THREE PSYCHO-PHYSICAL TESTS FOR MEASURING VENTILATION EFFECTS.

A thesis submitted to the Faculty of the Graduate School of the University of Minnesota by

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OUTLINE.

I. General Plan of the Experiment.

A. Description of Groups.
B. Description of Ventilating Apparatus.
C. Chronology of the Experiment.

II. Method of Testing.

A. Description of Tests.
(1) Division, (2) Substitution, (3) Motor.
B. Method of Scoring.
C. Discussion.

III. Interpretation of Results.

A. Division.
B. Substitution.
C. Motor.

IV. Summary and Conclusions.

Appendix.

This study is an attempt to measure the work of a group of school-children under two different conditions of school-room ventilation, and to determine what effect the change in ventilation had upon their mental and motor activities.

A room was chosen in the Jackson school of this city, and for three weeks was kept under one kind of ventilation (to be described shortly), and then for another three weeks was supplied with a different kind of air. The children in the room were tested (in a manner to be described later) every day of the third and sixth weeks, and a comparison of the results of these two series of tests was made in order to discover how much the children were affected by the change in ventilation.

The results of such tests are of little value in determining ventilation effects, however, unless one has some means of allowing for the numerous factors which always affect long-continued work. Practise in any activity always tends to increase facility, at least up to a certain point, so it would be only natural for the children to do more work the second week tested, than the first, regard-

less of change in ventilation. On the other hand fatigue has a tendency to reduce the amount of work the longer the tests are continued. Thus the results become confused and there is danger of ventilation effects being covered up by the factors involved in the work itself. One would not know how much to allow for the effects of practise and fatigue unless he had some plan by which they could be accounted for, leaving only effects due to change in ventilation. Isolation of ventilation effects was accomplished in the present experiment, as follows:

A group of children was chosen from the Adams school whose averages in the tests were practically the same as the averages of the Jackson group. This group was tested in the same manner as the Jackson group only a week later--- that is, on the fourth and seventh weeks. The aim was to have conditions the same in both groups except ventilation; whereas the ventilation at the Jackson school was changed at the end of the third week, that at the Adams was left unchanged. The results of the tests as applied to the Adams group, then, give a standard as to how the children in the Jackson group would work if the venti-

lation were left unchanged.

The use of the Adams group as a check involves the making of several assumptions. First, that the two groups, who were chosen for comparison because they averaged practically the same in the work tested, are equally efficient in the activities employed. This assumption is based on the similarity of their averages in the first series of tests. Both groups averaged the same within one per cent. The work of the Adams group is a trifle the higher in all the tests of the first series, so the assumption was made that this difference would remain constant, and in comparing the work of the two groups for the second week, it was allowed for by deducting the amount of difference. This placed the two groups on the same level at the beginning of the second test-week, and it was assumed that any deviation which then appeared in the work of the Jackson group could be ascribed to effects of ventilation change.

This method of equalizing test-groups differs from that used by Winch(4) who made similar tests to determine what time of day was most favorable for certain kinds of school-work. He tested his entire group for five days,

then using the averages of these preliminary tests as a basis, divided the group into two equal parts one of which was tested under each condition under investigation. The present method of equalization seemed more advantageous in several respects. In the first place, if the Jackson group, numbering 41 children, had been divided on such a basis, there would have been left only 20 in each group. Absences would have further reduced this number to at least 15, thus lessening the reliability of the averages by decreasing the number of cases. Furthermore, had the Jackson group been so divided, then half put under each kind of ventilation, Group A would have been tested three weeks after the preliminary tests, but Group B would have been tested six weeks after the preliminaries. Thus the first group would have been given an advantage due to recency of practise which would have decidedly affected the results. It seems reasonable to expect the two groups to be of approximately equal efficiency. Both contained 41 children doing the work of the B 4th grade, and all the conditions of their environment were similar with the exception of ventilation conditions. These, it was assumed, would remain practically the

same at the Adams school where it was that ordinarily found in a city school. Temperature was kept as near 68 deg. Fr. as possible, and inasmuch as this school is one of the largest and best-equipped in the city, conditions are likely to be quite constant.

Finally the assumption was made that any difference in outside weather conditions arising from the fact that the tests had to be given one week later in the case of the Adams group, would not materially alter the efficiency of either group. It must be remembered that children are under school-room ventilation only five hours out of the twenty-four. Furthermore this time is so divided by recesses at 10:30 a.m. and 2:30 p.m. and lunch hour from 12:00 to 1:30, that the children are never in the school-room more than an hour and a half at a time. This gives comparatively little time for effect of school-room ventilation to appear. The tests were given the last hour in the morning in order to have the effect of the indoor ventilation at its maximum. The objection may be made that three weeks under each kind of ventilation is too short a time for ventilation effects to be developed, but it was impossible to carry on the ex-

periment for more than six weeks without getting into spring weather and the season of open windows in the school-room. In the opinion of the experimenter, however, it seems likely that any effect which could not be detected in the length of time allowed, would be negligible.

Description of Ventilating Apparatus.

At the Jackson school where the ventilation was to be changed, a complete ventilating plant was constructed underneath the test-room in order to supply air to this room alone. In order to secure uniform ventilation for each child, the air was conducted to the front of each desk by separate pipes. A detailed description of the mechanism follows:

* "The air to be delivered to the pupils in the room was taken in through a window in the basement and passed over two Vento radiators to a Webster air washer and humidifier, thence to a heating coil from which the air was blown to the outlets in the room by means of a Sirocco blower. The main duct from the blower was carried along the ceiling at one end of the basement room immediately below the room in which the pupils to be the subjects of the experiment were located, and from it three ducts were ex-

* The engineering work connected with the experiment was under the direction of Frederic Bass, Professor of Sanitary Engineering, University of Minnesota.

tended parallel to the rows of desks. From these ducts the air was carried through two-inch risers extending through the floor to each desk in the room above, at which points it entered the room through funnel-shaped orifices. Previous experiment with a single desk and funnel ventilator had shown that with seven cu.ft of air per minute the head and shoulders of the pupil could be surrounded by air moving at a sufficient velocity to carry away the breath but still not great enough to be objectionable. In this was it was made certain that each pupil would actually receive the air both in quantity and quality that was desirable, and by means of a number of openings in the ceiling, through which the air was drawn by an exhaust fan, it was made equally certain that the exhaled air would be immediately removed from the room." (1) A long pipe was extended on two sides of the room where the black-boards were located. The pipe was placed mid-way between floor and ceiling; was about six inches in diameter and contained a row of orifices about 2 sq. in. in size along its front side, about two feet apart. These orifices furnished air for the pupils while working at the black-board. The temperature of the room

was kept as near 68 deg. Fr. as possible. Direct radiation in the room, the temperature of the entering air and the temperature of the water in the air washer were automatically regulated by thermostatic control. In addition to the above described apparatus, an ozone generator was installed and as the air entered the room it was injected with a small amount of ozone (about one part to a million). The room was heated by steam from the steam-plant which heated the building, but of course, all connection with the ventilating plant of the building was cut off.

On Feb. 17, 1913 the system was put into operation and run for three weeks, fresh air being brought in froma window in the basement and treated as described above. The fourth, fifth and sixth weeks, instead of introducing only outside air into the room, the intake window was opened only one inch, and the air was taken from the exhaust pipe which withdrew it from the room. It was then returned to the room(through the individual openings). Thus during the second three weeks of the experiment, the children were breathing the same air over and over again. During the third and sixth weeks (the last week of each ventilation

condition) mental and motor tests were conducted each day. On three days of these weeks, twenty of the children were examined for temperature and blood-pressure by Dr. Huenekens. The following table gives the chronology of the experiment.

Feb. 17-Mar. 7 inclusive, ventilation No. 1 at Jackson.
Mar. 3-7 inclusive, tests conducted at Jackson.
Mar. 10-14 " " " " Adams.
Mar. 10-31 " ventilation No. 2 at Jackson.
Mar. 24-28 " tests conducted at Jackson.
Mar. 31-Apr. 4 " " " " Adams.

Description of Tests.

Division, Substitution and Motor tests were used in forms to be described shortly. Promptly at 11 a.m. the tests were started, ten minutes being devoted to each activity in the above order. For the Division test each child was given a paper upon which were printed 140 problems in short division. The divisors were 6,7,8 and 9 used in rotation, and the dividends contained three digits. The numbers were so arranged that each problem came out even with two figures in the quotient. Owing to the impos-

sibility of combining the nine digits in such a manner as to furnish new problems every day, the same problems were given each day. Careful instructions were given before each of the three tests and two minutes practise allowed in each one the first day so as to permitpf slight familiarity and prevent misunderstanding ofthe instructions. After instructions and preliminary practise, the papers were laid face-downward upon the desks and the children were told to write in the upper left-hand corner, date, name, age and birthday. When all had finished, the children turned over their papers and the signal was given to start, timing always being done with a stop-watch. At the expiration of five minutes a signal was given and each pupil drew a line underneath the problem he was then working. This was done in order to furnish a means of comparing the work of the first five minutes with that of the last five minutes.

For the Substitution test a sheet of paper was given each child containing the letters of the alphabet arranged in two horizontal rows across the top. Underneath each letter was placed some number which lay between 11 and 36 inclusive. These numbers were arranged in chance order. The

rest of the paper was covered with seventeen rows of squares, ten in a row, each square containing a number and a space underneath in which to insert the letter which accompanied that number in the key above. The arrangement of the numbers in the key was varied from day to day. The procedure of this test was the same as that for Division. A sample of each test-sheet appears in the Appendix.

The motor test consisted of the side-wise movement of the index finger described by Bergstrom(2) with a modification in the manner of holding the rest of the hand in position. It was manifestly impossible to obtain kymographic records of the work of each child, so a simple ergometer was devised which could be adapted to group tests and obtain fairly accurate measures of movement against a slight pressure (the wire agitator described below). In this ergometer the finger is inserted into a circular hole in a lever, which, when raised up and down moves a slide back and forth. This slide runs horizontally in a standard which contains a hollow tube 5/32 inches in diameter. On top of this standard, which is three inches high, is a round wooden bowl serving as a hopper. When this is filled with steel

balls 1/8 " in diameter, they drop down one by one into the tube and rest upon the slide to which the lever is attached. This slide, which is exactly 1/8" thick, contains a small hole just large enough to accomodate one of the steel-balls. As the slide is moved outward by the raising of the finger-lever, it carries out the steel ball from the standard and drops it into a receptacle at the side. Then, as the lever is pulled down, the slide moves back into position and another ball drops into the 1/8 " hole. The standard is mounted on a thin base and clamped to the right side of the desk, with about two inches projecting beyond the edge of the desk. On the under side of the base is a small ledge upon which the middle finger rests. The fore-arm rests upon the desk. At the conclusion of the test-period the receptacles which catch the balls are collected and their contents weighed, from which it can be determined how many times the child raised his finger the required height.

Since the balls tend to clog at the mouth of the tube, a wire extending through the bottom of the hopper into the top of the finger-lever agitates the balls with every movement of the finger. Where a short test is made, how-

ever, a vertical brass-tube two feet in length replaces the hopper and the wire may be dispensed with. This arrangement affords a movement that is practically without friction.

It is to be noted that the structure of the apparatus compels the child to raise his finger to a certain height in order to have the movement counted. Every upward stroke of the lever must be high enough to carry the slide beyond the edge of the standard or the ball will not drop. On the other hand, every downward stroke must bring the lever clear down to the base or the hole in the slide will not lie underneath the hole leading from the hopper. This regulating of the lift insures a movement of the finger throughout a wide amplitude, and brings about a fatigue effect which can not be secured by only a moderately high lift.

This instrument, though not possessing the refinements of the Bergstrom ergograph, nevertheless lent itself very satisfactorily to the present experiment. It is easy to adjust and easy to operate; can be adapted to any size hand by using an aperture in the lever farther from or

nearer to the axis of the lever. Furthermore the element of interest is always present--- an important desideratum in dealing with children. It is made of hard maple and can be manufactured for fifty cents.

Various modifications of method can be employed; the time can be divided into several periods by the use of different receptacles. In the present experiment the record of each test was divided into two parts by the use of two differently colored boxes which were shifted at the end of five minutes, thus securing a measure of the first five minutes' work to be compared with that of the last five minutes.

Method of Scoring.

The method of scoring was as follows:-In division every correct solution was given a value of three. For an error in the first figure of the quotient, two was deducted, and for an error in the second figure, one was deducted. For every example omitted, one and one-half was deducted. Under this system of scoring the highest score attained by any individual during a ten-minute period was 335, the lowest, 10.

In substitution, every square correctly filled counted one; for each substitution omitted, one was deducted. The highest score attained by any individual during a ten-minute period was 144, the lowest, 24.

In the motor test, scores were obtained by weighing the total number of balls dropped by each individual and dividing by the weight of one ball. The highest score made in ten minutes was 1093, the lowest, 123.

Discussion.

The tests were chosen with a view to selecting activities of as varied nature as possible, so that there might be several chances of detecting ventilation effects, and if they were discernible, that they might be observed from several angles. That this end was attained is evident from the comparatively low correlation of the tests with each other. The work of the Adams group in Division correlates with their work in the motor test by .06; Substitution with motor, by .49; Division with Substitution, by .36 (using the method of rank differences). These low correlations show that the functions exercised by the three tests are quite diverse. Division work requires a high type of

selective thinking and good memory for multiplication tables. The motor test measures voluntary ability to move the finger rapidly and continuously. Success in the Substitution test requires quickness of perception and the ability to adjust oneself readily to new conditions. Inasmuch as the arrangement of the numbers in the key was varied every day, the child was obliged, in addition to adjusting himself to the new arrangement, to also work against the habit he had formed the day before. All three tests require close attention, and in the Substitution and motor tests there is opportunity for considerable economizing of effort by the gradual elimination of useless movements.

The value of the tests as constant measures of the work of one child relative to the work of another is indicated by the following table of reliability coefficients, computed by the method of rank differences.

Correlations in Work of Adams Group.		(No.of Cases.)
First and second days' work in Division	.91	25
Fourth " fifth " " " "	.90	
First " second " motor work	.87	19
Third " fourth " " "	.89	
First " second " work in Substitution	.83	28
Fourth " fifth " " " "	.75	

Inasmuch as the Substitution test seemed least reliable of the three, the first day's work in this test was compared with that of the tenth day, and a correlation of .77 was found. These high reliability coefficients indicate that the tests are good tests.

A feature that commends them for use with children is the high interest-value they possess. The children welcomed the test-hour with demonstrations of joy, and maintained, on the whole, a considerable amount of zeal. A few words of encouragement and commendation were given each day, and positive suggestion made that they do even better than they did the previous day. At the conclusion of the first day's work in Division and Substitution in each school, the children were asked to write down which of the two tests they liked better. The preferences were as follows:

	Jackson	Adams
Division	7	6
Substitution	32	32
Absent	2	3

Individual differences in performance were great, but the extremes were similar in each group as shown by the following table:

(Division.)

	First test-week.		Second test-week.	
	Jackson	Adams	Jackson(?)	Adams
Lowest score	10	11	29	26
Average "	98.1	99.9	160.2	125.4
Highest "	215	242	335	309

(Substitution)

Lowest score	35	32	24	24
Average "	65.3	64.3	70.1	73.3
Highest "	119	107	144	129

(Motor.)

Lowest score	164	123	154	194
Average "	423.3	440.4	519.9	549.2
Highest "	708	784	850	1090

From this examination of the tests it appears that they are admirably suited for measurements of work in ventilation effects. Their value in use with groups is evident from the tendency of each child to retain the same rank in the group in successive tests. Their value as group tests is further shown by the similarity with which the two groups worked, as will appear in the results. In addition to the extreme similarity of the averages in all three tests there was a corresponding similarity in extremes. The same test was preferred by an equal number in each group, and the effects of practise and fatigue were almost exactly the

? See p. 21.

same upon both groups.

The tests measure functions that are quite diverse, as the low correlations indicate. This makes them especially valuable in measuring effects whose exact nature is not known. It is further evident that the different tests also check each other as to effects of subjective disturbance. It is to be regretted that the Division results were injured by interference, still the clearness with which this interference is shown, is excellent evidence of the delicacy of the test.

Interpretation of Results.

After eliminating the records of all children who were absent on any of the test-days and who were thus deprived of practise, together with one who was pronouncedly feeble-minded and thus unable to do some of the work, the number of records finally used out of the Jackson group was reduced to 28 each for Division and Substitution. The number of motor records used was further reduced to 17 owing to the fact that some of the children experienced difficulty with their machines while others broke them. Although these were furnished new machines, each child working

steadily, still it seemed advisable to use only the records of children who retained the same machines throughout the tests. The Adams group was reduced in the same manner to 25 for Division, 28 for Substitution and 19 for motor. The total amount of work done each day by the average child is as follows:

Jackson Group(ventilation changed.)

	Mon.	Tues.	Wed.	Th.	Fri.	Total	P.E.
Division(Mar.3-7)	67.3	86.8	105.4	109.6	120.8	490.0	154.0
? " (Mar.24-28)	133.7	163.7	161.5	161.4	180.7	801.0	220.0
Sub. 1st. wk.	54.0	63.7	68.0	65.6	75.2	326.5	54.4
" 2nd. "	69.1	70.0	70.0	71.0	70.8	351.0	64.9
Motor,1st. "	(Omitted)	354.4	420.0	459.3	468.5	1693.2	295.3
" 2nd. "	"	501.0	473.3	530.6	574.6	2079.5	304.5

Adams Group (ventilation unchanged.)

Div.(Mar.10-17)	69.5	86.0	100.6	112.9	130.9	500.0	147.4
" (Mar.31-A.4)	107.3	111.7	129.1	139.4	139.5	627.1	186.4
Sub. 1st. wk.	52.5	61.2	68.8	66.0	73.2	321.7	46.2
" 2nd. "	69.8	74.7	73.9	75.9	72.3	366.6	69.9
Mot. 1st. wk.	(Omitted)	362.1	433.0	470.7	495.8	1761.6	334.3
" 2nd. "	"	518.6	554.0	556.7	567.4	2196.7	98.8

For graphic representation of results see Appendix.

The curves show at a glance extreme similarity in the work of the two groups. In view of the similarity of

? See p. 21.

performance during the first week, it is to be expected that the work of the second week will be equally similar unless some new element is introduced. It is then in the second week's results that one is to look for possible effects of the change made in ventilation.

A. Division.

The work of the Jackson group differs most noticeably from that of the Adams in Division. The total score made by the average child for the first week is 490, and for the second week, 801. This represents a gain of 64%, while the corresponding gain made byhthe average child in the Adams group group is only 25%. This enormous difference aroused the experimenter's suspicions, and upon investigation it was foun found that during the two weeks elapsing between the first and second test-weeks, the teacher had been coaching the children in short division, using as divisors, 6,7,8 and 9. The curve shows the res ults. The Adams group began the second week's work in Division at some distance below the mark of efficiency attained at the end of the first week, showing a loss in efficiency due to practise. The Jackson group, however, began the second week's work far in advance

of the point attained at the end of the first week, showing clearly the effect of the intervening two weeks' practise. The occurrence of this phenomenon, while extremely interesting from a psychological and pedagogical point of view, is most unfortunate for the purpose of this experiment, as it thus becomes impossible to compare the total work done in Division by each group.

Inasmuch as the work of each day was divided into two five-minute periods, it is possible to compare the two group groups with respect to their rate of fatigue. Although practise would tend to increase the amount of work, fatigue would act in the opposite direction, and the combined effect of these two factors may be measured by a "fatigue-index" found as follows:- The total score for the week, made by each child during the second five minutes of the tests, was divided by his total score for the first five minute periods. This was done in the case of twelve children in each group (only that number marking the time periods according to directions.). For the first week, both groups had the same fatigue-index---.8125, m.v., .11 For the second week, the fatigue-index for the Jackson group was .7609, m.v., .08,

and for the Adams, .7591, m.v. .11. The difference is only .0018, and as its probable error is .037, it will be seen that the slight difference is not at all significant. Thus the Division results, though not comparable en gros, nevertheless, as treated above, show no effect of change in ventilation.

B. Substitution.

The second week's record for Substitution shows a difference of 15.6 in the work done by the average child of the two groups. This difference is in favor of the Adams group. It is to be noted that the difference existing between the two groups at the end of the first week is that between 326.5 and 321.7 or 4.8. Assuming that this difference continued in the second week, the net difference becomes 10.8. The probable error of this difference computed by the formula P.E. of Difference $=\sqrt{P.E._1^2 \quad P.E._2^2}$, is 17.7. The chances are even, that a difference of about 3% would occur in fifty minutes, or the chances are two out of three that there will be some difference in favor of the first form of ventilation. Since four days out of the last five tested show against the Jackson group under the second condition of ventilation,

the chance that it had a slight effect is somewhat increased. Subtracting the daily average difference between the two groups of.96,(obtained by dividing 4.8. by 5) the daily record of the last week stands as follows:

	Mon.	Tues.	Wed.	Thu.	Fri.
Adams	69.8	74.7	73.9	75.9	72.3
Jackson	69.1	70.0	70.0	71.0	70.8
Difference	.7	4.70	3.90	4.90	1.50
Subtract		.96	.96	.96	.96
Net difference		3.74	2.94	3.94	.54

As the difference is only two-thirds of its probable error, however, it is not to be regarded as outside the range of a chance error due to the single week's sampling of the conditions.

A further comparison is made possible by computing the gain or loss made by each individual. This is done by subtracting the total score made by each child during the first week, from his total score of the second week, or in case of a loss, vice versa. This shows that out of 28 children in the Adams group, only 3 actually lost, while out of the 28 children in the Jackson group, loss occurred in 8 cases. The average gain made by those who gained is also greater in the case of the Adams group, being 16%,

while that of the Jackson was 13%.* This method of comparison is hardly justifiable, however, as it fails to take into account the fact that the Adams group was slightly superior to the other group at the start and would be expexted to gain faster than the Jackson group.

The fatigue-index for the first week, computed for seventeen children in each group was the same in both groups .896 with a m.v. of .099 in the Jackson average, and of .072 in the Adams average. Second week, Jackson .933 , m.v. .15, Adams .883, m.v. .10. The difference in the fatigue index of the second week is .065. It is possible that this difference may be significant, being a third larger than its probable error which is .037. The fact that this difference, slight as it is, favors the Jackson group, is hard to explain, in view of the fact that the total work done by the Adams group slightly exceeded that done by the Jackson group. It is hardly probable that the difference in fatigue-index is due to change in ventilation, as the fatigue-index was not affected in either of the other tests. The only hypothesis that offers any clue is in connection with the peculiar habit-making and -breaking

* The absolute amounts are as follows:

	No. of pupils who gained.	Amount of gain	Av.	M.V.	No. who lost	Amt.	Av.	M.V.
Adams	25	1319.5	52.8	27.8	3	59.0	19.7	39.3
Jackson	20	868.0	43.4	29.9	8	189.5	23.7	165.8

process involved in this test. It is possible that the Adams group, being naturally a trifle superior to the Jackson group, were able to completely adjust themselves to this feature during the first week, while the other group might still be showing the effects of this adjustment in the second week. The true significance of this difference can be determined only by further experimentation.

C. Motor.

The motor record forthe second week's work of the Jackson group shows a decided drop on the second day. As this drop is entirely out of proportion to the rest of the curve, it is probable that some constant error entered in--- possibly a mistake in weighing the balls which record the finger-movements. Omitting the second day's work from both records, the curves follow each other fairly regularly. The following table gives a comparison of the motor work for the three days of each week--Tuesday, Thursday and Friday:

Numbe r of movements made by average child.

	First week		Second week	
	Av.	M.V.	Av.	M.V.
Adams	1329.	291	1643	505
Jackson	1273	257	1606	230
Dif.	56		37	

The difference in favor of the Adams group at the end of the first week was 56. Assuming that this difference remained constant in the second week, the net difference between the work of the two groups for the second week is 56-37 or 19, in favor of the Jackson group. This difference is less than 2/10 of its probable error, (108) however, therefore it can only be attributed to chance.

The greatest difference occurring in any one day is that on Thursday---26. The probable error of this difference is 42. Since the difference is only 6/10 of the probable error, the chances are only two out of three that there would be any difference.

A comparison of gains distributed among individuals * shows a slight average gain in favor of the Jackson group, the difference being 24.2, but the number of cases is so small and the mean variations are so high that the difference can hardly be regarded as significant. The objection to this method of comparison was discussed in connection with individual gains in Substitution.

The average fatigue-index for the first week, computed for 16 children in each group is 1.016 in each group

* The absolute amounts are as follows:

	No. of pupils who gained	Amount of gain	Av.	M.V.	No. who lost	Amt.	Av.	M.V.
Jackson	14	6239	445.6	214.6	3	577	192.3	153.4
Adams	16	6743	421.4	247.0	3	776	258.7	174.6

with a m.v. of .077 for the Jackson and .12 for the Adams group. For the second week the Jackson fatigue-index is 1.056, m.v. 15, Adams, 1.060, m.v. .13. The difference is only .004 and is only 1/10 its probable error which is .045.

Thus the motor results, compared with respect to average amount, distributed gains and rate of fatigue, show no more than a chance difference between the two groups.

Summary and Conclusions.

The results of this study show that the change in ventilation made at the Jackson school produced no appreciable effect upon the work of the children in the tests with the possible exception of a slight difference in Substitution work which may be explained on other grounds. The work of the children in several forms of psycho-physical activity furnishes the basis for this conclusion: (1) solving problems in short division, a task involving a high type of selective thinking and memory processes,; (2) learning to make substitutions, a task partly mental and partly motor; (3) movement of the index finger, a strictly motor act. In neither the Division nor motor tests is there

indication of any effect of change in ventilation, and the slight difference observable in the second week's Substitution work is not outside the range of chance error. The work was examined with reference to total amount, rate of improvement, and rate of fatigue, and in all these respects except that cited above, the work of the Jackson group showed practically no variation from that of the Adams group where the ventilation was unchanged.

The attempt was made to furnish quite different conditions of ventilation. During the first three weeks air was furnished as fresh as possible, while during the second three weeks the children were breathing the same air over and over again. It is impossible to state the constitution of the air for either of these periods as it wa s not chemically tested. The engineer in charge of the mechanical side of the experiment states, however, that the carbon dioxide at no time reached the amount which has been found capable of producing effects, and the organic matter was probably largely burned up by the ozone which was supplied during the entire experiment.

Special attention was paid in this experiment, to the

distribution of the air. The attempt was made by means of individual air-ducts, to give air the same in kind and amount to all the children. Whether or not the results obtained in this way would be secured with non-distributed air is still a question.

A distinctly economic phase of the investigation relates to the cost of supplying air to the group. Under the conditions of the experiment, each child in the Jackson group was supplied with only 12 cu. ft. of air per minute from the ventilating plant. This includes that carried to the desks and to the black-board. This is less than half the amount considered necessary for school-rooms. An additional economy consists in the fact that the air did not require heating the second week, as it was taken direct from the warm room and recirculated. In asmuch as the children's work did not show posttively certain effects of this condition, it appears that considerable saving in operating expense is possible in school-room ventilation.

Conclusions can be drawn from the records of the Jackson group, which, while not pertinent to the present in-

quiry, are nevertheless interesting from a psychological and pedagogical point of view. The gain of the coached group for the second week's tests stands to that of the non-coached group as 64% to 25%. This gives an interesting side-light upon the work reported by Phillips (3) who found that a group of children who received ten minutes drill per day for two months, increased in ability to multiply three times as much as an undrilled group. The increase in ability to divide, shown by the present drilled group, is about 2 1/4 times as great as that shown by the undrilled group. As nearly as could be determined, drill was given about half an hour each school-day for two weeks previous to the second week's test.

The results of this study emphasize the fact that t there is wide scope for experimentation in the field of ventilation. With longer tests on a greater number of individuals and with analyses of air it would be possible to state conclusions more positively. The study of ventilation involves a large number of factors such as chemical constitution of the air, temperature, humidity, volume and distribution. Confronting the investigator are such

questions as these:- What is the effect of organic matter in air, and in what quantities can it be present without producing farmful effects? Is air used over and over again made good as new by ozone or other treatment? How much air is required per minute by each individual? Are the ill effects of old air due to stagnancy? To what physiological fact can we refer feelings of depression and fatigue accompanying some kinds of ventilation? These and many other questions are of prime importance in establishing a science of ventilation. Their satisfactory answer will require long and painstaking experimentation upon a large number of subjects. A great variety of activities must be studied under controlled conditions, and close attention must be given to physiological details such as red-blood counts, haemo-globin estimations etc. Feelings of depression, fatigue, etc. must be studied by psychological methods. Careful records must be kept of chemical analysis, temperature, humidity, volume, distribution, etc. The whole problem is one that requires the most thorough and intelligent cooperation on the part of engineers, physiologists and psychologists.

The present application of psychological tests to the solution of the ventilation problem is mainly important in demonstrating that methods are available for determining the effects of ventilation upon different sorts of mental and physical work performed by groups of schoolchildren simultaneously. Judged by the criteria usually applied to work-tests, those used in this experiment have been found remarkably satisfactory. The stability of the averages, the high reliability coefficients for repeated trials of the same tests, and the evidence that three differenc types of activity were reached, all speak for the value of the methods adopted.

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4. Winch, W.H. "Mental Fatigue in Day-school Children." Brit. J. of Psychol. 1911. 4. 315-341.

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APPENDIX.

(Sample of Division test.)

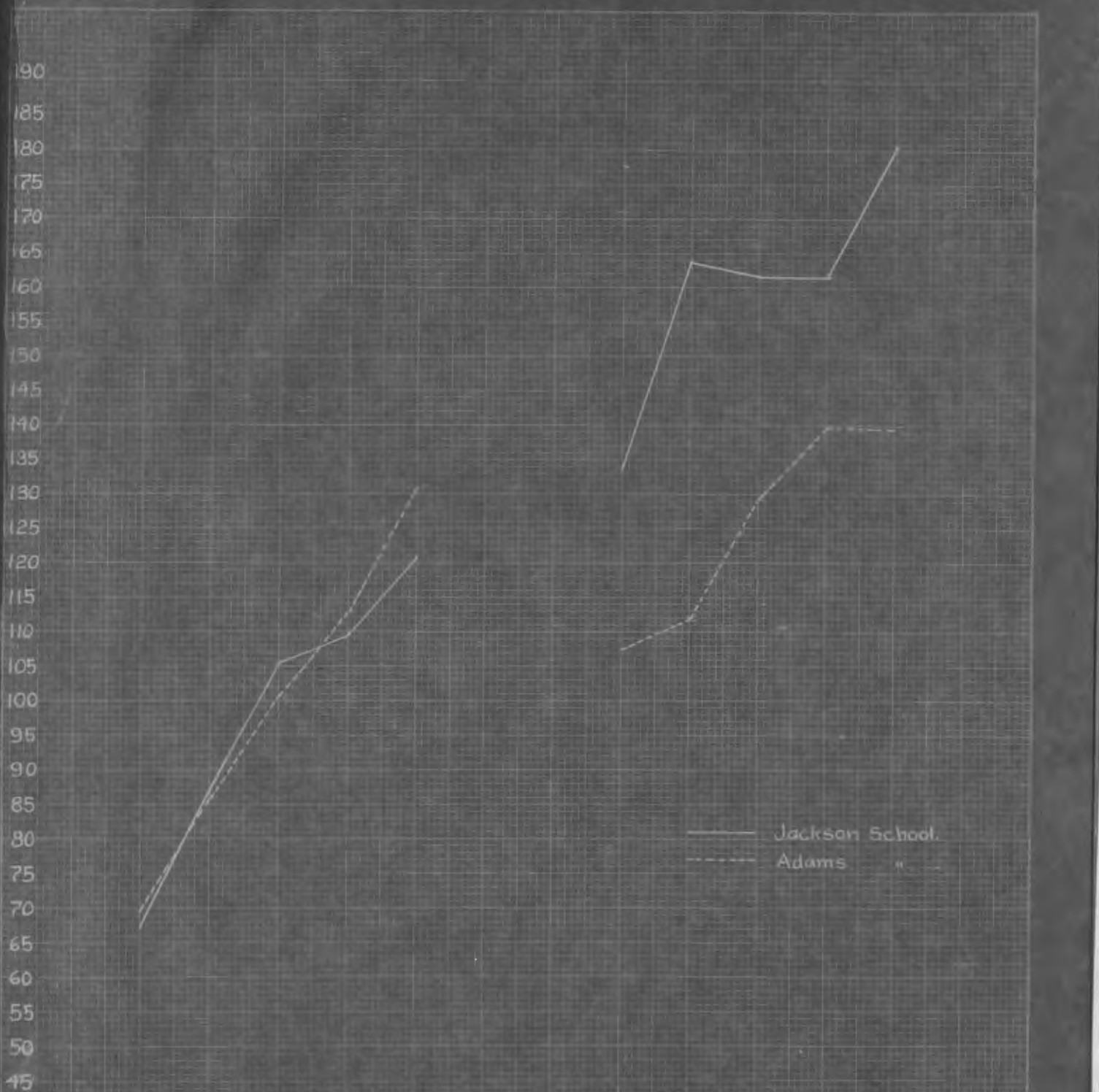
6)210	7)441	8)456	9)351	6)486	7)518	8)568
7)357	8)648	9)162	6)534	7)483	8)416	9)414
8)184	9)864	6)306	7)609	8)680	9)198	6)294
9)108	6)474	7)497	8)536	9)432	6)582	7)413
6)102	7)301	8)200	9)657	6)258	7)469	8)592
7)147	8)584	9)117	6)558	7)294	8)192	9)342
8)264	9)846	6)318	7)273	8)664	9)405	6)426
9)774	6)588	7)168	8)776	9)387	6)336	7)588
6)204	7)259	8)688	9)324	6)228	7)112	8)360
7)336	8)600	9)468	6)366	7)476	8)656	9)837
8)376	9)243	6)576	7)252	8)128	9)639	6)234
9)261	6)492	7)126	8)784	9)279	6)222	7)616
6)312	7)329	8)144	9)828	6)174	7)672	8)520
7)665	8)312	9)666	6)330	7)287	8)448	9)216
8)440	9)567	6)378	7)623	8)696	9)369	6)444
9)495	6)372	7)532	8)744	9)486	6)276	7)602
6)156	7)399	8)392	9)513	6)168	7)266	8)208
7)434	8)216	9)315	6)348	7)322	8)624	9)882
8)232	9)855	6)126	7)427	8)424	9)252	6)114
9)873	6)390	7)693	8)336	9)477	6)402	7)448

(Sample of Substitution test)

A	B	C	D	E	F	G	H	I	J	K	L	M	N
17	34	23	16	32	35	21	30	19	20	29	13	24	31

O	P	Q	R	S	T	U	V	W	X	Y	Z
11	25	12	26	33	15	28	36	18	27	22	14

28	19	17	24	31	18	16	30	21	14
29	12	25	33	35	15	22	26	20	27
34	11	23	13	36	32	20	11	28	30
16	22	12	19	23	18	17	29	34	32
15	31	13	26	25	27	24	14	21	36
35	33	20	32	30	19	26	23	33	18
16	14	12	21	17	25	31	11	22	34
35	29	15	36	24	28	27	13	30	33
15	13	27	36	11	12	34	14	17	32
22	35	18	16	19	25	29	20	24	28
31	26	23	21	28	34	18	30	20	29
36	21	14	16	23	22	11	31	24	33
25	17	27	32	12	13	15	35	19	26
23	25	32	14	34	31	36	24	13	11
22	27	21	17	33	35	30	20	28	15
29	19	16	12	26	18	28	19	17	24
31	18	16	30	21	14	29	12	25	33

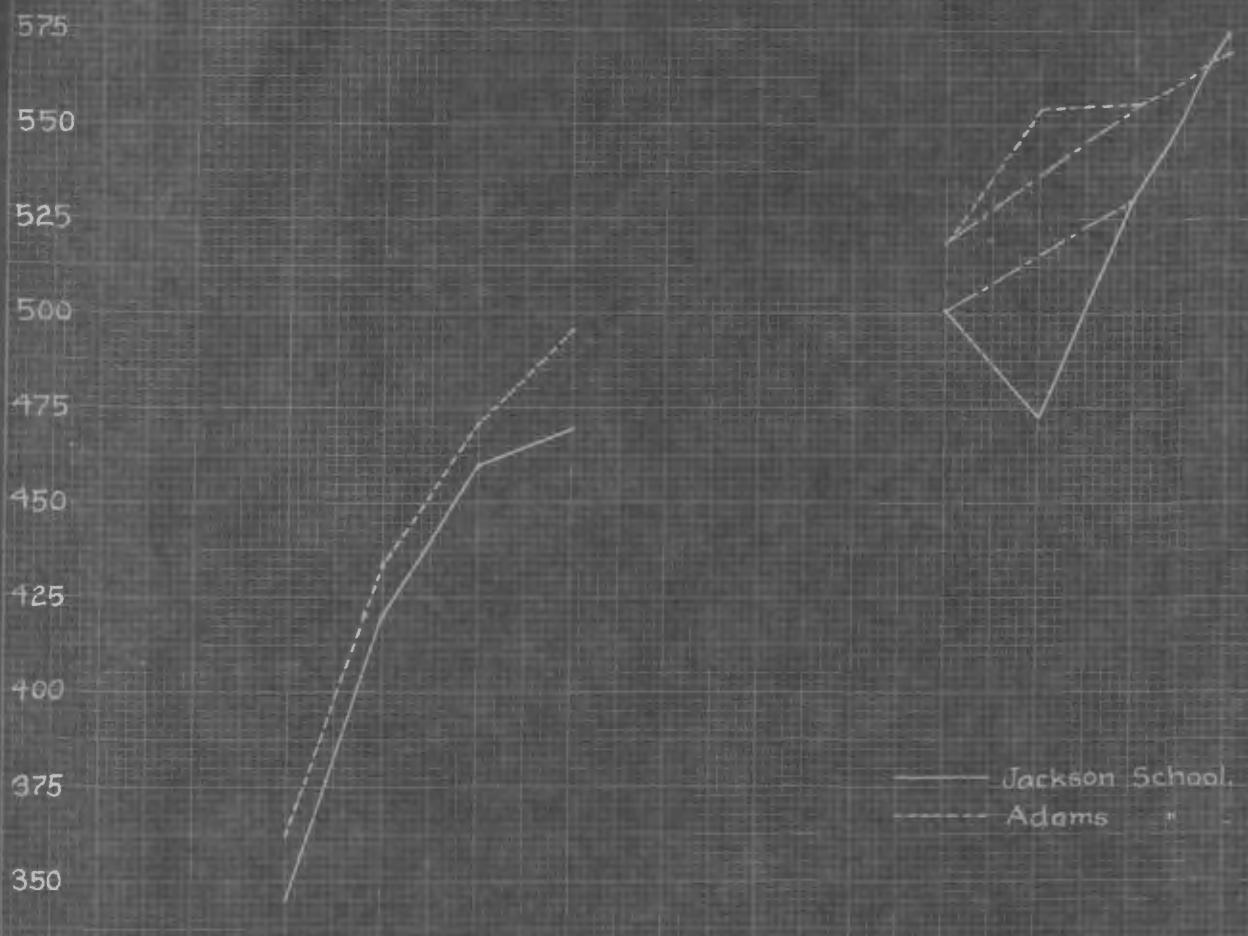


DIVISION TEST

PLATE 1.

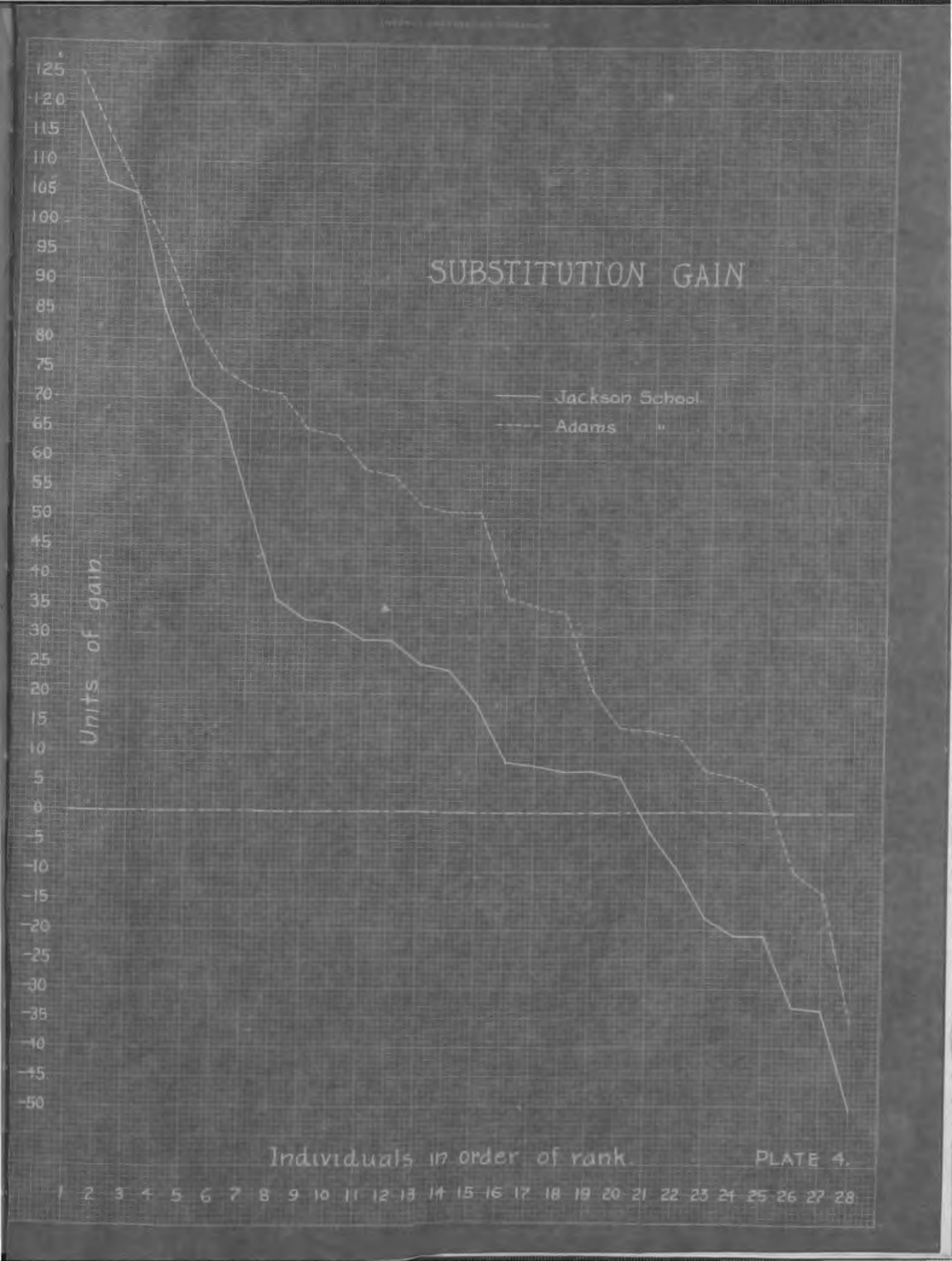
SUBSTITUTION TEST.

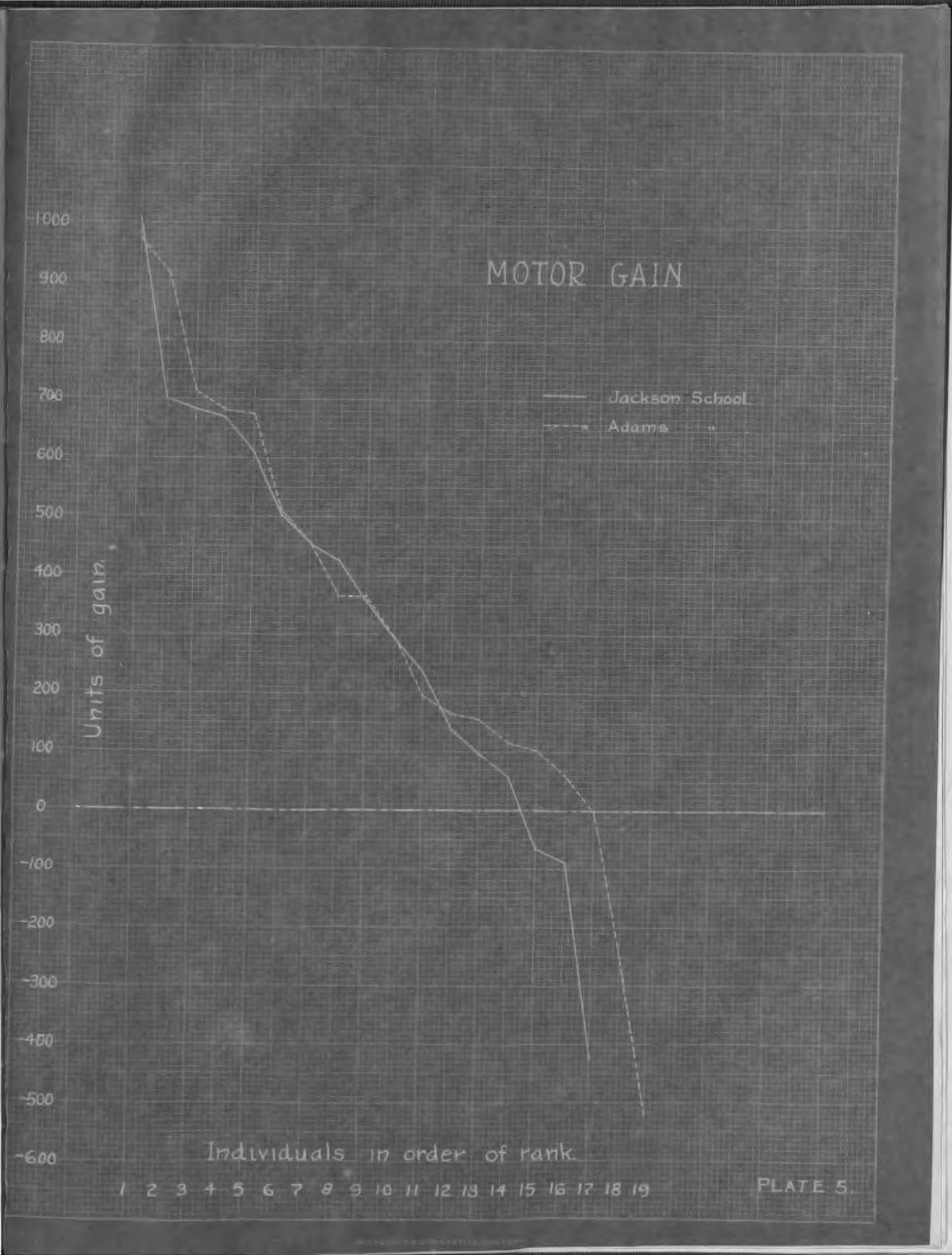
PLATE 2.



MOTOR TEST.

PLATE 3.


SUBSTITUTION GAIN
Jackson School.
Adams "
Units of gain
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Individuals in order of rank.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
PLATE 4.


MOTOR GAIN
Jackson School.
Adams "
Units of gain.
1000
900
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
Individuals in order of rank.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
PLATE 5.

Finis.