AN EXPERIMENTAL STUDY OF THE NATURE OF IMPROVEMENT RESULTING FROM PRACTICE IN A MENTAL FUNCTION[1]

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In another article[2] the writers discussed the need of determining more exactly the nature of improvement which results from practice and presented the results of a study in which a motor function—speed of tapping—was utilized. The present study, conducted along lines similar in most respects, utilizes a mental function and thus approaches more closely the problem of the nature of changes in human nature brought about by education in the more typically intellectual functions.

Concerning the character and limits of improvement which continued training may produce, there have been, traditionally, two main theories to which must now be added a third.

1. THEORY OF ACQUIRED SPECIFIC TECHNIQUES AND KNOWLEDGE

According to this theory, education or training produces improvement which is due to the development of particular skills and information, methods of work and knowledge used in working, subtle adaptations to the working conditions, "the tricks of the trade"—all these without any changes in the fundamental "capacities" engaged in the function. Thus in studying arithmetic, improvement is said to be due to knowledge of numbers and operations, speed and accuracy in handling these particular data, improved methods of writing and taking tests without any increase in ease of learning, in retentiveness or in memory or reasoning, or in any of the neural and other machinery involved in the tasks. The investigators who conceive "intelligence" to be a capacity or group of capacities which cannot be appreciably changed by education and experience usually subscribe to this view in some form.

2. THEORY OF IMPROVABLE CAPACITIES OR MECHANISMS

A second type of view affirms that practice may result not only in the acquisition of specific information and skill but also in the improve-

[1] From the Research Department of the Horace Mann School.

[2] An Experimental Study of the Nature of Improvement Resulting from Practice in a Motor Function. *Journal Experimental Psychology* (forthcoming).

ment of the neural and other machinery or in the "capacities" involved. The older faculty theory, which assumed that memory, perception, retentiveness, etc. were improved, in general, by practice in some particular type of training which involved the general power, has been modified, usually, in the face of the facts yielded by studies of the transfer of training, but newer views, differing only in degree, are still defended and defensible. To illustrate, it is possible to maintain that the training of a function brings about an improvement in the neurones or other mechanisms involved and that these, fundamentally improved, may operate in other functions which bring them into action. The observed transfer of training, in other words, may be due not wholly to the rôle of identical information, methods of work, techniques, etc. but partly, or mainly, to the influence of identical narrow capacities or bits of machinery which operate in various combinations in different gross functions. Views of this sort appear to be held by certain writers who are opposed to the notion that learning capacity, general intelligence and the like cannot be effectively improved.

3. Theory of Stimulated Growth

Recent work on the nature of growth and the factors which influence it suggest another view. Since such capacities as retentiveness, speed of motor response, intelligence, etc. are believed to grow gradually from birth to maturity, given a normal environment, *it is conceivable that continued, intensive practice preceding maturity might stimulate and increase the rate of growth of the capacities exercised.* Vigorous and persistent training might, by means of nutritive after-effects, by increasing the production or changing the distribution of "hormones" or in other ways now unknown, accelerate the process of growth and carry it on to higher levels before maturation. If such were the facts, the importance of early training and the biological significance of the period of infancy would receive new emphasis.

The Plan of the Experiment

The present experiment was designed to test, in some measure, the nature of improvement in a mental function. For this purpose it seemed advisable to use as subjects persons in whom growth was by no means completed and in whom growth was going on, presumably, with great rapidity and a mental function which had been little prac-

ticed and in which, presumably, the acquisition of technique would be of rather small amount. After some preliminary study, we selected as subjects a group of children, ages 4 to 5.8 years from the kindergarten of the Horace Mann School and as a function, memory for series of digits presented orally. Since this function constitutes one of the recurring tests in the Stanford-Binet Scale, the results should throw some light upon the nature of the functions which are accepted as criteria of intelligence.

The experimental procedure called for two groups of subjects equivalent in abilities related to memory for digits, one of which was to be trained intensively and the other tested only at the beginning and end of the practice period. From a larger group of children, two groups were made up by matching each child in one group with a child in the other as nearly as possible the same in each of the following traits:

1. Sex.
2. Age.
3. Mental age on the Stanford-Binet test.
4. Intelligence quotient.
5. Scholastic maturity as judged by teachers.
6. Memory for digits, presented orally,
7. Memory for letters, series presented orally.
8. Memory for series of unrelated words, presented orally
9. Memory for series of related words, presented orally.
10. Memory for a series of 10 geometrical figures, each presented visually for 5 seconds. After all were presented, test of the recognition type—originals mixed with new designs—was given. Tests were given to pupils individually.
11. Memory for seven pictures—boy, hat, cap, etc presented visually on a card strip for 15 seconds. Test by recognition method. All tests given individually.
12. Memory for picture "names." A series of 10 drawings of common objects with its common name under it in type. Task is to learn the "'name" of each picture. Each card presented 5 seconds: test by selecting words studied from a group including the old and new ones. Individual tests.

Two groups of 16 pupils, approximately matched in these traits and abilities, completed the experiment. The averages of these groups in the measurable traits are shown in Table I. It may be seen in the table that, in the averages, the two groups are substantially equivalent

at the beginning of the experiment, in the important traits taken into consideration.

TABLE I.—SHOWING AVERAGE SCORES OF PRACTICE AND CONTROL GROUPS IN THE INITIAL TEST

Traits	Age[1] Oct. 1	MA[1] Oct. 1	IQ	Memory digits	Memory letters	Memory unrelated words	Memory related words	Geometrical figures	Pictures	Picture names
Practice group.....	5.1	6.31	122	4.33	3.64	3.86	14.0	4.3	5.3	7.5
Control groups....	5.1	6.35	123	4.33	3.71	4.07	13.7	4.0	5.7	7.0

[1] Age and mental age as of Oct. 1, two months before the study was begun.

THE RESULTS OF SPECIFIC PRACTICE IN MEMORY FOR DIGITS

Beginning shortly after the completion of the initial tests, the pupils in one group were given, individually, on each available school day,

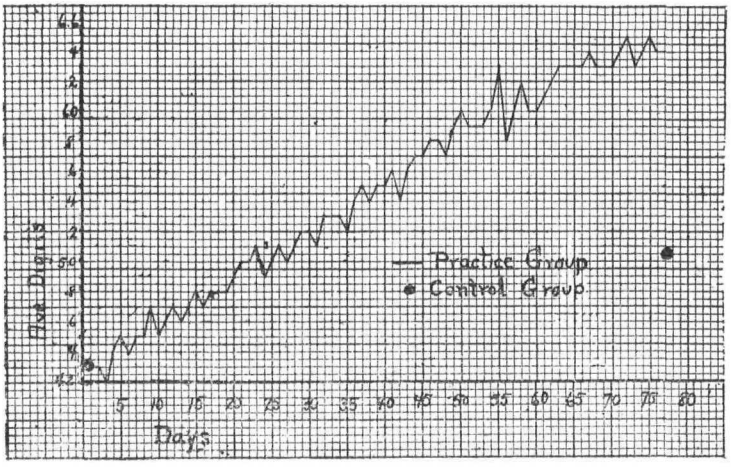

FIG. 1.

practice in immediate memory for digits. A large number of series of digits, arranged by chance, were prepared and presented according to the method prescribed in the Stanford-Binet scale. Each day, the pupil began with a series shorter than the largest one on which he

had succeeded in two out of three trials on the preceding day. Each child, then, on each day was tested on three series of each length from a short series to a series on which he failed in two out of three attempts. The results, presented in Table II and shown graphically in Fig. I, are based on the number of digits in the largest series in which the subject was successful in two out of three attempts. In the group of 16 from which the averages were computed, all attended fairly regularly. In the case of absences, the pupil was given the score earned on the preceding test. The training was continued until May 20, the end of the school year, 78 days of practice.

TABLE II.—SHOWING THE AVERAGE LENGTH OF DIGIT-SERIES RECALLED IN TWO OUT OF THREE TRIALS FOR THE PRACTICE GROUP OF 16 SUBJECTS 78 DAYS OF PRACTICE

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Average digits	4.3	4.3	4.2	4.4	4.5	4.4	4.5	4.5	4.7	4.5	4.6	4.7	4.6	4.7	4.8	4.7	4.8	4.8	4.8	4.9
Day	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Average digits	5.0	5.0	5.1	4.9	5.0	5.1	5.0	5.1	5.2	5.2	5.1	5.3	5.3	5.3	5.2	5.4	5.5	5.4	5.5	5.5
Day	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Average digits	5.6	5.4	5.6	5.7	5.7	5.8	5.8	5.7	5.9	6.0	5.9	5.9	5.9	6.0	6.3	5.8	6.0	6.2	6.0	6.0
Day		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	
Average digits		6.1	6.2	6.3	6.3	6.3	6.3	6.1	6.3	6.3	6.3	6.1	6.5	6.3	6.4	6.5	6.4	6.1	6.4	

The trained group progressed steadily from an initial score of 4.33 to a final average score of 6.40 digits—a gain of 2.07 digits. In the Stanford-Binet Scale, 4 digits is placed at year 4, and 6 at year 10. The practice group, then, advanced during a period of 4.5 months during which they practiced on 78 days, an amount equal to that which the average untrained child advances in approximately 6 years.

The control group was given the test on the first and last of the 78 days. The average score on the first test was 4.33 and on the last

5.06, a gain of 0.73 digits. The gain of the practice group is appreciably greater than that of the untrained group.

The Influence of Disuse on Improvements

The problem, now, is to determine whether the improvement in the case of the trained group is due entirely to acquired techniques in handling digits and adjusting to the test conditions, or partly or wholly due either to the improvement of capacities underlying immediate memory for digits by some direct means or to capacities improved indirectly by a stimulation of growth, or to both. We therefore decided to apply, as one means of discovering the character of the improvement, a test of the influence of disuse.

On Oct. 10, 1924, approximately 4.5 months after the final practice day in May—a period approximately equal in length to the practice period—14 pairs of the original group of 16 pairs were found and tested. The results for the two groups were as follows:

Table III

	Practice group	Control group
Average score, initial tests, Dec. 20, 1923	4.36	4.41
Average score, final test, May 20, 1924	6 36	5 08
Gain, during period of practice	2 00	0.67
Average score, test after disuse, Oct. 10, 1924	4 71	4.77
Gain over initial test	0 35	0 36

This result is most significant. While the practice group at the end of 4.5 months of training excelled the control group by an appreciable amount—an amount equal to about 4 years of average growth according to the Stanford Scale—after 4.5 months of disuse, the advantage has been lost completely, the two groups were as nearly equal as they were at the beginning of the study.

As we see it, the experiment indicates that in the case of memory for oral digits among these children, at least, improvement brought about by 4.5 months of practice, while appreciable, is due not to capacity increased directly or indirectly by means of accelerated growth but exclusively to the acquisition of technique. What constitutes technique, the experiment does not disclose. The factors may be better habits of attention under test condition, adaptation to the examiner's signals and voice, the elimination of strain or anxiety, or more subtle devices utilized in keeping the digits in mind, in seeing

relations among them, in visualizing them or whatnot. Whatever they may be, the study indicates that they are rather unstable at least in the sense that all the skills and mneumonic devices acquired during the period of training were apparently lost during an equal period of disuse.

Another fact also suggests that the techniques were instable. The tests in October, 1924 were given by a different—but skillful—experimenter from the one who gave the earlier tests. As shown in Table III, the average scores of both groups in the last test were smaller than those obtained 4.5 months before although somewhat better than those of the initial tests 10 months earlier. The suggestion is that improvement brought about by practice consists in part of adaptations to the voice, mannerisms, and features of the test-technique of the examiner.

Results from the Series of Transfer Tests

As a further check upon the nature of improvement, the series of memory tests, given before practice in digits was begun, were repeated in October. 1924.[1] The results of these tests are shown in Table IV.

Table IV.—Showing the Initial (I) and Final (F) Scores and Gains (G) in Several Tests of Memory for the Practice and Control Groups

	Letters	Unrelated words	Related words	Geometrical figures	Pictures	Picture names
Practice I	3.64	3.86	14.0	4.3	5.3	7.5
Group F	4.11	3 86	16 2	4 9	6 8	9.0
G.	0 47	0	2.2	0 6	1.5	1 5
Control I	3 71	4 07	13.7	4.0	5.7	7.0
Group F	4.28	3 93	17.2	5.2	6.7	8.8
G.	0.57	−0 14	3.5	1.2	1.0	1.8
Difference in favor of practice group	−0 10	0.14	− 1 2	−0.6	0.5	−0.3
PE difference	0 30	0 25	1 8	0 4	0 6	0.7

The differences in gains between the two groups are inappreciable; each group shows in about half of the tests, a slight but really unreliable superiority such as would occur if the groups were substantially equal. There is, in other words, no evidence that the prolonged

[1] It was unfortunate that circumstances beyond our control made it impossible to give these tests in May, 1924.

training with digits has brought about any permanent improvement in immediate memory for other materials.

RESULTS FROM A SECOND PERIOD OF PRACTICE, JAN.–APR., 1925

After reviewing the results of the "retention tests," *i.e.*, those given after the interval of disuse, the fact that they were not extensive led us to decide to give a longer series, a series which really amounted to another practice or "relearning" period.

Eleven of the originally trained pupils, all that were available, were matched as nearly as possible in sex, age, mental age, intelligence quotient and memory for digits, with 12 others,[1] 8 of whom were members of the original control squad. A comparison of the two groups is given in Table V.

TABLE V.—AVERAGES FOR THE TWO GROUPS IN JANUARY, 1925

	Age	MA	IQ	Digits
Original practice group. .	6 34	8 1	128	4.73
Unpracticed group..	6 46	8 2	126	4 83

Beginning Jan. 27, 1925—13.5 months after the beginning of the study, 8 months after the end of the practice period and 3.5 months after the "retention" tests—both squads of children were given 22 days of practice in memory for digits somewhat more intensive than before. Each child was given 3 series of digits from lengths well within his grasp to a length on which he missed 2 or 3 times in 3 trials. This procedure was repeated three times on each day, *i.e.*, 9 series of each length. The scores used for securing the averages were the number of digits in the longest series on which the subject succeeded in two-thirds or more of the trials. These exercises were conducted by two experienced examiners—each taking half of each group—who had given none of the earlier tests to these pupils.

The results, in terms of the average daily scores for the 22 practice days are shown in Table VI.

Table VI shows essentially equal improvement for the two groups. There is no evidence that the 78 days of training which ended 8 months earlier had brought about any improvement in the fundamental capacities underlying memory for digits either in some direct way or, indirectly, by the stimulation of growth of these capacities.

[1] Twelve were used since in one case it was necessary to take the average of two children to yield a match with one of the trained children.

TABLE VI —AVERAGE DAILY SCORES IN MEMORY FOR DIGITS

Day	1	2	3	4	5	6	7	8	9	10	11	12
Practice group	4 73	4 82	5 00	4 82	4 73	4 82	4 91	5.09	4.82	5 27	5 27	5.18
Unpracticed group	4 83	4 83	4 93	4 93	4 93	5.00	4 93	5 17	5 00	5 25	5 33	5.33

Day	13	14	15	16	17	18	19	20	21	22	Day 22–Day 1
Practice group	5 36	5 27	5 45	5 18	5 36	5 54	5 54	5 73	5 63	5 73	1 00
Unpracticed group	5 25	5 42	5 50	5 58	5 66	5 66	5 75	5 83	5 92	5 92	1 09

SUMMARY AND CONCLUSIONS

The main facts produced by the experiment are as follows:

1. Practice in immediate memory for digits on each of 78 days during a period of 4.5 months by young children results in a marked gain in ability.

2. A group of children of equal ability in memory for digits and in sex, age, mental age, IQ and in other forms of memory who were given no practice were, when tested at the end of the practice period, better than at the beginning but clearly inferior to the practice group.

3. After 4.5 months of no practice, the two groups were again equal—the practice group had entirely lost its advantage. They were also equal in tests of immediate memory for other materials.

4. After 3.5 more months without practice, both groups were given 22 days of intensive training at the end of which the 2 groups were still approximately equal. Neither in results (3) or (4) was evidence of any permanent effects of the 78 days of practice found.

The facts, we interpret as follows: The improvement brought about by specific practice is due to the acquisition of special and subtle techniques of work, to adjustments to the test conditions, familiarity with digits—to acquired information and specific methods of attack. These special techniques and mneumonic aids seem to be unstable and transitory inasmuch as after 4.5 months of disuse they had disappeared.

Since the effects of the intensive training are so evanescent and since no permanent results of any kind favoring the practice group were found, the conclusion suggested is that training, under the conditions of the study, produced no increase in the capacities which under-

lie the function either in some direct way, or indirectly, by means of the stimulation of growth. The improvement brought about by practice seemed to be wholly in the form of devices, information, adjustments to the test conditions, "tricks of the task." In suggesting these conclusions, the present study is in harmony with another, performed earlier, in which a motor function—speed of tapping—was utilized.[1]

The demonstrated unstable and transitory character of improvement in memory for digits, indicates the desirability of obtaining, in other studies of similar skills, a measure of the permanence of the improvement brought about by practice. Are the well known increases in efficiency in memorizing poetry and prose, in solving verbal and mechanical problems, in rate of reading of several types which are usually rapidly produced by specific practice as evanescent as the improvement secured in this study? Or, is such instability peculiar to but few functions or is it a unique characteristic of the learning of very young children? The present literature, so far as we know, gives no satisfactory answer to these questions.

The findings have, we think, a bearing on the general theories concerning the natures and relations of native and acquired ability, of capacity and proficiency, of which the problem of the nature of intelligence is a part. By capacity may be meant the functional possibilities of the neural and other mechanism which make possible an ability that appears without special or intensive training; a capacity which, as disclosed in the studies, develops with time, with or without intensive practice. Upon these factors training has no appreciable effect.

Proficiency normally depends in part upon capacity and partly upon techniques and information, adjustments to the task, etc. which may be acquired during practice and experience. No doubt the relative degrees of these two components vary greatly among different functions; in memory for digits the importance of native capacity appears to be relatively large, partly because of the instability of the acquired factors. While the relations may be different in other functions, the distinction between capacity and proficiency may be usefully recognized. Similar investigations with other functions are needed to clarify the significance of native capacities and acquired abilities. The completion of similar investigations with a variety of mental function would contribute appreciably to our knowledge of the special problem of the nature of intelligence.

[1] Gates, A. I., and Taylor, Grace A : *Journal of Experimental Psychology* (forthcoming).