MENTAL FATIGUE IN DAY SCHOOL CHILDREN AS MEASURED BY IMMEDIATE MEMORY. PART I.

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SUMMARY.

The chief defect in the measurement of mental fatigue in children by tests of immediate memory has been the irregularity and variation in intellectual work in the early part of a series of new exercises. In the present investigation practice was continued until the pupils' performance became "steady," before the fatigue tests were begun. Tests with a class of forty-five boys, averaging thirteen years of age, showed a relative inefficiency in the work of the late afternoon as compared with that of the early morning. The reduction in efficiency amounted to five or six per cent.

The Problem Stated.

Most of us who are adults are fairly certain, in so far as we can be from introspective evidence, that when we are weary our memories are apt to play us false. We feel, too, when we are tired, that we need to make more effort to remember, and we reproduce what we know more hesitatingly as well as more ineffectively. Especially do we find a difficulty in remembering non-connotative and unrelated names; and our language would probably be more vigorous than rational if, whilst feeling fatigued, we were asked to learn by rote, for purely experimental purposes, a number of meaningless symbols. I need not labor these points; they are probably within the personal experience of every one of us. These considerations induced me to make one more attempt to measure fatigue in children by means of tests in memory; but with no great hope of success, for when we turn to the work of those who have experimented much with children, we find a practical unanimity of opinion that immediate memory tests will not give satisfactory

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indices of fatigue.* Why should tests which appear *prima facie* to adults as specially likely to give indications even of small degrees of fatigue fail so hopelessly to indicate fatigue in children? One factor is doubtless the comparative immunity of the child to mental fatigue of a mechanical kind, but probably the most potent factors in the failure of these tests are the irregularities and variations to which intellectual work of this mechanical kind is subject, especially in the first few of a continued series of new exercises. If we could postpone the fatigue tests until the work of the children had become "steady" for that particular sort of exercise, more satisfactory results, I thought, might possibly be obtained. By "steady" I mean that the children in the group do not change places much from test to test. Expressed mathematically "steady" means that there are high positive correlations between the successive tests of the series. I do not mean that each child ceases to improve and henceforward oscillates about a mean which may be regarded definitely as normal work for the particular child. For improvement by practice is the rule and to stand still or retrogress is exceptional. And the practice effects are mingled with the fatigue effects. Thus an immediate memory test on, say, Tuesday morning, may give a lower result than a second one on the following Tuesday afternoon. Are we to conclude that Tuesday afternoon is a better time for memorizing than Tuesday morning? Not unless we find the afternoon results superior *after eliminating the practice effect,* that is the improvement by practice resulting from the work of the previous exercise. I have endeavored to do this by working with two groups, initially equal, and equally practiced. When the work in immediate memory has become steady, I have divided the children who were working the exercises into two equal groups. Then one of the groups has worked further tests in the mornings only, whilst the other group has worked the same tests late in the afternoons. A comparison between the morning results and the afternoon results may indicate the comparative freshness or fatigue of the two groups in the mornings and afternoons respectively.

*"On this point we have the unanimous verdict of Bolton, Ebbinghaus, Schuyten and Smedley." Whipple's *Manual of Mental and Physical Tests,* p. 385.

II. A First Experiment in a Boys' School.

The work was done with the whole of a Standard VI class, numbering 45, of an average age of 13 years, 0 months, on July 31, 1910, in a municipal boys' school situated in a rather poor neighborhood in London. The teacher of the class was a young man of much capacity, enthusiasm and energy; the school, as a whole, was strongly disciplined and the children worked hard.

In such a class it is probable that the boys, except in the intervals for recreation, give their attention to their school work for practically the whole of the school day. In cases like this is should not be hard to find some considerable differences between the best morning work and the worst afternoon work. It is true that the tests of immediate memory in which I am going to make such a comparison are of a mechanical nature, but it must not be forgotten that they are always of new material: the process can be mechanized, but the acquisition required is always a new matter.

i. *Tests and Method of Marking.*

The tests were for memory of visual percepts. Twelve consonants, arranged in the following way:

t	v	d	m
y	f	x	r
b	s	n	c

were exposed to view for 25 seconds, after which the boys wrote down as much as they could remember; 1 minute 35 seconds being allowed for writing and rest. At the end of 2 minutes a second test was given; then, similarly, a third, and so on. Ten tests were given on each occasion, so that the whole exercise lasted just 20 minutes. The boys were required to study the tests visually, audible articulation not being permitted. They were told to let their attention pass from left to right commencing with the top line, and then to the second and third lines, passing through the whole test before beginning a second repetition of any part of it. Three marks were given for each consonant correctly remembered and rightly placed; two, if it were "one place" before or behind its proper position; and

one, if it were "two places" out. It was found helpful to instruct the children to leave a space in the place of any consonant which they *knew they had forgotten.*

ii. *Chronology of the Series.*

Eight sets of preliminary tests were given to afford a basis for the division of the class into two equal groups.

On Wednesday, March 16, 1910, at 9.45 A. M., the first set of tests was given, following immediately upon a Scripture lesson. All the morning tests were given on Wednesdays at the same time, and likewise following immediately after Scripture lessons.

On Friday, March 18, at 4 P. M., a second set of tests was given, following immediately upon a grammar lesson in which the boys are required in this school to do some rather hard thinking. All the Friday tests were begun at 4 P. M. The school periods on Friday afternoons preceding the grammar lesson were occupied with spelling, physical drill, history, recreation.

On Wednesday morning, March 23, a third set of tests was given. The Easter holidays then intervened, but the work was resumed afterwards.

On Friday, April 8; Wednesday, April 13; Friday, April 15; Wednesday, April 20, and Friday, April 22, a fourth, fifth, sixth, seventh and eighth set of tests were given respectively.

On the results of the fifth, sixth, seventh and eighth tests the class was divided into two equal groups.

Henceforward, one of the two groups—Group A—worked memory tests in the morning only, and the other—Group B—worked in the afternoon only. The morning group worked them on Wednesday mornings from 9.45 to 10.05, immediately after a Scripture lesson; the afternoon group on Wednesday afternoons from 4 to 4.20 P. M. The preceding afternoon lessons were spelling and physical drill, recreation and algebra.

It was evident after the first fatigue test that the morning group did better work with the same test than the afternoon group; but it was thought well to continue the tests on succeeding Wednesdays to see if the same relationship was maintained

subsequently. Three fatigue tests were therefore given on April 27, May 4 and May 11, rspectively, to Group A in the mornings and to Group B in the afternoons.

iii. *Results.*

It is not intended to lay any stress on the results of the first, second, third and fourth preliminary tests, nor were the "coefficients of reliability" between them calculated in a rigorous way. It was obvious from an inspection of the figures that the children had not yet taken up a very steady position relative to one another; they had not quite settled down to what, in matters of sport, we should call their "true form." But the fifth preliminary test was correlated with the sixth. Working from the individual cases by the Pearson product-moment formula $r = \frac{\Sigma xy}{n\sigma_1\sigma_2}$, "r" was found to be + .901, with a "probable error" of .02.

The results of the sixth were correlated with those of the seventh, and "r" was found to be + .874, and the correlation between the results of the seventh and eighth was found to be + .884, with "probable errors" also approximating to .02.

I had now great hopes, if I divided the class into two equal groups on the results of these four sets of tests which correlated so highly, that I should obtain two groups which would be obviously sensitive to variations in the conditions as to freshness and fatigue with which the work was done. Two boys had 'left school' during the tests and one boy was omitted because he could not be paired.

The actual results of tests 5, 6, 7 and 8 were as follows:

Test	5.	Average	mark	237.6.	M. V.	30.7.
"	6.	"	"	234.6.	"	30.3.
"	7.	"	"	239.7.	"	30.7.
"	8.	"	"	251.5.	"	34.4.

Tests 5 and 7, will be remembered, were Wednesday morning tests, and tests 6 and 8 were Friday afternoon tests.

Two equal groups were then formed on the results of these four tests cited above; 21 boys were placed in each group and the groups were subdivided into sections, thus.

TABLE I, *Showing the Division Into Two Equal Groups.*

Av. marks per test in preliminary tests.	Group A. No. of boys.	Group A. Av. mark per boy per test in four prelim'y tests.	Group A. M. V.	Group B. No. of boys.	Group B. Av. mark per boy per test in four prelim'y tests.	Group B. M. V.
Over 280	4	300.2	11.9	4	298.7	15.7
240 to 280	5	256.7	10.1	5	259.1	9.5
200 to 240	9	222.5	9.8	9	222.4	9.4
160 to 200	3	189.9	8.0	3	188.8	8.4

Taking Group A and Group B as wholes, the former had an average mark in these four preliminary tests of 240.9 (mean variation 30.2), and the latter average mark of 240.9 (mean variation 30.6).

It now remains to present the results of the work of these two groups when Group A continued the tests in the mornings only and Group B continued them in the afternoons only.

I present at first the results in gross.

TABLE II, *Showing the Comparative Results of Groups A and B in the Morning and Afternoon Work, Respectively.*

Date.	Group A—(Morning). Total marks.	Group A—(Morning). Av. mark per boy.	Group A—(Morning). M. V.	Group B—(Afternoon). Total marks.	Group B—(Afternoon). Av. mark per boy.	Group B—(Afternoon). M. V.
27/4/'10.....	5375	256.0	40.1	5172	246.3	36.9
4/5/'10.....	5631	268.1	33.3	5283	251.6	40.4
11/5/'10.....	5812	276.8	32.5	5548	264.2	37.1

In the first week the morning group improved on its record in the preliminary tests to the extent of 6.26 per cent., calculated as a percentage on the average of the four preliminary tests; in the second week 11.3 per cent., and in the third week 14.9 per cent.; whilst the afternoon group improved on its preliminary record in the first week 2.2 per cent., in the second week 4.4 per cent., and in the third week 9.6 per cent. It seems clear that, though improvement by practice is still obvious in both groups, Group A is improving faster than Group B. The difference is taken as a measure of the difference in mental energy for this sort of work at 9.45 in the morning and 4 in the afternoon of a mid-week day, after the lessons specified in the chronological account of the experiment. On the assumption that both groups would have shown approximately equal practice effects had they continued the work under equal conditions, the decreased improvement in the results of the afternoon work as compard with the morning work is regarded as a measure

of fatigue. But it remains to be shown whether this relationship holds for the corresponding sections into which the groups are divided.

TABLE III, *Showing the Comparative Results of Groups A and B, Section by Section.*

Av. mark in preliminary tests.	Group A. No. of boys.	Av. per boy—Fatigue tests. 1st.	2d.	3d.	Group B. No. of boys.	Av. per boy—Fatigue tests. 1st.	2d.	3d.
Over 280	4	319.5	323.5	325.2	4	329.2	335.0	344.0
" 240	5	284.8	283.4	294.2	5	247.2	259.0	272.4
" 200	9	230.1	249.3	259.5	9	225.8	221.8	235.9
" 160	3	200.7	225.3	234.7	3	195.7	217.3	229.0

Improvement is obviously the rule, as the averages of the whole group seemed to show. But the division of the groups into sections indicates that the afternoon workers in every section but the best do worse work in the afternoon than the corresponding sections in the morning. The general falling off of the afternoon workers is, of course, a result which might have been expected; but I was not prepared to find that *any* section of school boys of this age and mental level would do *better* work in the afternon than another corresponding section would do in the morning. This result is not due to some astonishing and quite abnormal work on the part of one individual, for every boy in this section of the afternoon group has beaten the corresponding boy in the corresponding section of the morning group. May it be that the chilren strongly endowed in the natural function tested show rather the stimulating effect of the day's school work than its fatiguing effect? I append the figures:

TABLE IV, *Showing the Individual Work of the Top Four Boys in Groups A and B Compared.*

First Section—Group A. Name. (Initials only.)	Av. mark four prelim'y tests.	Av. mark three final tests.	First Section—Group B. Name. (Initials only.)	Av. mark four prelim'y tests.	Av. mark three final tests.
E. L.	320	333	C. M.	326	347
H. W.	304	320	A. S.	302	344
L. A.	296	311	W. B.	284	319
C. A.	281	326	H. B.	282	334

After those of the top sections, however, the results for the afternoon work as compared with the morning work tend steadily downwards, and in no other *section* does the work of the afternoon group excel that of the corresponding *section*

which works in the morning. But there are individual pupils lower down in Group B who reach higher results in the afternoon work than corresponding pupils in Group A—the morning group—so that the suggestion made above to account for the superiority of the upper section of the afternoon workers at once appears doubtful. I propose, finally, to show the comparative improvements of the individual pupils in Group A and Group B in the morning and afternoon work respectively. The improvements are calculated on the average of the four preliminary tests on which the class was divided. The averages and percentages are calculated to the nearest unit only.

TABLE V. *Showing the Comparative Improvement of the Pupils in Groups A and B in the Morning and Afternoon Work, Respectively.*

Group A.				Group B.			
Name. (Initials only.)	Av. of four prelim'y tests.	Av. of three final tests.	Percentage of improvement.	Name. (Initials only.)	Av. of four prelim'y tests.	Av. of three final tests.	Percentage of improvement.
L. F.....	321	333	+ 4	N. C.....	327	347	+ 6
W. H.....	304	320	+ 5	S. A.....	302	344	+ 14
A. L.....	296	311	+ 5	B. W.....	284	319	+ 12
A. C.....	281	326	+ 16	B. H.....	282	334	+ 18
S. J.....	274	333	+ 22	W. W.....	278	283	+ 2
B. W.....	265	297	+ 12	M. R.....	262	264	+ 1
M. V.....	257	286	+ 11	A. W.....	261	259	— 1
D. S.....	245	234	— 4	C. W.....	249	235	— 6
A. H.....	243	287	+ 18	L. W.....	245	257	+ 5
W. V.....	238	264	+ 11	M. C.....	237	256	+ 8
I. W.....	233	244	+ 5	K. H.....	234	251	+ 7
D. C.....	231	271	+ 17	W. W.....	229	221	— 3
H. F.....	229	255	+ 11	F. T.....	229	246	+ 7
A. H.....	227	238	+ 5	K. G.....	225	253	+ 12
B. W.....	220	232	+ 5	P. G.....	223	237	+ 6
S. C.....	219	244	+ 11	O. G.....	217	213	— 2
A. F.....	205	238	+ 16	C. G.....	207	184	— 11
F. W.....	202	231	+ 14	C. J.....	202	189	— 6
W. H.....	196	222	+ 13	K. F.....	197	223	+ 13
H. H.....	196	219	+ 12	P. T.....	194	199	+ 3
J. A.....	178	219	+ 23	B. A.....	176	219	+ 24
	5060	5304			5060	5333	
Averages.	240.9	266.7		Averages.	240.9	253.0	
M. V.....	30.2	34.5		M. V.....	30.6	35.9	

On inspection of the above table we find in the morning group 1 case only in which a positive improvement is not shown; in the afternoon group there are 6 cases. In the morning group there are 2 cases showing an improvement of 20 per cent. and over as compared with 1 case in the afternoon group;

there are four cases which show an improvement of 15 to 20 per cent. as against 1 case in the afternoon work; there are 8 cases between 10 and 15 per cent. as against 4 cases in the afternoon group; there are 5 cases which show an improvement between 5 and 10 per cent., as compared with 6 in the afternoon group; and there is 1 case between 0 and 5 per cent., as compared with 3 in Group B. These results are more clearly exhibited in the following table:

TABLE VI, *Showing the Comparative Percentages of Improvement Between the Members of Group A and Those of Group B.*

	Number of Cases.	
	Group A. Morning Group.	Group B. Afternoon Group.
Gain of 20% and over	2	1
Gain of 15% to 20%	4	1
Gain of 10% to 15%	8	4
Gain of 5% to 10%	5	6
Gain of 0% to 5%	1	3
Loss of 0% to 5%	1	3
Loss of 5% to 10%	0	2
Loss of 10% and over	0	1

The correlation of the results of the four preliminary tests between the corresponding cases of the two groups, A and B, worked out by means of rank formulæ, is, of course, positive 1. In the work of the final tests the A group series correlates with the B group series to the extent of + .87. This estimation was made by means of the Pearson rank formula

$$\rho = 1 - \frac{\Sigma d^2}{n(n^2-1)}$$

If we are entitled to suppose that Group B, if it had worked in the mornings, would have made as much improvement as Group A we can regard the extent to which it failed to do so as a fatigue effect. The "morning group" improves 10.7 per cent. from the preliminary to the final tests; whilst the "afternoon group" improves 5.0 per cent. from the preliminary to the final tests. For a class of boys of this age and mental level therefore, the fatigue effect thus calculated appears to be between 5 and 6 per cent. These results are not exposed to the dangers arising from the effects of novelty. Every boy whose work is here shown has worked no less than 110 memory tests

in 11 sets, spread over a period of some 8 weeks. A more serious difficulty—one which specially attacks long series—is that of boredom. I am not quite sure whether boredom may not be very closely related to fatigue for a particular function, especially if it be one in which we were formerly interested and in which we showed improvement. But assuming for the present that it is not, namely, that we *can* work without "objective fatigue," though the work bores us, will the assumption of boredom affect the conclusion drawn as to fatigue? I think not; unless we believe that the morning groups and afternoon groups are likely to be affected by this factor to a different extent.

III. Summarized Conclusions.

1. The use of immediate memory tests shows, in a normal group of school children constituting the whole of a class or grade, a certain amount of relative inefficiency in the late afternoon as compared with early morning work. This relative inefficiency is taken as a measure of fatigue. For children at this age and mental status it does not appear to be great for work of this kind, and is probably about 5 or 6 per cent.

2. One of the pupils in the morning group and six of the pupils in the afternoon group cease to improve, begin to oscillate in their work, and tend on the whole downwards. If this is not due to boredom (I have argued previously that it is not likely to be) it is an indication that these pupils are being generally overworked, or have reached their saturation point for the function in question. With about one-third of Group B the work done late in the afternoon has been futile.

. As a pedagogical conclusion, we might accept the following dictum: Wherever, under first-rate teachers and with earnest work on the part of the children, a series of exercises begins to produce a steady decline in improvement, it is an indication to us of the advisability of lightening the general work or of a cessation of those exercises, at least temporarily, until the children's reparative activities have had time to produce their proper effect. If this dictum be accepted it could be applied to discover the best age and time for starting new sub-

jects and parts of subjects in the school curriculum. For example, when should a child begin problematic arithmetic? I suggest when, with earnest work and first-rate teaching, improvement is shown generally from exercise to exercise, and not otherwise. Such a criterion would also serve to regulate the adjustment of the intervals between the successive lessons.

(Part II will appear in the February number.)