psych. vol. 4, p. 268.

2. Bagley — The Correlation between Mental and Motor Ability in School Children.
Amer. J. Psych. vol. 12, p. 193.

3. Binet & Vaschide — Epreuves de vitesse chez les jeunes garçons
L'Anne Psych. T. 4.

4. Bickersteth — Application of Mental Tests to Children of Various Ages.
Brit. J. Psych. Vol. 9 p. 23.

5. Bolton — Relation of Motor Power to Intelligence.
Amer. J. Psych. vol. 14, p. 615

6. Burt, Cyril — Experimental Tests of Intelligence.
Brit. J. Psych. vol. 3.

7. Buyse, R. — Introduction a l'Etude Psychographique de la Fonction Motrice.
Bulletin de l'Institute General Psychologique, 1920, nos. 1-3.

8. Dresslar — Some Influences on Voluntary Movement.
Amer. J. Psych. vol. 4, p. 514.

9. English — Experimental Study of the Motor Capacity of School Children Correlated with Social Status.
Psych. Mon. 1917 vol. 23, p. 266.

10. Franz — Handbook of Mental Examination Methods,
2nd Edit. 1919. New York.

11. Gesell — Accuracy in Handwriting as Related to School Intelligence.
Amer. J. Psych. vol. 17.

12. Gilbert — a) Mental and Physical Development of School Children.
Yale Psych. Lab. Studies vol. 2, p. 40.
b) Research upon School Children and College Students.
Univ. of Iowa Studies in Psych. vol. 1, p. 1.

13. Glenn — A Report on the Correlation of Mental Tests with Academic and Manual Subjects.
J. of Ed. Psych. vol. 3, p. 496.

14. Hancock — Study of Motor Ability.
Ped. Sem. vol. 13, p. 9.

15. Hansen — Serial Action as a Basic Measure of Motor Ability.
U. of Iowa Studies in Psychology, vol. 8, published as Psychological Monographs, vol. 31.

16. Johnson, J. B. — Motor Ability of School Children.
Johns Hopkins Ph.D. Thesis, 1916.

17. Hollingworth — Correlation of Abilities as Affected by Practise.
J. Ed. Psych. vol. 4, p. 405.

18. Kelly, R. L. — Psychophysical Tests.
Psych. Rev. vol. 10.

19. Kirkpatrick — Individual Tests of School Children.
Psych. Rev. vol. 7, p. 274.

20. McDonald — Experimental Studies of School Children.
Report of Commission of Education 1897-8 (published 1899) p. 989-1390 espec. Charts XXI and XXII.

21. Muscio — Motor Capacity with Special Reference to Vocational Guidance. Brit. J. Psych. vol. 13, p. 157 (1922).

22. Perrin — An Experimental Study of Motor Ability. J. of Exper. Psych. vol. 4, p. 24.

23. Pintner & Patterson — A Scale of Performance Tests. N. Y. 1921.

24. Ream — a) The Tapping Test: A Measure of Motility. Psych. Mon. vol. 31.
b) A Statistical Method for Incomplete Order of Merit Ratings. J. Appl. Psych. vol. 5, p. 261.

25. Scripture, Smith and Brown — Education of Muscular Control and Powers. Yale Psych. Studies, vol. 1.

26. Simpson — The Correlations of Mental Abilities. Teachers College, Columbia Univ., N. Y. 1912.

27. Terman — Genius and Stupidity. Ped. Sem. vol. 13, p. 307.

28. Thompson — Psychology and Pedagogy of Handwriting.

29. Toops, H. A. — a) Eliminating the Pitfalls in solving Correlations. J. Exper. Psych. vol. 4, p. 434.
b) Solving Intercorrelations by Polar Coordinates. J. Exper. Psych. vol. 5, p. 68.
c) Computing Intercorrelations of Tests on the Adding Machine. J. of Appl. Psych. vol. 6, p. 172.

30. Toulouse, Vaschide et Pieron — Technique de Psychologie Experimentale. 2nd Edit. Paris 1911.

31. Whipple — Manual of Mental and Physical Tests, Vol. 1, 2nd Edit.

32. Wissler. — Correlation of Mental and Physical Traits. Psych. Mon. Suppl. No. 3 to vol. 6 (1901).

33. Woodworth, R. S. — Le Mouvement. Paris 1903.

34. Wooley, H. T. — A New Scale of Mental and Physical Measurements for Adolescents. J. Ed. Psych. vol. 6, p. 521.

35. Wooley and Fischer — Mental and Physical Measurements of Working Children. Psych. Monographs, vol. 18, p. 200.

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Training School Bulletin. Vineland, N. J.: The Training School.
Subscription $1. 160 pages annually. Edited by E. R. Johnstone. Founded 1904. Monthly (10 numbers). Psychology and training of defectives.

Journal of Educational Psychology. Baltimore: Warwick & York.
Subscription $4. 540 pages annually. Founded 1910.
Monthly (9 numbers). Managing Editor, Harold O. Rugg.
(Educational Psychology Monographs.
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Comparative Psychology Monographs—Baltimore: Williams & Wilkins Co.
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Published without fixed dates, each number a single research.

Psychoanalytic Review. Washington, D. C.: 3617 10th Street, N. W.
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