VOL. X. No. 4 July, 1903

THE PSYCHOLOGICAL REVIEW.

STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF THE UNIVERSITY OF CHICAGO.

COMMUNICATED BY PROFESSOR JAMES ROWLAND ANGELL.

IV. PSYCHO-PHYSICAL TESTS OF NORMAL AND ABNORMAL CHILDREN. — A COMPARATIVE STUDY.

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The tests reported below were made upon the pupils of the elementary school of the University of Chicago, and the cases in the Chicago Physiological School. The pupils in the first school are normal children, between the ages of four and fourteen, influenced by hereditary and environmental conditions probably superior to those of the average child. The cases in the Physiological School are backward and defective children who have failed to show the necessary ability to make satisfactory progress in the public schools. Some of these children rank quite low in intelligence but all are believed to be educable. They range in age from nine to nineteen years. The physician's examination frequently, in fact usually, brings to light quite unfavorable hereditary influences. There are also numerous and sometimes pronounced stigmata of degeneracy present. In some cases the defects are due to arrested development, either pre- or post-natal. The present study, however, is devoted to the existing conditions and possible progress of these cases under such favorable surroundings and pedagogical procedure as the Physiological School affords.

The Nature of the Tests.

The tests covered rather a wide range. This is a necessary incident of pioneer work. Very few tests were made, however, which did not yield readily to consistent interpretation. Despite their number the tests may be divided roughly into three classes. There were the ordinary tests of the senses of hearing, sight, taste, smell, touch and temperature together with sensitiveness to pain. There was a series of muscular tests, involving numerous forms of motor coördination with special reference to rapidity, accuracy and steadiness, of movement, and fatigue. And third, a number of tests were made with special reference to prevalent forms of imagery in peculiar types of children, certain emotional reactions, etc. Effort was made to conduct the experimentation under approximately identical conditions of time, place, environment, fatigue and so forth. At the Elementary School there was taken simultaneously a series of physical measurements, including weight, height, lung capacity, strength of grip, and the numerous girth, depth and breadth measurements.

These measurements, however, are not reported in this paper. At both schools the record of each child was carefully preserved for comparison and reference.

The Purpose of the Tests.

Certain definitely formulated purposes were held in view throughout this work which extended over part of one school year and all of the next.

(*a*) It was deemed desirable to get psychological data which would serve in determining the most fruitful pedagogical procedure for each child. This purpose proved immediately practical in numerous cases.

(*b*) It was believed by fashioning the tests to the possibilities of the two widely divergent classes and making them as nearly identical as possible, some ready and simple method might be determined of differentiating the abnormal from the normal child. Observation shows that about one child in fifty in our public schools is utterly incapacitated by physical defect or mental incapacity from reacting spontaneously to certain valuable parts of his environment.

(*c*) Furthermore, it was believed that some light might be obtained upon the problem of finding a substitute for the present formal, arbitrary and confessedly inadequate methods of determining children's real mental capacity.

(*d*) And finally and chiefly, it was hoped that some contribution might be made to the present meager knowledge of the psychical life of the child in each of the two disparate fields of investigation. The author of the present paper makes no claim to have accomplished much as yet in the realization of the last-named purpose. In fact, the work here reported has been done with the belief that such knowledge will not be secured by the promiscuous massing together of data obtained from different sources, by different individuals of varying ability in observation and insight, nor by one well-trained individual selecting his data from the same sources, but who, ignoring the necessity of following up the children in their slow development, fails to adopt the principle of repetition in his experiments. Most of the tests here reported have been repeated one or more times and it is with the expectation that the process of repetition will be continued that the work is now made public.

The Sensory Tests with the Normal Children.

An astonishing thing about the ordinary sense tests is the fact that although no great amount of skill or expenditure of means is required for their prosecution, teachers and parents remain ignorant of readily detectible and usually remediable defects. These defects, moreover, are continually interfering with the progress of the child if not indeed threatening the existence of much of the valuable content of his life.[1]

Hearing and Sight. — Of 53 pupils in the Elementary School whose hearing was tested, 3 were found seriously defective. But 1 pupil was found lacking in keenness of vision. 61 per cent. of the pupils tested were astigmatic, though of this number but 2 or 3 required immediate medical attention. Out of a total of 66 there were 27 cases of slight color blindness, 2 cases being so pronounced as completely to incapacitate the pupil for certain

[1] Rowe's 'The Physical Nature of the Child' is the briefest and most concise statement of practical technique in this series of tests.

kinds of school requirements. 11 of these matched the standard colors but were confused on shades, 13 were confused on greens and blues, though most of these could distinguish between the standard blue and green. 4 confused green and yellow shades, 2 pink and blue, and 1 green, blue, and yellow.

Taste and Smell.

The facts as to sensitivity in taste and smell are illustrated in Tables I. and II. Table I. shows the threshold of sensitivity

Table I.

Taste and Smell, Elementary School; Threshold.

		Taste.				Smell.	
		Quinine.	H_2SO_4	Saccharine.	Salt.	Violet.	Cloves.
a	Boys.	4	2	3	3	7	2
b		16	15	18	16	8	4
c		6	8	6	8	16	22
d		1	1	0	0	0	0
Total		27	26	27	27	31	28
a	Girls.	1	2	2	0	7	0
b		13	11	11	13	3	3
c		2	3	3	3	6	13
d		0	0	0	0	0	0
Total		16	16	16	16	16	16

Table II.

Taste and Smell, Elementary School; Discrimination.

		Taste.				Smell.	
		Quinine.	H_2SO_4	Saccharine.	Salt.	Violet.	Cloves.
Named.	Boys.	25	12	27	27	28	7
Not Named.		6	19	4	4	1	16
Total.		31	31	31	31	29	23
Named.	Girls.	15	15	15	16	19	4
Not Named.		0	0	0	0	0	10
Total.		15	15	15	16	19	14

as indicated by the naming of the sensation quality. While this ability to command the word corresponding to a sensation quality may not be a strictly reliable criterion as to the point

where the actual discrimination occurs, it has in its favor the fact that it is sufficient for all practical purposes. Besides with children it is quite difficult for the observer to hit upon any more reliable criterion for the determination of the discrimination limen. That the actual discrimination sometimes occurs before the required linguistic capacity appears, is not to be questioned.

In Table I. the letters *a*, *b*, *c*, *d* refer to the different strengths of solution. For quinine they are respectively:

.00004 per cent.; .0004 per cent.; .001 per cent., and .0021 per cent.

For Sulphuric Acid — .001 per cent.; .008 per cent.; .016 per cent., and .024 per cent.

For Saccharine — .0005 per cent.; .0025 per cent.; .025 per cent., and .05 per cent.

For Salt — .01 per cent.; .13 per cent.; 2 per cent., and 2.8 per cent.

The smell solutions consisted of extract of violet: .0000001 per cent.; .00001 per cent.; .1 per cent., and .5 per cent.; and oil of cloves, .0000001 per cent.; .00001 per cent.; .001 per cent., and .004 per cent.

The first in each series is below and the fourth is above the ordinary threshold; the second and third are within the range of the normal threshold. The girls have a uniformly lower taste threshold than the boys.

The results in smell are interesting though the significance is sociological rather than psychological. Half of the boys failed to detect the violet until the third solution was reached, while almost half of the girls detected it in the first solution. There is a general deficiency in detecting cloves, but the difference between violet and cloves is much more marked in the case of the girls than the boys. While nearly half of the girls detected the weakest solution of violet, four fifths of them failed on cloves until the third solution was reached. Since cooking is a part of the course of study in the Elementary School, it seems a little startling that the æsthetic odor entirely out-distances the practical one in the race for recognition.

In the discrimination tests, as was said, the sensation qualities were named. It was not required, however, that the article

producing the quality be named. For instance, 36 children said 'bitter' to 4 saying 'quinine,' and 21 said 'sour' to 2 'lemon' and 1 'puckering.' All said 'sweet' and all said 'salt.' In the first smell test 35 answered 'perfumery,' the other 12 answering 'violet,' 'cologne,' 'rosewater,' etc. Cloves afforded the greatest perplexity. Less than one third gave the correct answer and the other answers included cinnamon, peppermint, pepper, birch-bark, lead-pencil, spice and paste. Of the tastes sour is the least readily detected and named, particularly with the boys, three fifths of whom failed entirely in naming it. The transition of an agreeable into a disagreeable sensation was frequently illustrated in the case of the strong sweet solution. In 24 cases it was noticed that the fourth sweet solution was called 'bitter,' 'sour,' 'bitter and sweet,' etc., accompanied by expressions of the disagreeableness of sensation. In three cases this result was obtained from the third solution.

The Sensory Tests With the Abnormal Children.

A great deal of skill and patience are required for experimentation with the backward children. They must be sufficiently acquainted with the experimenter to have the 'at home' feeling. One will be suspicious of the apparatus and will even refuse to coöperate in the suggested 'play.' Others will be overwhelmed with curiosity and inquisitiveness. One who has evidently been maltreated by teachers will unconsciously place the experimenter in this 'enemy class' and will assume accordingly the attitude, if not the insignia, of a combatant. Another will consider that he is dealing with a 'doctor,' and the difficulty of getting a pure response will be chiefly due to the unconscious prejudice. John, one of the most alert cases, displayed his insight into the situation by asking the question, "You're going to see what kind of a man I will be, are you?" The different linguistic capacities of the children also introduce an element of ambiguity into the meaning of many of the responses, and the experimenter needs to understand not only each child's vocabulary but the peculiar meaning which each word conveys to his mind. In short he ought as much as possible *to live with the children*. The children reported upon in this paper ranged in age from ten to twenty-two.

Color.—The appreciation of color is certainly not so highly developed as is sometimes thought. Of twelve carefully tested six showed unmistakable evidences of color blindness, while of the total number only two (both girls) possessed anything like an accurate color vocabulary. There were four distinct cases of green-blue blindness. One, a very backward child, who was not deemed sufficiently educable to remain in the school, showed no evidences of any color appreciation, though very persistent efforts were made to elicit such. She sorted the yarns without a mistake on the basis of their form and this in the face of the fact that their form-difference was so slight that the work was almost completed before the experimenter himself detected what was going on. Another showed after repeated tests of different kinds covering the entire school year, that her ability at color discrimination was practically limited to yellow and red. In sorting colored beads great readiness was shown by her in discriminating yellow from red while there was utter confusion on blues and greens. Beside the above-mentioned color names, brown, purple, and pink figured prominently in the color vocabularies of these children.

Color Threshold.—An experiment was devised to determine the color threshold. Color disks were arranged on the wall and the child led so far away as to be unable to detect any color. He was then led up slowly until the colors appeared in succession. The impossibility of maintaining a uniform degree of illumination, together with numerous other drawbacks in the matter of technique makes the absolute distance here of little value, but the relative results are believed to give an accurate expression of the situation. The experiment was conducted satisfactorily with seven of the cases. With each of these, red appeared first both in the first series of tests and in the second, which was taken some months later. In the first series green came second in four cases, blue being second in the other three cases. Green was third in one case and yellow in six cases. Without further particularization, the order was *red*, *green*, *blue*, *yellow*. When the series of tests was repeated some months later, red still uniformly held first place but there was a general disposition to move yellow forward, the other colors,

except in one instance, maintaining the same order as before. This change in yellow was due partly to the intervening color education and partly to the fact that the child had learned that when he saw no color the color was probably yellow. Experiments of this kind are absolutely valueless, unless the experimenter is intimately acquainted with the vocabulary of the sub-ject.

Color Preference. — An effect was made to get at the children's color preferences. Many of the results were conflicting, but five had a distinct preference for red. One each preferred indigo, pink, and green. There were a few marked cases of emotional accompaniment in this color preference. Ralph called red 'my color' and told with much glee of a red, white and blue flag which he had at home. J. liked indigo best and had an indigo ribbon in her hair. Frances liked pink best and her room at home was furnished in pink. John did not like red for he was once 'scared almost to death by a red cow.' The persistence of this prejudice was shown in the fact that the same circumstantial evidence against red was produced by him four months later than the first test. E. — a cretinoid — seems to partake of the ancient Greek conception of the beautiful. On both occasions — months apart — when the color preference question was put to him he carefully arranged the yarns in symmetrical rows, but did not seem to care to commit himself to any one color. The 'pretty' or 'like best' idea seemed to be better expressed in symmetry, form and order than in color. Other evidences of this peculiarity will be cited under another head.

Hearing. — But three cases in the Physiological School had perfect hearing in so far as this could be determined by the ordinary watch tests. In most of them both ears were affected.

Pitch. — The Galton whistle tests indicate a poor ability at pitch discrimination also, the upper limit never being above 28,000, which was rare, and running down as low as 14,000 vibrations.

Sight. — The eyesight of these abnormal children is poor; about half of those tested were below the standard in keenness of vision, and some degree of astigmatism was found in every child but one or two.

Taste and Smell. — It was usually impossible to distinguish between the threshold and the discrimination point. Three cases were entirely lacking in the sense of smell, no distinction being recognized between the strongest solution of violet and cloves. Four were more or less deficient in taste, while the average threshold is much higher on all than in the normal children. Nearly 80 per cent. of the children tested recognized nothing below the third strength of quinine solution.[1] Nearly half failed entirely with sour, 65 per cent. failed on sweet, and 63 per cent. on sour until the third solution. Their detection of violet perfume was almost as accurate as with the normal children, but one only detected the first solution of cloves and no other one detected the second solution. El. called all strengths of sour solution 'water.' R. called salt 'sweet' and sour 'bitter,' and while he called quinine 'bitter,' he applied the same name to each of the other tastes, and gave no indications of especial displeasure at the strongest quinine solution. When asked, he said he didn't like it. Em. uniformly called sugar 'bitter' and sour 'sugar.' Similar phenomena have been observed by Wylie in the laboratory of the Minnesota School for Feeble-Minded.[2]

Pain. — On the right temple the algometric readings range in kilos from 1.01 to 4, half of them being above 3.25.

Temperature. — *Discrimination.* — One case was able to discriminate differences as low as 5° C.; two as low as 1° C., while the rest ranged from 2° C. to 10° C. This power of discrimination tallied very closely with the general intelligence of the cases. The standard from which measurements were taken was about 30° C.

The threshold of the sensation 'warm' was located on the C. scale at a region ranging from 18° to 32° that of 'hot' from 30° to 55°, and that of pain from 49° to 65°.

Fatigue. — Dynamometric readings range with the right hand from 5 to 63, all but the lowest cases in intelligence being above 24, while nearly all were above 30. With the left hand the readings were almost uniformly a little lower (except in

[1] See Tables I. and II.

[2] *Journal of Psycho-Asthenics*, p. 109, March, 1900.

case of the left-handed subjects). The dynamometer readings were taken after the day's work and are considerably smaller than readings obtained on days when no gymnasium work was given. This emphasizes the fact brought to light on all sides, that fatigue with backward children, as would be expected from their low vitality, is very rapid and considerable.

A little experiment was made with four cases with the double purpose of testing this fatigue and also the effect of summation of stimuli under fatigue. Fifteen successive trials were given with dynamometer in each hand. The average of each five tests are reported. During the last five the experimenter, simultaneously with the subject, went through the customary movements accompanying the gripping process. With some cases lower in intelligence than here cited, the additional energy was expended but it took the form of divers facial grimaces and other contortions not measurable with the dynamometer. The following results are of interest: Ralph: R, 29, 24, 28; L, 23.5, 17, 18. John: R, 61, 56, 58; L, 60, 58, 53. Tom: R, 30, 25.8, 26.4; L, 25, 24, 23. Joe: R, 37.6, 36.6, 34.4; L, 20.4, 19.4, 20.8. (Joe is left-handed.[1])

Touch. — An effort was made, but without very satisfactory results, to obtain information as to the sensitivity of the tactual, pressure and muscular senses. Two serious difficulties lie in the way here. The process is tedious under the most favorable conditions and the abnormal child does not possess the delicacy of attention necessary to insure reliability in results. The fatigue element is also a serious interference. Beside this the child soon lapses into a series of rhythmic responses the stress of which prevents successful procedure. By means of the method of right and wrong cases, however, some work was done with E. which is considered approximately correct.

The æsthesiometric compass reading on the forefinger was 10 mm., while there seemed to be but one touch area on the little finger. The reading on the palm was 41 mm., wrist 10.5 to 11 mm. and forearm 55 to 60 mm.

[1] The ordinary dynamometer is wholly unfit for tests with children. Mr. F. W. Smedley, of the Chicago public schools, is using an excellent dynamometer constructed for use with children.

The average error in locating spots touched on the wrist was 15 mm. with the prevailing tendency 'in' and 'up.' Spots touched on the fingers were located quite accurately. No finer discrimination was made in active weight than that between 100 g. and 60 g.

Imagery. — A great deal of time and patience were expended in the effort to determine the prevailing form of imagery in each of the abnormal children. Table III. contains some of the re-

TABLE III.

IMAGERY OF ABNORMAL CHILDREN.

Case.	Age.		Ear.	Eye.	Ear and Voice.	Eye and Hand.	All.
E.	19	4	$\frac{57}{80}, \frac{4}{20}$	$\frac{49}{80}, \frac{2}{20}$	$\frac{56}{80}, \frac{1}{20}$	$\frac{37}{60}, \frac{0}{15}$	$\frac{74}{80}, \frac{18}{20}$
J.	13	4	$\frac{80}{80}, \frac{5}{20}$	$\frac{62}{80}, \frac{5}{20}$	$\frac{74}{80}, \frac{9}{20}$		
F.	14	5	$\frac{80}{80}, \frac{20}{20}$	$\frac{80}{80}, \frac{17}{20}$	$\frac{73}{80}, \frac{13}{20}$	$\frac{80}{80}, \frac{14}{20}$	
El.	12	5	$\frac{15}{80}, \frac{3}{20}$	$\frac{46}{80}, \frac{2}{20}$	$\frac{60}{80}, \frac{10}{20}$	$\frac{39}{60}, \frac{4}{15}$	
Em.	14	5	$\frac{80}{80}, \frac{20}{20}$	$\frac{57}{80}, \frac{4}{20}$	$\frac{52}{80}, \frac{6}{20}$	$\frac{78}{80}, \frac{7}{20}$	$\frac{57}{64}, \frac{3}{16}; \frac{44}{44}, \frac{11}{11}$
R.	9	5	$\frac{67}{80}, \frac{10}{20}$	$\frac{53}{80}, \frac{6}{20}$	$\frac{79}{80}, \frac{13}{20}$	$\frac{24}{80}, \frac{8}{20}$	
M.	13		$\frac{80}{80}, \frac{10}{20}$	$\frac{78}{80}, \frac{12}{20}$			
Jn.	12	6	$\frac{80}{80}, \frac{20}{20}$	$\frac{78}{80}, \frac{0}{20}$		(?)	
T.	9	4	$\frac{26}{80}, \frac{0}{15}$	$\frac{57}{60}, \frac{14}{15}$	$\frac{61}{80}, \frac{11}{20}$	$\frac{24}{24}, \frac{6}{8}$	

sults obtained. The first column shows the highest number of nonsense numerals the child could repeat immediately upon their being given him *orally*. It was found that the number varies somewhat according to the character of the original impression. It was also found that the length of time such a series can be remembered depends upon the same condition. Some can do better, both as regards number and time, with a spoken series, others with a written series and so forth.[1] This suggests an important shortcoming in the ordinary method of procedure here; it at least puts an important limitation on the meaning of the responses obtained by the ordinary procedure, and this limitation has, of course, greater applicability to abnormal than normal individuals.

As it was found when numerals were memorized that no case 'broke down' under four numerals, that number was chosen and uniformly used in subsequent experimentation. Five series of tests were made. In the first, four numerals were repeated orally three times. After ten seconds the subject repeated the

[1] Cf. G. Whitehead, PSYCHOL. REV., 1896, p. 258.

series. In another ten seconds he was asked to do the same and so on, until he had had five trials at this series. This made a total of twenty possible numerals and five series. This process was repeated with a new set of numerals over and over, until the subject had a chance at a possible eighty numerals and twenty series.

The numerator of the first fraction indicates the number of numerals correctly given out of a possible eighty. The numerator of the second fraction is the number of correct series out of a possible twenty. In the second test the same *modus operandi* exactly was followed except that the numerals were *written* and the subject silently looked at them ten seconds. In the third test the subject *heard* and himself *pronounced* the numerals and then waited the customary ten seconds. In the fourth, the subject himself *copied* the numerals after which the paper was removed. In the last test all methods of stimulation were combined. The prevailing types of imagery in each subject are apparent from the table. Some of the results are quite pronounced and are verified by other forms of tests. T.'s results are not complete, but there is cumulative evidence that he is a visualizer. Three cases are perfect in the auditory form. R. does best in the vocal-motor form. It was found that the results vary considerably according as the responses were given *orally* or in *written* form. This phenomenon was so pronounced in Em.'s case — a child with a marked speech defect — that some special results are given in her 'all' column. The first fractions are her oral answers and the second fractions are her written answers on identically the same series. That is to say, she would be confused in her oral answer but would immediately proceed to write not only the numbers but the series with absolute correctness. Moreover, she was utterly unconscious of the disparity in the results thus successively given in the two distinct ways. This test was repeated some months later and the same phenomenon occurred. This case seems to be similar to one reported by Charcot, and will doubtless yield to neurological interpretation. The work showed the familiar result that in the process of breaking down of memory there occur in order: (1) a change of *order* of the numerals, the same numerals being

present in the response, (2) *the dropping out* of certain ones and the *inserting* of others, (3) the *dropping out*, decreasing the number and (4) the *adding* of extra numerals. The evidences of the operation of rhythm appear not only in this statement, but are constantly cropping out in the daily work of the children.

Motor Coördination.

Table IV. contains some results in motor coördination, accuracy and rapidity. The coördination tests consisted in sorting 100 beads into four boxes on the basis of color, there being 25 each of red, yellow, blue and green beads. The beads were put into a bag and one was withdrawn at a time, the time to complete the entire work being accurately recorded. The bag was held by one hand while the sorting was done with the other. This color test was followed by a sorting test of 100 forms of the same color under like conditions. The forms consisted of cubes, cylinders, spheres and parallelepipeds. In both cases the number of mistakes made was counted, although as this was not done with all the children the results are suggestive rather than scientifically valuable. This feature should be more carefully attended to in future tests.

Accuracy. — The tests in accuracy were made upon the first joint of the forefinger and upon the axial joint. A straw twelve inches long was attached to the finger, all the other joints of the finger being stiffened except the first joint, and with eyes closed the child made the 'least possible movement.' A light fishing pole 79 inches in length was under similar conditions attached to the arm and the least perceptible movement was made from the shoulder. The subject was not allowed to grasp the pole with the hand. Three trials were given in the case of each test and the average computed. In the table these results are expressed in terms of angular measurement. It would be well in subsequent tests carefully to keep the results of the three trials *in their order*, as it is believed some significant truth would come to light here. It is by no means true that the first trial shows the lowest degree of accuracy as might be expected.

Rapidity. — In the rapidity tests a fatigue counter was used. The subject being in a comfortable position, his arm was fastened

TABLE IV.

MOTOR COÖRDINATION.

A.	Group.	Color.				Form				Accuracy.				Rapidity.			
		No.	R.	No.	L	No.	R.	No.	L.	No.	Finger.	No.	Arm.	No	Finger.	No	Arm.
	Kindergarten.	5	443	4	393	4	346.25	2	349	4	2°13′	3	1° 9′33″	4	13.6	4	23.7
	III.	12	320	8	333	7	300.3	7	285	7	2°55′47″	7	1° 9′02″	7	21.5	6	21.8
	IV.	13	293	10	289.6	10	255.6	10	262.8	11	1°47′35″	10	38′52″	13	22.9	13	29.3
	V.	5	295	1	283	1	232	1	233	1	2°37′47″	2	1° 9′02″	2	25	2	21.
	VI.	5	294							2	2°26′30″	2	1°26′20″	9	24.5	8	27.
	VII.	14	224	9	229	9	188.5	8	195	15	1°47′04″	15	22′45″	12	27.9	12	32.5
	VIII.	7	219	3	215	3	204	3	178.3	5	1°13′16″	5	22′47″	8	29.6	8	28.6
	IX.	7	190	8	211.3	8	180.6	8	178	16	0°54′	16	19′31″	11	30.5	11	35.9
	X.	9	184	9	181	6	158.8	6	126	8	0°44′	8	16′26″	7	32.4	8	36.6
B	Total.	83	263.5	52	265.7	48	247.5	45	224.6	73	1°31′	68	36′37″	72	26	73	30
C		44	254.4	44	259	44	225 3	44	224.1								

To determine the average age of the children in each group add three to the number designating the group.

to the table in such a way as to allow free movement of the fore-finger only. He then manipulated the counter with the utmost rapidity possible. The test continued for 60 seconds, the readings being taken at the end of each ten seconds. The number in each ten-second interval was then computed and the average taken for the six intervals. It is this result which is found in the table, column 'Finger.' The other 'rapidity test' was similar to this except that the shoulder joint moved, the arm and wrist being stiffened. From these same results the subject's fatigue curve was computed and the results preserved on his card for future reference. By comparing the number marked by the counter during the first ten-second interval with the number marked during the sixth interval the rapidity of fatigue comes to light and is subject to mathematical statement. Some of these results are made use of later on, and this should be made a prominent feature of subsequent work.

Table V. gives corresponding results for the cases of the Physiological School. In seven instances the tests were repeated after an intermission of about three months. The results of the second trial follow in the table, immediately after the first. The columns marked 'm' contain the number of mistakes made. In the color test for the first trial 100 colors were used, 25 of each of those mentioned in connection with Table IV. Unfortunately, however, but 75 forms were used at first, 25 of each kind. Later, when the value of this work had become manifest, the experiment was reduced to a uniform system and 80 colors and forms respectively were used. This number was chosen, as it was found that 100 makes too great a tax upon the attention of backward children. Each series of results is, therefore, inherently valuable, but the series are not subject to reliable comparison among themselves. The 'accuracy' and 'rapidity' sections in Table V. are constructed in the same way as the corresponding sections in Table IV. Under accuracy, however, it will be observed that two columns are given to the finger and two to the arm. It was found that these children could only understand what was required of them in this test by first allowing them to perform the work with the *eyes open*. The second column in each case gives the results taken immediately after-

TABLE V.

MOTOR COORDINATION. PHYSIOLOGICAL SCHOOL.

Case.	Color.				Form.				Cards			Accuracy.				Rapidity.		Fatigue	
	R.	*M.*	*L.*	*M.*	*R.*	*M.*	*L.*	*M*	Colors	Forms.	Pictures.	*F—o.*	*F—cl*	*A—o.*	*A—cl.*	*F.*	*A.*	*F.*	*A.*
E.	360	1			230	5			127	130	115	2° 5′ 14″	3° 34′ 35″	0° 30′	2° 37′ 37″	35	29	75%	Inc.
R. S.	358	2	366	0	372	1	290	2	152	187	134	1° 47′ 22″	5° 3′ 35″	1° 13′ 24″		21	19	66	75
T.	360	14			225	11			(?)	160	115	2° 5′ 14″	5° 3′ 35″	1° 16′ 8″	3° 48′	21	23	36	84
T.	244	1	340	11	270	11	237	5								26	20	31	40
Jn.	250	1	310	1	221	3	207	1	105	125	112	1° 29′ 30″	1° 47′ 22″	1° 21′ 33″	2° 43′	28	26	66	77
Jn.	270	1	275	1	237	2	207	0	82	101	114	3° 16′ 43″	5° 21′ 20″	1° 2′ 31″	4° 4′ 20″	30	20	87	76
J.	320		430		250		230		178	180	155	2° 41′	17° 53′ 45″	1° 59′ 35″	4° 45′	28	22	51	54
J.	352	9	325	1	282	1	274	1	145	152	200	1° 29′ 30″	5° 56′ 47″	1° 27″	1° 51′	22	25	Inc.	90
F.	345	11	488	11	223	1	240	12	85	100	93	2° 41′	7° 42′ 41″	2° 15′ 53″	4° 9′ 45″	23	22	81	91
F.	332	4	325	4	230	0	260	0	102	97	88	1° 29′ 30″	2° 58′ 50″	1° 51′ 27″	2° 37′ 37″	25	22	34	71
R. N.	380	2	410		200		228		73	60	62	2° 23′ 8″	9° 27′ 43″	1° 29′ 42″	1° 29′ 42″	21	24	72	81
R. N.	266	1	252	2	216	2	230	2	55	102	84	1° 47′ 22″	2° 23′ 8 ″	0° 49′	2° 30′ 30″	20	23	70	Inc.
El.	600	16	480	28	300	2	210	4	(?)	160	170	7° 7′ 30″	14° 3′ 10″	2° 29′ 26″	5° 47′	14	9	Inc.	Inc.
El.	455	many	450	25	275		263	0	120	115	130	4° 45′ 44″	8° 0′ 14″	2° 15′ 53″	2° 54′	19	14	46	83
Em.	400	5							180	215	245	2° 23′ 8″	3° 34′ 35″	1° 24′ 16″	1° 29′ 42″	10	22	Inc.	Inc.
Em.	450	6	430	2	383	3	380	3	160			2° 23′ 8″	4° 28′	1° 24′ 16″	1° 51′	10	19	(?)	(?)
1st av.	379		425		236		223		112	125	118					22	21		
2d av.[1]	335		345		268		263		109	113	87					21⅝	20⅜		

[1] J being left-handed is omitted from the average.

1st trial=100 colors, 25 each. 1st trial = 75 forms, 3 kinds. 40 of each kind of cards.
2d trial= 80 colors, 20 each. 2d trial = 80 forms, 4 kinds.

ward with the eyes closed. The 'Fatigue' column in this table gives in per cents. the value of the numbers recorded by the counter during the last ten seconds, in terms of the number recorded by the counter during the first ten seconds. The letters 'inc.' mean that in the instance cited the last number was larger than the first number. This does not mean so much an absence of fatigue, as an increase in skill in the required manipulation.

Tests were also given with three sets of cards. There were forty cards in each set. In one set, ten each of blue, red, green and yellow disks had been pasted on the cards. In another set there were printed ten each of four familiar pictures, *i. e.*, a boy, a hand, an ox-head and an eye. In the third set there were printed on ten cards a triangle, on ten a square, on ten a parallelogram and on ten a circle. The columns of the table contain the number of seconds required to sort the different sets. The card tests, though they have been much used, are essentially misleading. They have their value, but it is not that usually attributed to them. They afford a crude means of determining reaction time when the afferent current is visual. They also indicate a child's relative appreciation at a given moment for pictures, colors and forms, which is of pedagogical interest. But it is unpsychological to suppose that they offer any reliable comparison between color and form perception, since they entirely ignore all elements of form appreciation except that by means of vision!

We call attention first to Table IV., *B*. Here the results are given in totals. The actual results here are not considered of importance, for all the experiments of a given kind are dumped together regardless of the age or advancement of the children. But the results in the larger view, as gathered from Table IV. and Table V., have this importance, that they show in every case the abnormal children take more time for coördination, are less rapid and accurate in movement, and more rapid in fatigue. Both normal and abnormal children agree in taking *more time for color coördination than form coördination* — that is when the beads are used, and as for the cards they offer no test of the tactual sense so invaluable in form appreciation.

There is a vast difference between feeling and seeing forms. The chief value of the card results, so far as they throw light upon color and form appreciation, is this negative consideration. Both classes of children agree also in *more rapid form discrimination with left hand* and *more rapid color discrimination when the right hand is used.* This will be referred to again. It will also be seen that both classes of children are *more accurate with the large than with the small joint.* With the abnormal children the finger joint has a fractional advantage in the rapidity test, but as the apparatus for testing the axial joint was somewhat complex, these children had difficulty in keeping it going. The lower average is probably due to this fact.

In Table IV. the normal children are arranged on the basis of their standing expressed in terms of groups in the Elementary School. From each of the four columns showing coördination times it will be seen that there is a steady and uninterrupted decrease in the time of coördination from the kindergarten to the tenth group. The only exceptions to this statement are found in the fifth and sixth groups, color, right hand, but it will be observed here (*a*) that the number tested in these two groups is quite small and (*b*) even in spite of these facts, if the results of one pupil were taken out in each case, the totals then obtained would swing readily into line. The well-demonstrated fact must not be overlooked also, that children of this age are undergoing certain very definite and rapid physiological changes. The general principle stated above applies, though not with such absolute uniformity, in the cases of accuracy and rapidity. The fact much emphasized in recent writings is also worthy of notice—and this is particularly important educationally speaking—that children are *more accurate in their movements and move with greater rapidity when using the shoulder joint than the finger joint.* This suggests the necessity of what is already becoming recognized in some places, the necessity of a complete readjustment of kindergarten methods to the freer and larger movements for which the child is physiologically prepared. The setting of children to tasks requiring fine finger movements and delicate discrimination is certainly a species of malpractice. The figures also show that as children increase

in wisdom and stature they become comparatively more dexterous with the finger, although even in the tenth group the arm has the absolute advantage.

In the course of such experiments as the above, the experimenter has over and over again many opportunities for getting a practical picture of the child's mental alertness and mental habits as well as his ethical motives. A fruitful field in which the latter crops out is found when the child picks up two beads, after having been strictly enjoined to take but one at a time. The numerous alternatives taken in this particular crisis are very significant indeed. A comparison of the coördination time with the right and that of the left hand disclosed some interesting results. A hint at the question is obtained from Table IV., *B*, and again from Table V., '2d *av.*' In both cases it appears that the longest time for sorting is with colors and the left hand. The colors right hand comes next, and quite below *these* figures come in order the forms right hand and finally for the shortest time the forms left hand. When it is remembered that Table IV., includes all ages and that only about one half of the normal children were given each of the four tests it may be concluded that the results have no significance. The average, made up from data representing such children as those reported in Table V., if taken alone, would certainly be no trustworthy guide to scientific truth. To be sure of the situation the results for 44 right-handed children are given in Table IV., *C*. Each of these 44 children took the four tests. The *relative numbers* are the same as shown in the tables just cited. Of the 44 cases 20 actually sorted the forms sooner with the left hand and the margin was close in some of the other cases. Of the same 44 cases 28 sorted the colors more quickly with the right hand and 8 of the others took the experiment with the left hand from 2 to 4 months after that with the right hand. This gave the left hand a decided advantage. In several cases where children were using forms with the left hand it was clearly apparent that the motor operation could not keep up with the tactual discrimination and numerous mistakes were made on this account. More mistakes were made with the forms than with the colors and this result is believed to be largely due to this fact.

Table VI. shows four left-handed children, '*II.*' and '*III.*' of whom, however, have been taught to use their right hands. These children were more proficient both in colors and forms

TABLE VI.

COÖRDINATION. LEFT-HANDED CHILDREN.

Subject.	Color.		3 Forms.		4 Forms.	
	R.	*L.*	*R.*	*L.*	*R.*	*L.*
I.	261	241	153	155	225	204
II.	198	220	112	110	160	177
III.	200	210	115	125		
IV.	237	270	168	137	208	191

with the right hand, as will be seen. '*I*,' however, who has remained left-handed, illustrates our hypothesis completely, the times being in order of decrease; colors right, colors left, forms left, forms right! This is when three forms were used. When the experiment was tried with four forms the results are more ambiguous. This matter is worthy of attention. Several other children reversed their order when four forms were used from that obtained when three forms were used. As the number of forms increases from three to four the motor phase of the coördination problem rises in complexity. There are 24 possible chances here while there are but six in the other case. This is illustrated in the possible ways of arranging the boxes. This side of the problem then is increased in complexity 400 per cent. Now the tactual phase of the problem is not so much affected — only to the extent of 25 per cent. This consideration seems to throw weight in favor of the proposition that in those children who sorted forms more readily with the right hand, the *motor* facility turns the balance — the results might be accounted for even if it were proved that the children had finer sensitivity to touch with the unused hand. Subject '*IV*' in the last table is a boy who is not only right-handed, but who insists he has particular difficulty in using his left hand. He is slower in colors with his left hand and swifter on forms with his left hand, both when three forms are used and when four forms are used.

With considerable unanimity the evidence seems to point one way. One point at least is beyond question, *i. e.*, in the

given tests *children discriminate form more readily than color.* In about 100 tests there have been no exceptions to this statement. It is true that in the tests given the form experiment had one advantage in its favor because the child perceives the form immediately upon contact *in the bag* and may at once begin the motor phase of his task. It is not believed that this is the whole story, although this suggests the necessity of a different method of counting time in the experiment. There are strong indications, especially with abnormal children, that form appreciation chronologically precedes color appreciation. Witness, for instance, the cases cited on page 351. Bearing upon this point of the comparative priority and sensitivity of touch and other forms of sensation Dr. Martin W. Barr, chief physician of the Pennsylvania Training School for Feeble-Minded says[1]: "The basis of this scheme of development is the recognition of *touch* as the most sensitive as well as the most reactive of all senses; therefore we utilize it as the master key which shall set free the powers of the head — the hand — the heart." The other point which appears to be true is that the sense of touch is more delicate — at least relatively more delicate as compared with the motor power in the left hand of the right-handed people and the right hand of left-handed people. The interpretation of results of this kind is no simple matter. It is difficult to draw the line between the tactual discrimination and the motor control. It seems impossible to get either in perfect isolation. It would appear that with a right-handed person the right hand would have the same advantage with forms as with color. It may be that the left hand had a slight advantage on the score of practice, for it was the rule to take the right hand first. This statement could certainly be questioned, however, in the light of our knowledge in other psychological fields. This advantage, if any, was greatly counteracted, however, by changing the position of the boxes between tests. Furthermore, it would appear that practice should help in color as well as in form. Another factor, however, worked in the opposite direction to practice. That was fatigue.

[1] 'The How, the Why, and the Wherefore of the Training of Feeble-Minded Children.' *Journal of Psycho-Asthenics*, September, 1899.

In the younger children fatigue would tend to outweigh the value of habit. The novelty of the work soon wore off for them. On the contrary, with the older children the interest was maintained and habit may have helped in the solution of the problem. Further facts will throw light upon the question. The hypothesis is perfectly plausible, theoretically, when there are taken into consideration the comparative passivity of the unused hand and the persistent interpretative mood of the used hand. The theory, moreover, does not require that the unused hand shall be actually more sensitive to touch, but that when the algebraic sum of the sensitive qualities is obtained the tactual has a larger balance in its favor.

At this juncture there is submitted another table, VII., which gives the record of eleven pupils in the Elementary School who were subjects in these experiments in two successive years. The results are shown side by side. Each of these children has been promoted a group during the year and we find a *corresponding increase of ability in the lines of our inquiry*. The table plays very readily into the hands of the general relation already indicated of the power of attention to motor coördination. Table VII., also indicates the value of a method already suggested of studying children which the 'Science of Child-study' has thus far practically ignored. The effort heretofore has been to give a cross-section view of a larger number of children. This method suggests a longitudinal view of a few children as likely to be of more value. If the spider were tested by the cross-section method in motor coördination, some results quite derogatory to the child would be obtained. If the longitudinal method were applied to the spider and the child, the outcome could be easily prognosticated. There is about as much reason in measuring one child by another child as in measuring one child by a spider. The cross-section method is static and has little real meaning. This little meaning will be buried effectually, if the result is dumped in with a mixed multitude of others. The longitudinal method is dynamic; it is a measure of *progress*. The differences, not the resemblances, are the chief value, pedagogically at least. For such a purpose the 'average' is worthless; it is impersonal. When it is

TABLE VII.

Name.	Coordination.		Accuracy.				Rapidity				Fatigue.			
	1899.	1900.	1899.		1900.		1899.		1900.		1899.		1900	
	Colors.	Colors.	Finger.	Arm.	Finger.	Arm.	*F.*	*A.*	*F.*	*A*	*F.*	*A.*	*F.*	*A.*
Clifford	249	189	1° 2′ 8″	34′ 16″	26′ 13″	32′ 33″	33	34	35	35	I	97	82	87
Edwin	209	208	0° 53′	20′ 33″	23′ 29″	11′ 19″	27	33	29	35	76	66	85	82
Fletcher	245	158	1° 46′	18′ 49″	33′ 49″	2′ 51″	23	16	28	35	36	I	80	90
William	206	162	26′ 31″	0° 12′	41′ 18″	13′ 8″	43	44	38	46	70	97	86	73
Barrett	290	222	4° 8′	23′ 55″	1° 7′ 38″	17′ 6″	31	29	30	34	46	51	86	76
Howard	304	205	1° 2′ 8″	18′ 49″	3° 11′ 30″	25′ 31″	27	27.5	28	30	66	80	72	70
Mary		191	44′ 20″	0° 12′	0° 30′	14′ 16″	31	32.5	30	37	82	50	50	86
Donald	252	213	0° 53′	30′ 49″	29′ 36″	10′ 49″	26		32	43	60		48	70
Henry	399	244			35′ 20″	15′ 24″	30	30	22	27			82	87
Stephen	460	285			2° 37′ 47″	59′ 6″	23	15	21	24	72	68	87	88
Lander	260	225	1° 18′ 33″	37′ 41″	1° 18′ 33″	17′ 6″	12	21	22	29	75	80	72	E

NOTE.—'I' = increase, 'E' = even.

considered that each individual is unique in temperament, rapidity and order of his nascent periods, heredity, environment and personal equation, the inadequacy of any 'average' standard is made manifest. The individual's progress should be measured by the possibilities of his own self-realization.

In the discussion thus far we have had under consideration as a rule no smaller unit than the group. Of course it is desirable, if the pedagogical side of the purpose is to be made practicable, to devise a system which will have individual applicability. In this kind of a device two things must be kept in mind. One is this longitudinal method and the other is that the tests, if they are to be of value without repetition, must cover a sufficiently long period of time, or if short in duration, must be of a sufficient degree of complexity. Two of the tests of Mr. Kirkpatrick[1] appear to me to be of questionable value for purposes of individual classification. In one he requires the children to count orally as rapidly as possible for ten seconds; in the other, to make vertical marks as rapidly as possible for ten seconds. The correspondence between the results obtained in this way and those given by the teachers is certainly so remarkable as to throw the burden of proof on any one who might attempt to criticise the tests. But I have not been equally fortunate. My results obtained by the use of the fatigue counter, the readings being taken every ten seconds for a minute, indicate no trustworthy correspondence between the work of the first ten seconds and the child's real mental power, so far as it may be applied to any practical problem of life. It is not only easily conceivable, but results in this study show it to be the case, that the 'C' grade pupils make excellent records for the first ten seconds. Under the novelty of the experiment they pull themselves together and work on borrowed energy as their fatigue curves show. They are among those who have no root in themselves and so endure but for a time. Of 16 pupils marked 'A' by the teachers of the Elementary School ten were graded 'A' by my scale of 'coördination,' 'accuracy' and 'rapidity' results. This is as close a correspondence as any two teachers would be likely to reach in marking the same children, especially when

[1] PSYCHOLOGICAL REVIEW, June, 1900.

it is remembered that the Elementary School pupils are already grouped on the basis of ability alone.[1] But when I came to the pupils marked 'C' by their teachers, of whom there were 11, only two are put 'C' by my system. The 'C' pupils work better at my tasks than they do at the tasks the teachers put them at. This suggests a serious weakness found in every device thus far suggested, so far as the writer knows. The fact of there being in the schools two distinct types of children, *i. e.*, the sensory child and the motor child is ignored. If a motor child does not do the ordinary sensory tasks of the school well is it the fault of the child or the requirement? Leaving for the moment the question of requirements untouched, it seems clear enough either that there must be a different series of tests for the two different classes of children, or there must be found some common denominator in terms of which each class may be evaluated. The standard must not be chosen arbitrarily and it may be arbitrary and still have the custom of centuries behind it. This paper does not claim to have found that standard. If, however, these same 'A' and 'C' pupils are compared on the basis of the fatigue tests, the correspondence sought is marked. These results are computed from the 'rapidity' test, the record of the first and sixth ten second interval being compared. The figures given in Table VIII. show the per cent. which the sixth interval bears to the first interval.

It will be observed first that the 'C's' fatigue more readily than the 'A's,' there being a difference of more than 10 per cent. in both finger and arm in favor of the 'A's.' Both classes fatigue more readily with the finger than with the arm. Of the 10 'C's,' 6 fatigued more readily with the finger. One maintained his rapidity of arm movement and one increased it during the minute. Of the 13 'A's,' 7 fatigued more with the finger, one maintained his rate with the arm and one increased it, while two increased the rate with the finger. The general lesson of the table is clear and unmistakable. While it may be necessary to vary the tests to meet the peculiarities of the motor

[1] Two of the leading teachers of the Elementary School were asked to grade a given list of pupils and there was a considerable degree of variation in the results.

TABLE VIII.

FATIGUE.

No.	'C' Pupils.		No.	'A' Pupils.	
	Finger	Arm		Finger.	Arm.
1	62	55.5	1	88	67
2	66	76	2	73	96
3	48	70	3	93	96
4	94	70	4	67	59
5	82	100	5	66	90
6	76	79	6	85	82
7	89	79	7	86	73
8	53	74	8	142	112
9	89	55.5	9	70	90
10	91	105	10	81	91
			11	91	100
Av.	77	76.4	12	86	87
			13	107	97
			Av.	87.2	88

and sensory child, it would appear that the element of fatigue, if once understood and properly applied, would serve as a practicable common denominator.

The Emotions. — A study of the emotional life of abnormal children is of peculiar interest. While the cases in the Physiological School are emotionally erratic as all such children are, they, nevertheless, on the whole possess emotional tendencies. They are much less plastic in their adaptations to their surroundings than are normal children. But for detailed knowledge of the facts of their emotional life we must wait on empirical observation. Experimentation is of limited value.

The abnormal children though lacking intensity in their psychical powers, seem to possess the extent of the normal individual, so that Ireland seems to be justified in saying: 'I do not know of any power which existed in the mind of Shakespeare or Napoleon of which they are totally destitute.' It is also significant that throughout the whole range of the psychic processes here studied the laws of procedure harmonize in an unexpected degree with those already determined for normal adults.

SUMMARY.

The following considerations seem to come prominently to light from the work thus far done:

1. There is need of frequent psycho-physical examinations of children. This need applies not only to the neglected classes but to all classes regardless of social condition. Children of the most cultured, the most wealthy and the most alert parents frequently suffer not only physically but mentally because of the unknown physical defects which such an examination would readily bring to light. The amount of mental anguish which children suffer entirely on account of ignorance of parents and teachers is by no means duly appreciated.

2. The prosecution of this kind of work will soon result in the establishment of norms in terms of which a child can readily be scientifically classed for pedagogical purposes.

3. The work of the psychological laboratory is demonstrating that pedagogy will never become a science in truth, until the principle of individualization becomes its watchword.

4. Approximate uniformity of results in psychical reactions is a characteristic of the healthy consciousness. Inability to secure this uniformity is at once a sign of a neurotic condition, which if neglected may become permanent.

5. The study of 'what is in a child's mind' at a given moment is of very questionable scientific value; it is scarcely a psychological study at all. The most of the content of a child's mind at any stated time is determined by his environment. A child of arrested development has a well-developed *automobile consciousness*. He has power of imagery with reference to this machine, visual, and auditory, and motor, which measured in terms of race development alone would indicate a degree of intelligence far advanced. The child's 'religious ideas,' 'ethical ideas,' and so forth are largely the ideas of his elders unconsciously appropriated.

6. The scientific value of tests made on children by those unfamiliar with their habits, vocabularies, environments, etc., is very slight and this value reaches its minimum when the reports are dumped in with others of like character.

7. These tests with both classes of children agree in indicating that touch is a more primitive sense than color. It develops first and maintains its precedence for some years. (How long is as yet undetermined.)

8. Bright colors are generally preferred by these abnormal children.

(The experiments were not extended to the normal children.)

9. The grosser movements of the body develop before the finer ones. There is greater accuracy and rapidity of movement with the shoulder than with the finger and this rule is followed by children up to the highest group (tenth) in the Elementary School.

10. There is a uniform increase of ability at motor coördination as the intelligence rises. This runs through the groups and applies to individual cases.

11. The stress of motor imitation is so strong as frequently to overcome the deteriorating effects of fatigue. See dynamometric readings, page 354.

12. The lower the intelligence the more prominent the element of fatigue appears.

13. The effect of tendencies to rhythm in conscious activity is a very considerable though almost neglected factor in the attempt to teach children.

14. The chapter in children's imagery is yet unwritten.

15. It is quite possible for the simple motor test which discloses the degree of intelligence to be so conducted as to give valuable ethical data as well.

16. The abnormal child is deficient in intensity and not in extent of psychic function.

17. An interesting question is raised as to whether the sense of touch is not relatively more delicate than motor ability in the left hand of right-handed individuals and *vice versa*.