

PSYCHOLOGIC TESTS APPLIED TO DIABETIC PATIENTS *

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Diabetes is well known to exert an important influence on the central nervous system. Kraus¹ recently summarized the more common neurologic lesions, and the psychoses occasionally associated with diabetes have been the subject of numerous studies.

The diabetic patient, on his own part, complains of loss of memory and of poor ability to concentrate the attention. So far as we are aware, there are no objective data which either substantiate or contradict this clinical picture in reference to attention and memory. We have undertaken to gain some light as to the extent of the impairment if such exists, comparing diabetic patients as a group with controls who are of about the same mental status.

METHOD

At the New England Deaconess Hospital in Boston, Dr. E. P. Joslin has for some years conducted twice a week a patients' class in diabetic hygiene. We took advantage of meetings of this class which commonly contained all of the ambulant diabetic patients then in the hospital together with a few who had returned for observation, and conducted group tests over a period of two and one-half months. Usually from eight to fifteen persons were present. Data were collected on forty different diabetic patients. Some were tested several times, others only once; the group consisted of seventeen men and twenty-three women, ranging in age from 15 to 55 years, with an average of 46. At the time patients were first tested they were without exception free from acidosis but usually not sugar free. None were tested on a fasting day or on a day just succeeding a fast. Most of them were in the hospital for the first time and their initial tests were usually within a week of admission.

The control group consisted of two doctors, nurses and mostly of relatives and friends of patients. It is, of course, difficult to secure a control group which can be proven comparable to the diabetic group in everything except the diabetes. We took for controls adults who visited the class and were not patients. Several of the patients in the diabetic group were people of superior intelligence and of good education who probably in regular mental tests would have ranked above many of

* From the Nutrition Laboratory of the Carnegie Institution of Washington, and the New England Deaconess Hospital, both in Boston.

1. Kraus: *M. Clinics N. America*, July, 1920, p. 225.

those in the control group. The possibility of making a mental test of each diabetic was considered, but it seemed unwise to add anything more to their burden.

The four simple group tests which we used required about twenty-five minutes. They were conducted in a large, light room, comparatively free from distraction and following breakfast when the patients were usually at their best. The tests were as follows:

1. *Cancellation of Digits*.—This is one of the Woodworth and Wells² tests in which one thousand digits, each appearing an equal number of times, are printed in twenty lines of fifty digits each. The subjects methodically crossed out a certain digit every time it appeared, completing as much of the blank as possible within a time limit of two minutes.

2. *Memory Span for Digits*.³—A series of numbers were pronounced slowly and regularly, and at the end subjects tried to write them down in proper order. Trials were given, starting with five place numbers and gradually working up to nine place numbers. The same amount of material was given at each test and subjects were marked on the per cent. of the total material correctly reproduced.

3. *Memory Span for Four-Letter Words*.⁴—A list of twenty-five one syllable English words, each word composed of four letters, was read at the rate of one word per second. When the list had been completely pronounced to the patients, they then wrote down all of the words that could be recalled without regard to order.

4. *Addition of One-Place Numbers*.⁵—These addition blanks were very legible, being printed in 12 point type, well spaced, arranged in blocks of 100, i.e., ten digits in a column and ten columns wide. The patients added as many columns as possible in five minutes.

The tests on the different days were, so far as we know, of equivalent difficulty and were always conducted in the same manner. Due to the readiness with which diabetics are fatigued, it was not possible to make tests as long or as intensive as otherwise would have been desirable. So far as possible, we tried to make the testing period pleasurable rather than boring, and if patients showed disinclination to do them, they were freely excused without argument on our part. A careful but unobtrusive watch was kept as to the accuracy with which instructions were followed and doubtful records were thrown out.

2. Woodworth and Wells: *Psychol. Mon.* **13**:24, 1911.

3. Whipple: *Manual of Mental and Physical Tests*, Baltimore, 1915, Pt. 2, p. 155.

4. Benedict, Miles, Roth and Smith: *Human Vitality and Efficiency Under Prolonged Restricted Diet*, Carnegie Inst. Wash. Pub. 280, 1919, p. 142.

5. *Ibid.* p. 143.

RESULTS OF INITIAL GROUP TESTS

In the first place, we will compare the ability of diabetics beginning treatment with other individuals equally unfamiliar with the tests.

Cancellation of Digits.—Per cent. of task performed.

39 diabetics: Range, 19-75; average, 48; variation, 23%; errors, 3.5%.

15 controls: Range, 37-100; average, 61; variation, 21%; errors, 3.1%.

The diabetics were able to accomplish an average of 48 per cent. of the task while the controls covered 61 per cent. in the same time. Substantially the same result is shown in the ranges covered by the subjects of the two groups. The per cent. variation (coefficient of variability) among the diabetics is only a trifle higher than among the controls, and the same applies to the per cent. of errors which is small in both. The difference lies, therefore, in the amount accomplished rather than in the degree of accuracy, the diabetic patients showing an inferiority of about 21 per cent. if we reckon the controls as 100.

Objection may be raised that visual defects so common in diabetes account for this difference. In that case, we should expect a higher percentage of error among the diabetics whereas the percentages are almost the same. Furthermore, the patients were specifically questioned with regard to this point, and two patients were excluded who were at the time experiencing the well known temporary blurring of vision. Ophthalmoscopic examination in several showed no retinal lesions. It seems from this that the diabetic is retarded, but whether this is in discrimination or in speed of movement or both cannot be determined from this test.

As the test of memory span for digits was necessarily brief, it was not possible to give enough trials with six place, seven place, etc. numbers to certainly establish the number of digits which could be recalled correctly.

Memory Span for Digits.—Per cent. of material recalled.

39 diabetics: Range, 30-81; average, 56; variation, 20%.

14 controls: Range, 40-100; average, 66; variation, 21%.

If all of the material given in this test be considered, then the diabetics, on an average, recalled 56 and the controls 66 per cent. of it. This difference is reflected in the ranges covered by the individuals composing the two groups. The per cent. of variation within both groups is nearly the same. The diabetics showed a decrement in this memory span test of 15 per cent. As an approximation we might say that if the average control is able to remember for immediate recall a seven-place number, the diabetic can barely remember one of six places, and, as compared with normals, they are much more likely to find difficulty with even a four-place telephone number.

In the memory span for words, the diabetics showed a larger variation among themselves from their average number of words correctly recalled than did the other groups. One diabetic could not correctly recall any word (two words were put down but they were both errors, i.e., not pronounced in the list) and another patient, a school teacher, had eleven words correct and one error word.

Memory Span for Four-Letter Words.—

39 diabetics: Range, 0-11; av. correct, 4.9; variation, 31%; av. errors, 1.7.

18 controls: Range, 3-10; av. correct, 6.2; variation, 24%; av. errors, 1.9.

24 students:⁶ Range, 3-13; av. correct, 7.0; variation, 24%; av. errors, 1.4.

On the average, the diabetic patients show 4.9 correct words as compared with 6.2 for the controls and 7.0 for a group of male college students who were given the same test in another experiment at an earlier time. It is common in such a test that some words are written down which were not in the list pronounced for memory and which have not been obviously suggested on the basis of similarity of sound. Such may be called errors. Of the thirty-nine diabetics, thirty-one gave such errors which range from 1 to 4 and average 1.7. The controls and students show average errors of 1.9 and 1.4 per cent., respectively, so there seems no significant difference between the diabetics and the other groups as to number of wrong words entered. An illustration of the difficulty which diabetics experience in remembering instructions came out in this test. The word "go" was written down by four of the diabetics in spite of the instruction "all the words are four-letter words. When I have finished pronouncing the list, I will say the word 'go' which is a signal for you to start writing." On the basis of the number of words correctly recalled in this test, the diabetics show a decrement of 21 per cent. below the controls who themselves are 11 per cent. poorer than the group of college students.

Probably of the group tests given, addition is most likely to have been practiced through the regular occupations of certain subjects. It is difficult to secure groups of people who are directly comparable in respect to this factor of preliminary practice. Any person who without recent practice can correctly add thirty columns of ten digits each within five minutes may arbitrarily be considered as being professionally practiced in addition. To simplify comparison we have excluded each such case among the diabetics, controls and students compared. As stated, many of the patients were very intelligent and capable people. It is significant to find that among thirty-seven diabetics who took the addition tests, seven at the first trial correctly added thirty or more columns. In each case the person is known to be an accountant, a school teacher,

6. Ibid. p. 577.

or store keeper. Besides these, there was one accountant and one teacher whose scores we have not omitted who each did twenty-eight columns correctly. It is, perhaps, questionable that these should have been allowed to remain in the group. Of the eighteen controls, only one, a doctor, did as well as thirty columns, and of the twenty-four college students who took the test, three did at the rate of thirty or more columns in five minutes. One of these students was a bank cashier. On this basis the comparative results are as shown in Table 1.

TABLE 1.—ADDITION OF ONE-PLACE NUMBERS

Subjects	Columns Correctly Added	No. Incorrect
30 diabetics.....	Range 2-28, average 14.0	3.0
17 controls.....	Range 4-24, average 14.7	2.9
21 students.....	Range 5-28, average 16.9	4.6

If we consider the average number of columns correctly added, the thirty diabetics did only 5 per cent. less than the seventeen controls, while the latter were 13 per cent. poorer than the twenty-one college students. Since in addition accuracy is of prime importance rather than the number of columns attempted, we may deduct the average number of columns incorrectly added from the correct for a combined score. In this way we find:

Diabetics, 11.0 Controls, 11.8 Students, 12.3

Taking the controls as a basis, the students are 4 per cent. better and the diabetics 7 per cent. poorer.

In this discussion of addition we have eliminated the professionally practiced adders for reasons which seem pertinent. The diabetics do not show a large decrement in their ability to add, and it may fairly be questioned if the decrement found is a real fact. Two or three very poor adders might press the average below that found for normal controls. As we have eliminated the very expert, we may do likewise for the extremely inefficient and thus compare in all cases modal groups. Any person who in five minutes cannot add correctly more than five columns of ten digits each we will arbitrarily exclude. This eliminates three of the thirty diabetics, two of the seventeen controls, and one of the twenty-one students, and provides for number of columns correctly added the following scores:

Diabetics, 15.3 Controls, 16.1 Students, 17.5

Viewed in this way, the diabetics are again 5 per cent. poorer than the controls who, in turn, are 8 per cent. below the students. It is a treacherous thing to draw conclusions from arbitrarily selected data,

but from that available, viewed from different angles, it appears that the diabetic patients suffer a small decrease of about 5 per cent. in their ability to do simple sums in addition.⁷

REPEATED GROUP TESTS ON DIABETICS

We have discussed what the diabetic patient at the very beginning of treatment can do in his first performance of certain psychological tests given under practically ideal group conditions. As compared with available controls, we have found that his performance level is somewhat poorer, in amount, 5 to 20 per cent. It is quite important to discover if his ability to improve with practice is very different than normal. There were twenty diabetics who took the tests two or more times. A comparison may be made of their first and second trials to note if the latter averages are the higher, and if so, how much in terms of per cent. of the first trial averages. Such a comparison among twenty diabetic patients, seven controls and eleven young men college students is embodied in Table 2.

TABLE 2.—THE AMOUNT OF IMPROVEMENT BETWEEN THE FIRST AND SECOND TRIALS WITH PSYCHOLOGIC TESTS

Subjects	Trials	Cancellation	Memory Words	Memory Digits	Addition	Average
20 diabetics.....	First	48	4.7	55	20.6	
	Second	56	5.7	68	21.9	
Per Cent. improvement.....		17	21	23	6	17
7 controls.....	First	66	5.9	58	19.3	
	Second	71	6.6	63	22.1	
Per Cent. improvement.....		8	12	9	14	11
11 students.....	First	..	7.3	..	19.6	
	Second	..	8.7	..	21.0	
Per Cent. improvement.....		..	19	..	7	13

Without specifically discussing the average scores made in the different tests by the different groups of subjects we may note the per cent. of improvement with practice. In this, the diabetics show percentages of gain as follows: cancellation, 17; remembered words, 21; remembered digits, 23, and columns correctly added, 6. All four tests gave an average gain from practice of 17 per cent. The seven control subjects who took the tests twice show gains of 8, 12, 9 and 14 per cent., with an average of 11 per cent. The eleven college students who, under normal conditions but with a somewhat longer interval between trials, took the memory for words test and the addition test a second time, demonstrate improvement of 19 and 7 per cent., respectively. In the

7. The question may be raised as to any change in the accuracy of addition work by the seven diabetics who were discarded as being expert. These averaged 37.7 correct and 2.5 columns incorrect. The three students who were discarded averaged 37.8 columns correct and 3.0 incorrect. While the one discarded control showed 33 and 1 columns.

addition test, the controls gained more than did the diabetics but in the three other tests the diabetics are well in the lead with large percentages of improvement.

It must be recognized that in the trials which came after the first experience with the tests, the subjects were often sugar free and were receiving more food. This doubtless contributed to their comfort and efficiency. We have no diabetic quotient, i.e., no way of numerically stating the diabetic condition of a patient or of a group of patients. Such a quotient would be useful in assessing the value and progress made with different types of treatment and for correlation of diabetes status with numerous other factors and conditions. At present, it is impossible to say to what extent the improvement shown is due to improved physical condition or to the subsidence of certain symptoms. Of twelve patients who were tested from three to nine times we found that the improvement in the performance of these tests shown at the second trial was maintained with a slight tendency to a continued gain in efficiency. We may at least say that the treated diabetic quickly responds in psychologic level and is able to learn rapidly from practice, as is shown in repeated tests. It is also clear that under treatment he rather quickly approaches the normal, although he seemingly does not reach that level. This rapid response to adequate treatment is a fact which should much encourage both physician and patient.

PSYCHOMOTOR TESTS OF INDIVIDUAL DIABETICS

A few diabetic patients were given certain neuromuscular tests at the Nutrition Laboratory. These measurements were made with a view to sampling the performance of these subjects as to their quickness of action, accuracy and steadiness of muscular control, etc. Data may be reported for five persons, two women and three men, all of them very intelligent and cooperative subjects. All were subjects of pronounced diabetes and had been under treatment for some time, all were free from sugar and acidosis when tested, but their total food intakes were low, and, as a class, they were quite emaciated. The testing was done in the morning shortly following breakfast and required about two hours. Only one subject came on any day. Care was taken to instruct and adjust each patient to the tests. Rest periods were introduced so that fatigue might be slight.

Detailed descriptions of the tests and methods used have been published elsewhere. It will be sufficient here to characterize them briefly.

1. Station: Standing erect for two minutes with the least possible swaying at the vertex; eyes closed, feet in V position.⁸

8. Miles: Static Equilibrium as a Useful Test of Motor Control, *J. Indust. Hyg.* **3**:316, 1922, p. 186.

2. Finger movement: Alternate flexion and extension of a finger at maximum speed for ten seconds.⁹

3. Eye movement: Speed in looking successively back and forth from one mark to another while the eye is being photographed.¹⁰

4. Eye reactions: Quickness of turning the eye to a new point of regard as to a flash sign that unexpectedly illuminates.¹¹

5. Pursuit coordination: Catching in a narrow cup liquid that is expelled from a swinging pendulum.¹¹

The results in these five tests are briefly presented in the same order as above.

1. A group of twenty-seven normal adults, sixteen men and eleven women, of widely varying ages, weights and statures, gave an average of 740 mm. in the station test. This value represents the sum for all the swaying movements, front, back, left and right, during a period of two minutes standing with eyes closed and feet in V position. Every diabetic tested swayed more than 740 mm. while no normal adult did as poorly as the average for the five diabetics which was 1160 mm. Accordingly, they show about 50 per cent. increase in swaying.

2. In this modified and graphic form of the tapping test, thirty normal men were able, on the average, to execute 66.5 finger movements in ten seconds. With the same apparatus and conditions the five diabetics average 54.5 movements, i.e., they were 18 per cent. slower. The difference in level between the two groups is also indicated in that no diabetic was as fast as the average for the normals, and only one man in thirty was as slow as the average for the diabetics.

3. The speed with which the eye can move horizontally back and forth between two marks which are located 40 degrees apart on the arc of vision has been found a sensitive measure in other studies. Averaging together movements from left to right with those from right to left we find that the five diabetics show a group average of 0.102 seconds for an eye movement of 40 degrees. In comparison with this, twelve normal men¹² at their initial trial of this test show an average eye movement time of 0.092 seconds, by which it appears that the diabetics are about 11 per cent slower. Both groups took the test in the morning when they were quite free from any sleepiness.

4. The eye quickly turns in the direction of any part of the visual field that suddenly moves or changes; and the every day experiences of life cause this act to be rather well practiced. In the eye reaction test, the subject looked at the center of a dark screen which was pierced with many small holes, through any one of which a light could be made

9. *Ibid* p. 184.

10. *Ibid*. p. 159.

11. Miles: A Pursuit Pendulum, *Psychol. Rev.* **27**:361, 1920.

12. *Ibid*. p. 619.

appear suddenly. The photographic record showed the elapsed time from the moment the light was turned on until the subject's eye began to turn toward it. Quite a number of trials were invariably made on each person tested. Twelve normal men gave an average eye reaction time of 0.237 seconds while the five diabetics show 0.254 seconds, which is thus slower by only 7 per cent.

5. It requires rapid and accurate coordination of eye and hand to catch liquid expelled in a stream of one-eighth inch diameter from the tip of a pendulum which swings through a horizontal distance of 70 cm. in 1 second, the mouth of the cup being six-eighths of an inch in diameter. But everyone, even small children, can do something at the test. A single trial in this case consisted in catching the liquid expelled during one double swing of the pendulum and the whole test comprised twenty-five such trials. A group of fifteen men and ten women at their first performance caught a total average of 378 c.c. out of a possible 1250 c.c. As against this, our five diabetics averaged 291 c.c., which is poorer by 23 per cent. So far as is known, the diabetics were not at any disadvantage in the tests which were made at the Nutrition Laboratory. In all of the tests, they seemed to do definitely poorer than the so-called "normal" subjects who we felt could reasonably be compared with them. The five diabetics who were tested were all persons whom we selected with the impression that they would do as well, or, perhaps, better than the average on account of good intelligence, education and adaptability. It is altogether probable that another group of five would show somewhat different results. Knowing the subjects thoroughly, we feel that results obtained in our tests are probably characteristic, although on the actual amount of change we cannot, of course, be dogmatic.

To what extent the carefully treated, severe diabetic gradually changes from year to year is at present only a matter of surmise. After making the tests just described, we had an opportunity a full year later to test one of the five subjects a second time. This man, age 38 years, height 189 cm., and weight 51 kg., had kept himself constantly sugar free throughout the year and had lived on a daily intake of 940 calories. His diabetes is of about eight years standing. He, of course, did but little physical work; however, during the day, he is always dressed and about, employing half his time as a locksmith. During the year he had gradually lost about 1 kg. in weight but his fasting blood sugar was 0.10 per cent. as compared with 0.23 per cent. one year before. Otherwise he appeared unchanged. He spoke of feeling physical weakness, especially in the knees at stair climbing, and of being very sensitive to cold. Comparing the measurements of December, 1920, with those made in January, 1922, we find that in only one test (station) did he do as well on the latter date. In this there seemed to be almost no change. In

four other tests, he showed some decrease in efficiency, ranging from 5 to 27 per cent., judged on the performance of his former record. The testing on the latter date was done very thoroughly and occupied two different mornings separated by two days so that we are quite confident that the later results do not misrepresent his condition. Hence, we must conclude that he now shows a loss of about 10 per cent. in neuromuscular efficiency as compared with his condition a year ago.

DISCUSSION

We have found objective justification for the complaints of loss of memory and of ability to concentrate attention mentioned frequently by persons suffering from diabetes. The old and well established mental associations, such as are involved in doing simple addition of numbers seem but little influenced. But new tasks which demand immediate retention and recall, with little reference to past experience, are the ones which suffer and at which the patient finds himself below his former ability. There appears to be no marked increase in the errors which the diabetic makes in his work as compared with the normal person but rather a loss of speed, a decrease in the span, or amount that can be grasped at one time. That the change is chiefly in the nature of a retardation of the neuromuscular processes is indicated by those tests which more especially involved the muscles. In these we have found that the eye requires more time to turn and to react; that the fingers cannot make as many taps in a given interval, nor can the hand as accurately pursue a moving object. To what extent this retardation may be due to discouragement or mental depression on the one hand or specifically to the diabetes, as such, on the other, it is impossible to state. If we had available similar observations for groups of patients suffering with other diseases it would be possible to more satisfactorily make an appraisal of the influence of diabetes as compared with other conditions. There is clear evidence that with treatment, most of the individuals tested showed rapid improvement on the psychological side.

If we say that the diabetic is below normal in his neuromuscular efficiency, it may also be pointed out that few persons work to the limit of their powers, and that few situations in every day life demand or stimulate the laboratory grade of performance. While memory span and muscle movement speed are of fundamental importance for the activities of life, still there is a rather wide margin and undoubtedly very many diabetic individuals will be able to do as much light physical or mental work as is actually done by many normal men and women. In other words, while the diabetic is not at all fitted for racing in top-notch competition, still he is fairly well off for living comfortably and usefully.

It was found in the Nutrition Laboratory research on the effects of low diet that men living on one half to two thirds of their normal ration were able to do their college work and in some cases make even higher grades than before so it is quite possible that many diabetics will not experience from a reduced diet any marked change in their ability to perform their usual duties.

SUMMARY

1. Diabetic patients frequently complain of poorer memory and power of attention, but objective proof of this has been lacking.
2. By certain psychologic tests applied in such cases as well as to suitable controls it was found that diabetic patients with hyperglycemia and glycosuria at the beginning of treatment show a decrement of about 15 per cent. or more in memory and attention tasks. The loss is in amount rather than in quality.
3. With treatment the diabetic improves rapidly in his psychologic status, approaching but not quite reaching normal.
4. In accuracy and quickness of movements five treated diabetics, each case of long duration, were 20 per cent. below normal.