pig), then the technique I employed does not agree with that of the "original" test, for I used in my "hæmolytic system" human red blood corpuscles (always obtained, it must be remembered, independently of the bloods to be examined). Otherwise my technique conformed with the principles of the "original" test, and as shown in my paper everything was done to render the determinations as accurate as possible. Major Mott questions the accuracy of the "unheated" reactions. I agree with him, but I do not think they in any way invalidate the final interpretation of the results obtained. I should like to emphasise the fact that 12 and not 42 should be taken as the total percentage of the positive results. I have recorded the other reactions merely to indicate that they have been obtained, and in my paper I have given reasons why they should be rejected as "negative."

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Reaction Time in Nervous and Mental Diseases. By E. W. SCRIPTURE, M.D., Ph.D.

I. *Introduction.*

OUR knowledge of whether a person is normal, or suffers from neuritis, or is a case of dementia præcox, is derived entirely from observations of how he reacts to his environment—that is, to various stimuli. The thought at the basis of these researches is that an attempt may be made to produce an environment where the results will be accurately recorded in a simple, direct way.

The study of the nervous and mental condition of human beings consists of a study of their reactions—that is, of their responses to stimuli. By using stimuli of sound or light to which the person must respond by a voluntary movement, some degree of simple mental activity is involved. By requiring discrimination between two stimuli, and choice between two actions, more complicated mental action is included. These researches have not gone beyond this rather simple degree of mental action involving sensation, perception, discrimination, choice, and volition. They should be extended to higher forms of reaction to include association of ideas, judgments, emotions, etc., in fact, to all and more than what is included in a regular examination.

The method here employed differs from other methods of examination and study by resulting in a measurement. The simple reaction to a light or a sound, involving sensation and volition, results in a measurement of time—the "simple reaction time." The more complex response involving discrimination and choice results also in a measurement of time—the "complex reaction time." The various higher mental activities can be tested by methods of experiment that result in measurements of time or accuracy or force.

Such a series of self-recording tests may perhaps be developed and extended to include all the essentials required for a diagnosis, while the increased precision in certain tests may make a large part of the ordinary examination unnecessary.

The researches of past years in physiology and psychology have shown that the time of a reaction changes with the condition of the individual, with the complications of the situation, etc. Hitherto these researches have been confined almost entirely to normal persons. It is the purpose of this investigation to determine how persons with various nervous and mental diseases respond to certain simple definite problems.

The simplest problem is that of being required to watch for a signal, and to respond by the movement of a finger when the signal is perceived. Such a response is termed a "simple reaction." Although a reaction may be studied in many ways, the time it requires—the "reaction time"—is that factor for which the technique has been most developed.

The ordinary measurements of reaction time involve a fine clock-work registering in hundredths or thousands of a second. Each result has to be recorded by the experimenter. The taking of 100 reaction times can hardly be accomplished in less than one hour. Such a method is entirely too cumbersome for clinical use. I have therefore devised a self-recording method that shows directly to the eye without measurement just how quick the reaction time is, and just how it varies. The whole series of experiments in all their details is fixed on paper in a few minutes in a way that would require hours of work by the older methods. The diagnosis, in so far as it depends on these records, is settled on the spot. The actual reaction times can be obtained with the greatest accuracy by measuring the automatic record at any convenient time.

II. *Apparatus.*

A recording drum (kymograph) turned by clock-work, carries a surface of smoked paper (Fig. 1). On the axle of the drum there is a spring that makes contact once every revolution with an insulated metal point held by a support. Every time the spring passes the contact point an electric circuit is closed for an instant. This circuit includes a magnetic signal or miniature incandescent lamp. The magnetic signal makes a movement once every revolution. This movement can be used as a visual signal by making the action noiseless with a piece of cotton, or the sound itself can be used as an auditory signal. The little lamp is used as a visual signal.

The record on the smoked paper of the drum is made by a magnetic marker on a stand. The marker is placed so that its recording point rests against the drum with no current passing through, and is pulled away from the drum as soon as the circuit is closed. A separate circuit with a battery current interrupted by a telegraph key is connected with this marker. The closing of the circuit by the key holds the point of the marker away from the drum.

Before an experiment the drum is turned until the spring touches the insulated point and the signal is given. Holding the drum in this position, with the marker circuit broken so that the point touches the drum, the marker is run up or down on its support. The vertical white line thus drawn indicates the point of the drum directly under the marker at the moment the signal circuit is closed; it is called the "zero line."

To make a record the patient holds his finger on the key to keep the circuit closed, and the point of the marker away from the drum. The drum is set in motion. When the signal is given he releases the key, and so lets the marker draw a white horizontal line on the smoked paper. The rate of revolution of the drum can be regulated to suit the occasion.

The scheme of a record is shown in Fig. 2. The space from the zero line to the beginning of the horizontal line represents the time that elapsed between the moment of the stimulus and the moment of the reaction; it is called the "reaction time." The length of the horizontal line represents the "holding time," or the time the patient held his finger off they key.

After the reaction occurs, the recording point is moved down

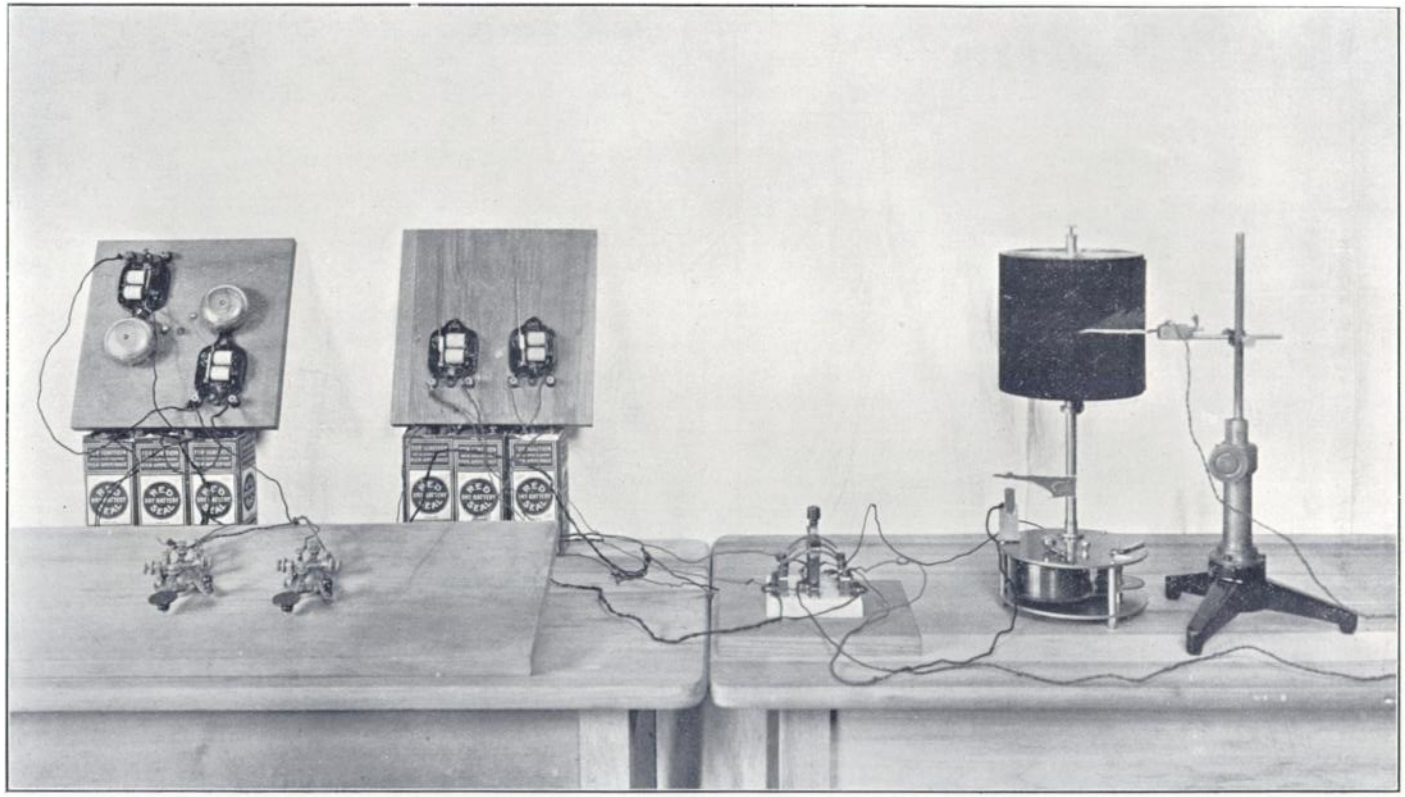

FIG. 1.—Recording apparatus.

To illustrate paper by Dr. E. W. SCRIPTURE.

Adlard & West Newman.

about half a millimeter by a notched wheel. The drum continues to turn, and after a short time (four and a half seconds) the signal is made again, and the patient again reacts. In this way records are made at small distances apart.

Before or after each record a time line is drawn on the drum by applying to it a fine point at the end of a tuning fork vibrating one hundred times a second. Each wave of the time line represents one-hundredth of a second. After the record has been varnished a portion of the time line is cut out, and used as a scale to measure the reaction time and the holding time.

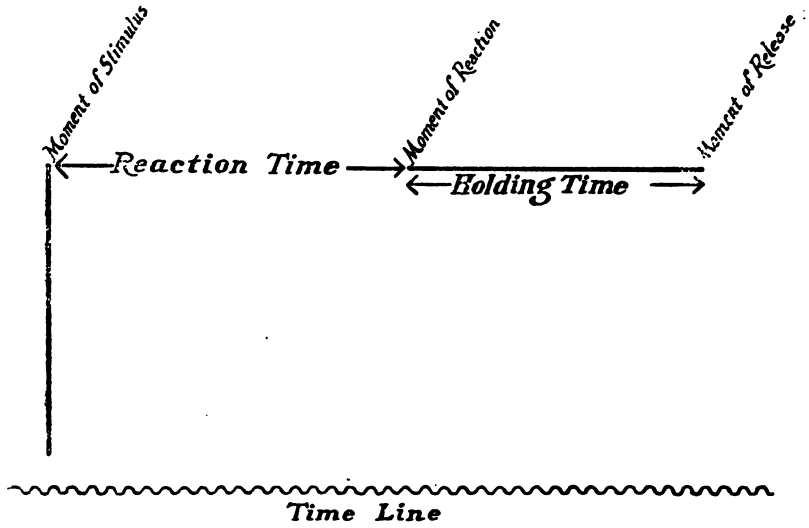

FIG. 2.—Scheme of reaction record.

The important advantage of having the successive records at equal distances apart is gained by placing the marker on a support that can be lowered by rack-work similar to that of a microscope. The following arrangement is added. On the inner side of the small wheel that lowers the support by connection with the rack-work shallow depressions are drilled in a series. A dull-pointed steel pin is fixed in a barrel against a spring so that its point rests in a depression of the wheel. As the wheel is turned the point is forced out of the notch, but falls into the next one; this is sufficient to cause the hand to stop in turning the wheel.

Recording reaction times in this way gives at once a complete

picture of how the reaction times grow longer or shorter, how they become more or less irregular, etc. For much clinical work it is not necessary to make measurements; the record sheet presents a sufficiently accurate picture of the condition.

The time required for the marker to touch the drum after the current is broken—its "latent time of the break"—is registered by passing the current from the battery through the marker, and then through the contact on the drum. This arrangement also registers the time required for the point of the marker to leave the drum after the current is made, that is, the "latent time of the maker." For the small marker used here the latent times of the break and of the make averaged less than 0·005 sec. These times are very regular, the average error being 0·002 sec.

The latent time of the magnetic signal was measured in the same way as that of the marker. It was very small and regular, averaging 0·01 sec.

The time required for the lamp to light up after the contact is made—its latent time—was measured in the following manner. The lamp was placed back of the drum, and just below its lower edge. Exactly opposite it in front of the drum there was placed a long tube with a vertical slit at one end. The observer looked through the other end and adjusted the tube so that he could see the lamp through the slit. On the bottom of the drum there was placed a strip of cardboard with a horizontal slit in it; this slit was covered by a paper slide. The cardboard was so placed that, the moment the contact was made, the left end of its slit was in a line with the lamp and the slit in the tube. The paper was pulled aside so as to leave a narrow slit in the cardboard. If the lamp had lit up exactly when the contact was made, it could have been seen through the narrowest possible slit in the cardboard, but as it took time for the lamp to light up, the drum had turned a certain distance in that time, and so a larger slit was necessary. The slit was enlarged until the observer could just see the light. Then the time of exposure through the slit was measured. In this case the latent time of the lamp was found to be approximately 0·01 sec.

The zero line nominally indicates the moment of the occurrence of the visual or auditory signal. Actually the signal occurs afterwards by the amount of the latent time. All the records are therefore too long by the amount of the latent time

of the signal, namely, in these researches by approximately 0·01 sec. To get the true reaction time this amount must be subtracted. The marker makes its registration too late by the amount of its latent time. Therefore this amount must be subtracted from the registered reaction time to get the true reaction. These two latent times are subtracted in the computations.

The holding time is not affected by the latent time of the

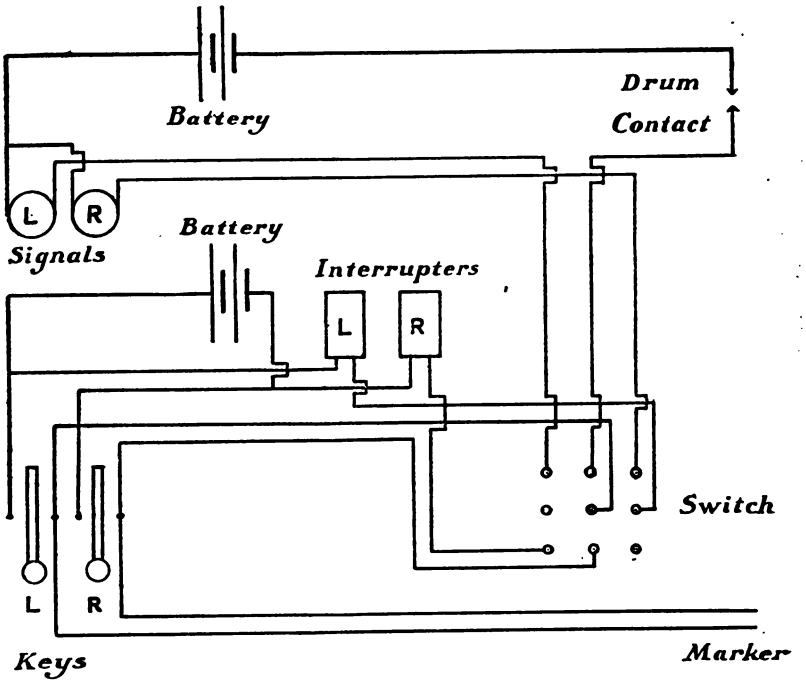

FIG. 3.—Diagram of electrical connections.

marker, as the marker touches the drum about 0·01 sec. after the reaction is begun, and leaves it about 0·01 sec. after the reaction is ended.

The regularity of the drum is tested by having an electrically driven tuning fork register continuously for a large number of revolutions without rewinding the drum. There should be an equal number of waves for each revolution. A test for forty-one revolutions showed that the speed did not decrease to any amount that could be detected, and that the average irregularity amounted to 2 *per cent.*

In a complex reaction the person has to discriminate between two stimuli, and choose between two acts. In one set of experiments two magnetic signals were used. These consisted of two electrical bells, with the knobs bent so that they did not touch the bell. They were thus noiseless and were used as visual signals. They made contact only once, the self-interrupter having been removed. For a movement of the left hand signal the person was to release the left one of the two keys; for a movement of the right hand the right key. The two signals were fastened to a board some distance in front of the telegraph keys. A triple pole double-throw switch was so connected with the telegraph keys that in one position it caused the right hand bell to move, or the white light to flash; in the other position the left hand bell to move, or the green light to flash. An electric buzzer was inserted in each key circuit so that it acted if the wrong key was used. Thus with the double-throw switch in one position, the right hand bell moved, and the right hand key registered a straight line on the drum, just as in the preceding arrangement for simple reactions; but if the left hand key was released by mistake the buzzer interrupted the current, and the magnetic marker registered a dotted line.

In another set of experiments two lights, a white and a green, were used, and also two keys, one for each hand. When the white light was flashed, the person was to release the right hand key, when the green one was flashed, the left hand key.

III. *Interpretation of Results.*

The great advantage of this form of experiment is that it furnishes at once a picture of the quickness with which a person responds to a stimulus, and also of his variability. For a quick person the horizontal lines are near to the vertical line; for a slow person they are further away. For a steady person the ends of the horizontal lines are at about the same distance from the vertical; for an unsteady person their positions vary more or less greatly. Any lengthening of the time or increase of variability is presented at once to the eye without measurement.

When detailed information is desired, the distance from the vertical line to the beginning of each horizontal line is measured by means of the waves of the time line. This gives the reac-

tion times in hundredths of a second. The average of these reactions is taken for the whole record, or for any portion that may be selected.

To obtain the person's variability for a set of reactions the difference is found between the average and each individual measurement, and then these differences are averaged without regard to sign. For example, the first fourteen reactions for a certain normal person are given in the first column below.

Reaction times.	Variations.
0·20	0·007
0·16	0·047
0·21	0·003
0·24	0·033
0·23	0·023
0·18	0·027
0·20	0·007
0·21	0·003
0·18	0·027
0·24	0·033
0·24	0·033
0·19	0·017
0·25	0·043
0·17	0·037
Average . 0·207	Average . 0·024

The average reaction is 0·207 sec. The difference between this and the first reaction (0·20 sec.) is 0·007 sec. The second column gives these differences for the entire set of fourteen. The average of these differences, 0·024 sec., is called the average variation. The average variation is $\frac{24}{207}$ or 12 *per cent.* of the average reaction time. Although computations are made in thousandths, the results are best stated in hundreths in the present case. The average reaction is thus 0·21 sec. and the average variation 0·02 sec. The latter value is a good index of the irregularity of the results. Another value, the mean square error, is a slightly better one, but in the present case it hardly repays the additional labour of computations.

IV. *Normal Records.*

A typical normal record is shown in Fig. 4; it was made by a physician known for his remarkably equable temperament.

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Inspecting the record we notice that the results fall into five groups. There is first a very irregular group reaching through the fourteenth record, which represents the period of "training in." Then there is a regular group reaching from the fifteenth through the forty-fourth, which might be called a period of "steady gait." At the forty-fifth experiment there is a sudden great lengthening of the reaction. This is undoubtedly due to a readjustment in the person's mental condition, which we can attribute to some "distraction." From the forty-fifth through the fifty-fourth there is a steady gain in rapidity as the person returns to his condition of steady gait. From the fifty-fifth through the eighty-first there is a very regular group which again can be considered a period of steady gait. After that the reactions become irregular and longer, representing a condition of "fatigue." The average reactions and the average variations are given in Table I.

TABLE I (Fig. 4).—*Normal Person, A. Simple Reaction.*

	Average reaction.	Average variation.	Average holding time.	Average variation.
1st group, 1–14, training in .	0·20	0·03	0·16	0·03
2nd group, 15–44, steady gait .	0·16	0·02	0·19	0·02
3rd group, 45–54, distraction .	0·20	0·03	0·19	0·03
4th group, 55–81, steady gait .	0·15	0·01	0·19	0·02
5th group, 82–95, fatigue .	0·18	0·03	0·17	0·02
Whole average . . .	0·18	0·02 11%	0·18	0·02 11%

The shortest average reactions are found in the groups of "steady gait," namely, 0·16 and 0·15, the small average variations being 0·02 and 0·01. "Training in," "distraction," and "fatigue" are marked by long reaction times, and greater irregularity. The time of holding does not seem to vary much either in length or in regularity.

The record shown in Fig. 5 is that of a physician of normal temperament. The period of "training in" reaches through the seventeenth reaction; it includes one very late or "delayed" reaction, and one reaction due to anticipation of the stimulus, or "anticipated reaction." The explanation of the atter case is that since the experiments occurred at regular

intervals, the person knew about when to expect them. If he were nervously excited, he would be liable to react before the actual stimulus. This is the "anticipation reaction." The next following twenty-one reactions belong to the period of "steady gait," a condition of confident expectation and reliant self-control. There is, then, evidently a third period reaching through the sixty-third reaction that shows steadily increasing

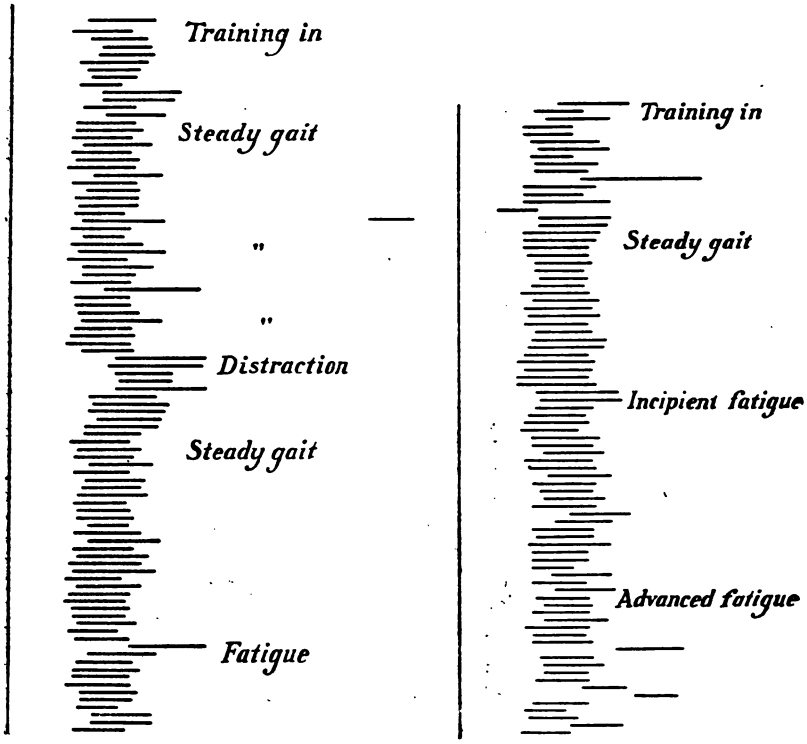

FIG. 4. FIG. 5.

Reaction records, simple, normal.

irregularity. Such an increase indicates a change in condition, which we can term the "effect of fatigue"; when the change is small it can be termed "incipient fatigue." In the last period the reactions are very irregular, showing a high degree of fatigue. The results are given in Table II.

In this case the period of "training in" shows itself mainly in the great irregularity, the average variation being 0·04 sec., while the average reaction, 0·17, is scarcely different from that of the period of "steady gait." Likewise the average holding

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time, 0·17, does not differ. Its quick movements indicate a condition of strong mental concentration; in spite of this the lack of adjustment during the training in is shown by the irregularity. The effect of fatigue on the reaction time is demonstrated quite strikingly in the average variation for the last groups.

TABLE II (Fig. 5).—*Normal Person, D. Simple Reaction.*

	Average reaction.	Average variation.	Average holding time.	Average variation.
1st group, 1–17, training in .	0·17	0·04	0·17	0·03
2nd group, 18–39, steady gait .	0·16	0·01	0·17	0·03
3rd group, 39–63, incipient fatigue	0·18	0.02	0·16	0.02
4th group; 64–85, advanced fatigue	0·20	0·05	0·14	0·01
Whole average . . .	0·18	0·03 17%	0·16	0·02 13%

TABLE III (Fig. 6).—*Normal Person, C. Simple Reaction.*

	Average reaction.	Average variation.	Average holding time.	Average variation.
1st group, 1–6, training in .	0.29	0·04	0·27	0·05
2nd group, 7–31, steady gait .	0·23	0·02	0·23	0·06
3rd group, 32–39, beginning of fatigue	0·20	0·03	0·22	0·02
4th group, 40–58, great mental fatigue	0·13	0·12	0·24	0·05
Whole average . . .	0·21	0·05 23%	0·23	0·05 22%

The record shown in Fig. 6 is that of a physician of equable temperament who was somewhat fatigued. We note that the first six reactions show the usual characteristics of "training in." The reactions that follow through the thirty-first correspond to the condition of "steady gait." We notice that the reactions steadily become shorter as the person gets more accustomed to the experiment. Thereafter the reactions begin to show increasing irregularity, indicating the beginning of

fatigue. The following ones show signs of very great mental fatigue. We note particularly that the first two reactions of this last group show extra movements of the finger. There are also three anticipatory reactions, and several more repeated movements. One reaction anticipates the stimulus by a long time, and the finger is held down longer than in any other case. The results are given in Table III.

The record in Fig. 7 is that of a rather highly strung professor, who had just been lecturing to a large audience; the record was made, moreover, in the presence of a number of

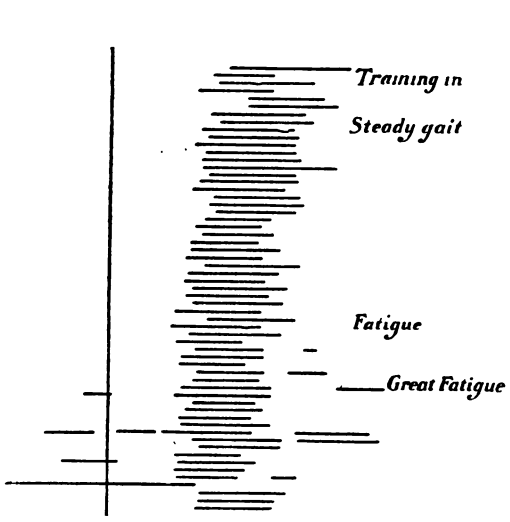

FIG. 6.

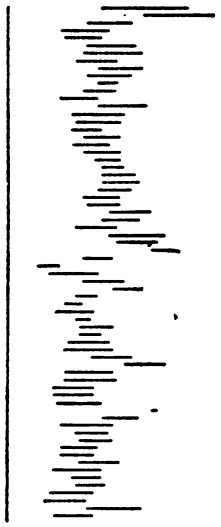

FIG. 7.

Reaction records, simple, normal.

visitors. The quick reactions and the sudden release of the key are characteristic of the person's energetic nervous temperament; the great irregularity represents the condition of nervous excitement. The results are given in Table IV.

In this record the results for the first ten are very irregular, owing to the factor of "training in." The next two tens are very regular. Thereafter great irregularity exists, showing the condition of fatigue and excitement.

The preceding records have been those of "simple reaction," that is, response to an expected stimulus of known character by the same movement.

TABLE IV (Fig. 7).—*Normal Person, S. Simple Reaction.*

	Average reaction.	Average variation.	Average holding time.	Average variation.
1st ten	0·20	0·04	0·14	0·03
2nd ten	0·17	0·03	0·10	0·02
3rd ten	0·21	0·02	0·09	0·01
4th ten	0·20	0·07	0·09	0·03
5th ten	0·16	0·04	0·10	0·02
6th ten	0·16	0·07	0·10	0·02
Last eight	0·13	0·04	0·11	0·02
Whole average	0·18	0·04 22%	0·11	0·02 18%

TABLE V (Fig. 8).—*Normal Person, M.*

	Average reaction.	Average variation.	Average holding time.	Average variation.
		Simple	*Reaction.*	
1st group, 1–23	0·19	0·03	0·10	0·02
2nd group, 24–39	0·15	0·01	0·11	0·02
3rd group, 40–56	0·15	0·02	0·09	0·01
Whole average	0·16	0·02 13%	0·10	0·02 20 %
		Complex	*Reaction.*	
Whole average	0·39	0·07 18%	0·10	0·02 20%

To introduce a more complicated mental condition, two stimuli were prepared as described above. The person was told to react with the right hand to one and with the left hand to the other. The subject was thus obliged to distinguish between the two objects, and to choose which hand he was to move. The two mental processes of discrimination and choice were thus added to the simple reaction. The lower part of Fig. 8 shows a record of such complex reactions to white and green lights. We note at once the enormous irregularity, and the long average. Contrasted with this is the record of the same person in the upper part of the figure, which shows the simple reaction time for the same person on the same

occasion. The average simple reaction time is scarcely more than one-third of the complex reaction time. The average variation is small. This man's holding time seems to be remarkably constant. The results are shown in Table V.

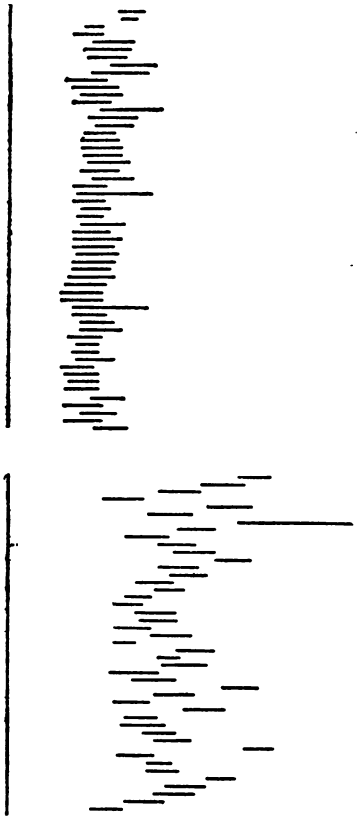

FIG. 8.—Reaction record, simple and complex, normal.

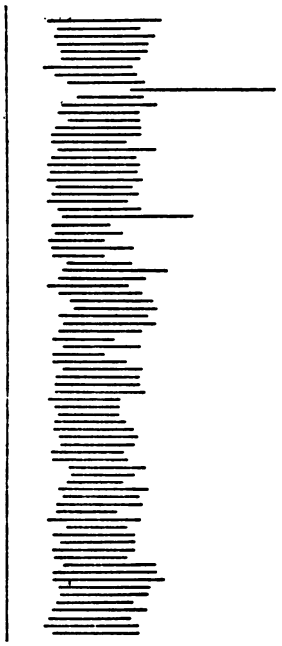

FIG. 9.—Reaction, record, simple, alcoholism, tense type.

V. *Records for Alcoholism.*

The records for alcoholism show three distinct types, all differing from the normal.

One type is that of persons who have been long addicted to alcohol, but who at the present moment are not markedly under its influence. Fig. 9 shows the simple reaction of a confirmed alcoholic who had been abstinent for three weeks. He held his muscles tense and reacted with great vigor; his

eyes and his expression showed fierce attention. For the eighty-two reactions the results were: average simple reaction, 0·14 sec., average variation, 0·02 sec. or 14 *per cent.*; average holding time, 0·22 sec., average variation 0·03 sec. or 14 *per cent.* His reactions were as quick and regular as those of the best normal subjects. This fact has already been observed by

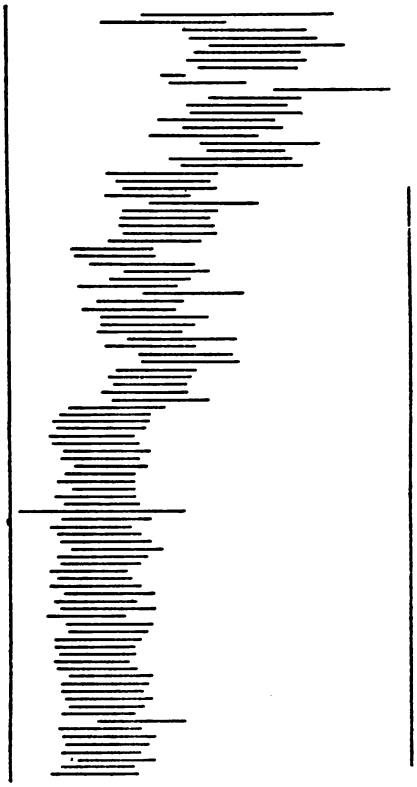

FIG. 10.—Reaction record, simple, alcoholism, sluggish type.

FIG. 11.—Reaction record, simple, alcoholism, disintegration type.

Nadler in the case of alcoholics.(1) There is practically no period of "training in" and no fatigue, although the test included eighty-two experiments. Such a record shows a state of abnormal excitement that may be called "alcoholic tension."

A different type is shown by the record in Fig. 10. The patient is a chronic loafer who lets his wife support him by washing. He drinks beer constantly. The sluggish condition is apparent in the very long reaction times and holding times

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at the start. He is gradually aroused; toward the close his record approaches the normal.

The reactions fall apparently into three groups. The first group is very long and irregular; it has an average reaction time of 0·47 sec. and an average variation of 0·06 sec. (13 *per cent.*). The second group has an average of 0·28 sec. and an average variation of 0·04 sec. (15 *per cent.*). The rest of the record is evidently the patient's "steady gait," with an average reaction of 0·14 sec. and an average variation of 0·02 sec. (14 *per cent.*). The mind in this case is dull and unresponsive, showing a condition of "alcoholic sluggishness."

A very different condition is that of a patient whose record is shown in Fig. 11. He had been four days on a spree, he could not sleep, and he felt that he was on the verge of delirium tremens. His record shows great irregularity. He frequently forgets to react at all. His average reaction is 0·44 sec.; his average variation is 0·11 sec. (25 *per cent.*). The condition expressed by this record we might term that of "alcoholic disintegration." The mind has difficulty in fixing its attention. It acts slowly and irregularly; it often makes mistakes.

A comparison of the results of alcoholics with those of normal persons indicates some rather striking conclusions. It may be suggested that the drinking of malt liquors like beers produces a sluggish condition of mind that is very unfavourable to clearness of thought and action. Further records may be expected to show that the habitual beer drinker is a much less efficient person than the abstainer. On the other hand, many records have shown that the whiskey drinkers respond with greater rapidity and precision than the normal person. This, however, has no bearing on the ultimate effect of whiskey on the nervous system.

VI. *Records for Hysteria.*

The mental inhibition characteristic of hysteria shows itself in the reaction records in great irregularity, unreliability, and hesitation. The hysterical person is keenly sensitive, and is quick to perceive, but the disturbed condition of mind prevents steady, consistent, decisive reactions.

One girl, æt. 19, came to the clinic complaining of her inability to speak above a whisper. Her voice was always like that of a hoarse, shrill whisper. Other symptoms of hysteria

were present. The diagnosis given was hysterical aphonia. In attempts to use the Jung association experiments she would sit motionless; when asked why she did not respond with a word she would answer that she was only thinking of the word given. Her voice returned upon an occasion when the physician put his finger into her larynx. Her reaction records are given in Figs. 12 and 13. The average simple reaction was 0·36 sec. with an average variation of 0·08 sec. or 22 *per cent.* The average complex reaction time was 0·55 sec., with an average variation of 0·40 sec., or 73 *per cent.*; the average complex

FIG. 12.—Reaction record, simple, hysteria.

holding time was 0·72 sec., with an average variation of 0·55 sec., or 76 *per cent.* Both the simple and the complex reaction times and the holding times were longer and more variable than in the case of normal persons. The patient complained of her eyes troubling her. She sometimes gazed vacantly, and apparently did not wake up to the light until after an interval; this reminds us of the vacant waiting condition during the association experiments. These results differ very greatly from those in the normal records. The intermission of action and the irregularity are characteristic of hysteria.(2)

A patient, æt. 18, had a peculiar hysterical cry. Her record, Fig. 14, shows the characteristics of hysteria. The average

simple reaction time was 0·31 sec., with average variation of 0·12 sec., or 39 *per cent.*; this is much longer than the normal and very much more irregular. The same is true of the average holding time, 0·44 sec., with an average variation of 0·15 sec. or 34 *per cent.*

A man, æt. 28, had paralysis and tremor which copied the condition of an old man seen ten years ago by the patient. His record of simple reaction gives an average reaction of 0·63 sec., and an average variation of 0·20 sec. (32 *per cent.*) ; an average holding time of 2·00 sec., and an average variation of 1·14 sec. (57 *per cent.*)

Such records with long average times, great irregularity, hesitation, and mistakes are what would be expected from a person preoccupied by some thought. The mental condition in hysteria consists in mental disturbance by an emotional complex which has been pushed out of consciousness but which still makes itself felt: the distraction is by a mental factor that is not in consciousness. This distraction produces delay and uncertainty in action.

VII. *Records for Epilepsy.*

The records of a number of epileptics may be illustrated by the following three cases:

A patient, æt. 25, had been an epileptic for twenty years. He had just had a fit in the clinic. His voice showed the typical epileptic speech.(3) His record for a simple reaction is shown in Fig. 15. The record is characterised by a reaction time of 0·50 sec.; this is long when compared with the normal reactions which range round 0·20 sec. The holding time, 0·78 sec., is also much longer than normal.

These facts seem to be connected with the well-known mental sluggishness of the epileptic. The fact that the holding time is very much longer at the start, and becomes shorter at the end, seems to indicate that the mind is gradually aroused from its sluggishness. The average variation for the reaction time is 0·16 sec. (32 *per cent.*) ; this is also very large when compared with that of normal cases. The average variation of the holding time, 0·55 sec. (65 *per cent.*), is likewise very large. There seems to be a great difference between the first and last parts of the record. The first part, with a reaction time 0·44 sec. (average variation of 0·12 sec. or 27 *per cent.*), and holding time of 1·26

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sec. (average variation of 0·69 sec., or 55 *per cent.*) shows a condition of more steady sluggish mentality. The latter part, which has a reaction time of 0·55 sec. (average variation, 0·17 sec., or 31 *per cent.*), and a holding time of 0·28 sec. (average variation, 0·57 sec., or 49 *per cent.*), gives evidence of fatigue and perhaps strain.

A patient, æt. 31, had her first fit two and a quarter years ago, and her last fit one year ago. There was no apparent mental deterioration. Her record, as shown in Fig. 16, indi-

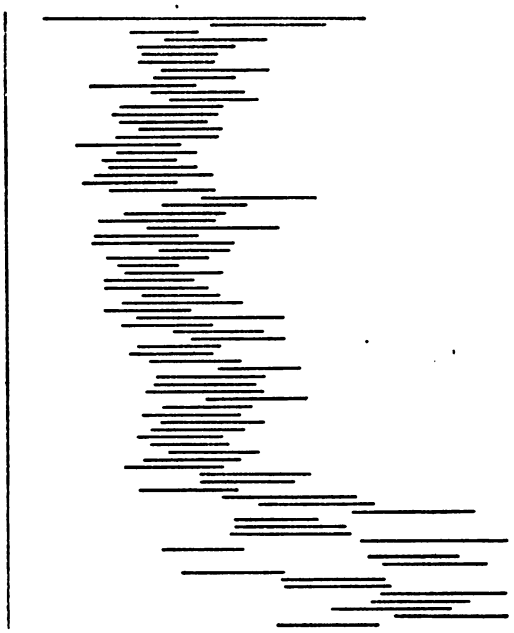

FIG. 16.—Reaction record, simple, epilepsy.

cates three periods like that of a normal person, namely, "training in," "steady gait," and "fatigue." There is a marked difference from the normal in the long time of reaction, and in the long time of holding; the fatigue is also far more marked than in any normal patient. The measurements gave the averages: simple reaction, 0·43 sec. (average variation, 0·16 sec., or 37 *per cent.*).

A patient, æt. 43, had had fits for ten years. Two fits had occurred during the previous week. Her reaction time, Fig. 17, showed great lengthening and great irregularity as compared

with those of a normal person. The measurements gave the averages: simple reaction, 0·47 sec. (average variation, 0·10 sec., or 21 *per cent.*); holding time, 0·22 sec. (average variation, 0·05 sec., or 23 *per cent.*).

The mental sluggishness and readiness to fatigue of the epileptic are characteristics strikingly brought out in these

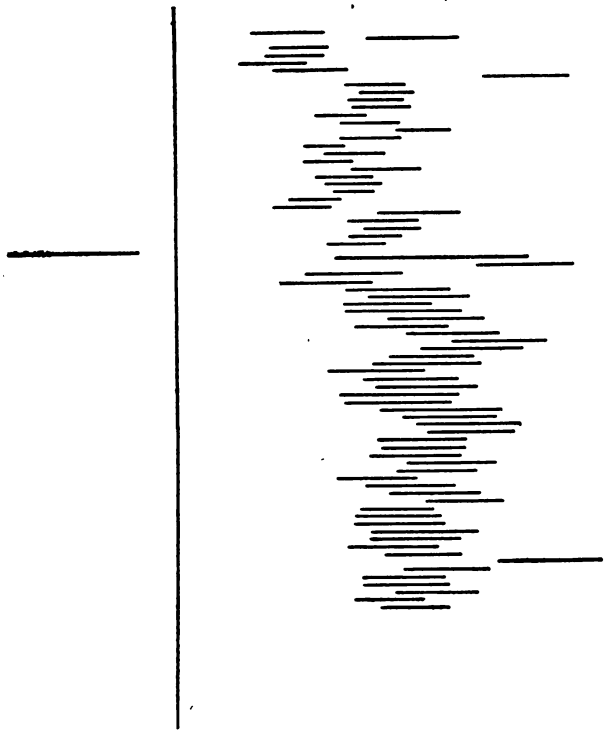

FIG. 17.—Reaction record, simple, epilepsy.

records. The unreliability of the hysterical person, the various mental states of the alcoholic, all give different types of records none of which could be due to such slow and deliberate mental processes as in the case of epilepsy. Even the sluggish alcoholic does not show such deliberateness, especially in the holding time.

The history of the patient often leaves doubt whether the trouble is epilepsy or hysteria. All the well-known symptoms of epilepsy have been counterfeited in some cases of hysteria.

It is quite probable that no condition of hysteria can give up its own natural distracted form of reaction, and adopt the sluggish epileptic form.

VIII. *Records for General Paralysis.*

General paralysis, or progressive paralysis, is characterised by gradual deterioration of the mental powers; there is loss of memory, deficiency of attention, apraxia, etc. Response to a signal is probably as simple a mental problem as any that could be presented.

The patient, J. K—, æt. 35, first noticed his thickened speech and mental dulness two years ago. His record (Fig. 18) gives an average reaction time of 0·47 sec., with average variation of 0·09 sec. (19 *per cent.*); this is about twice the length of a normal reaction time. The holding time, 1·08 sec., with average variation of 0·46 sec. (43 *per cent.*) is extremely long and irregular.

When the disease is in a more advanced stage the characteristics become more marked, as is seen in the record of P., Fig. 19, whose average reaction is 1·24 sec., with an average variation of 0·62 sec. (50 *per cent.*), and an average holding time of 0·99 sec., with average variation of 0·47 sec. (47 *per cent.*). The broken line in the figure is a record of the tremor.

The resemblance between these records and some of those for epilepsy seems to be an indication of the common factor of mental deterioration. It would be interesting to know if similar results are obtained in other conditions of mental degeneracy.

IX. *Comparison of Results.*

The averages for each of the cases reported above are given in the table on p. 719.

X. *Conclusion.*

The life of an organism consists of reactions, or responses to stimuli. Different organisms, and different conditions of the same organism, give different responses. Different nervous and mental conditions show themselves by different responses to sensations.

The preceding investigation had as its object to develop a technique for the simplest kind of reaction in such a way that a result could be obtained quickly and visibly. The ordinary

reaction time technique gives the results in figures; here the whole reaction picture is presented directly to the eye, with no necessity for measurements.

TABLE VI.—*Summary.*

Type.	Figure.	Kind of Reaction.	Reaction Time.			Holding Time.		
			Average time.	Average variation.	Relative variation.	Average time.	Average variation.	Relative variation.
					Per cent.			Per cent.
Normal . .	4	Simple .	0·18	0·02	11	0·18	0·02	11
„ . .	5	„	0·18	0·03	17	0·16	0·02	13
„ . .	6	„	0·21	0·05	23	0·23	0·05	22
„ . .	7	„	0·18	0·04	22	0·11	0·02	18
„ . .	8	„	0·16	0·02	13	0·10	0·02	20
„ . .	8	Complex	0·39	0·07	18	0·10	0·02	20
Alcholic . .	9	Simple .	0·14	0·02	14	0·22	0·03	14
„ . .	10	„	0·30	0·04	14	0·25	0·03	12
„ . .	11	„	0·44	0·11	25	0·65	0·09	14
Hysteria . .	12	„	0·36	0·08	22	0·62	0·14	23
„ . .	13	Complex	0·55	0·40	73	0·72	0·55	76
„ . .	14	Simple .	0·31	0·12	39	0·44	0·15	34
Epilepsy . .	15	„	0·50	0·16	32	0·78	0·55	65
„ . .	16	„	0·43	0·16	37	0·26	0·04	15
„ . .	17	„	0·47	0·10	21	0·22	0·05	23
General Paralysis	18	„	0·47	0·09	19	1·08	0·46	43
„ „	19	„	1·24	0·62	50	0·99	0·47	47

The few diseases already studied show marked reaction types even for simple forms of reaction. It should be quite possible to develop more complicated forms of reaction whose variations will give diagnoses directly in the records. In other words, it is my belief that the reaction test can be made so complete and reliable that a diagnosis of epilepsy, hysteria, general paralysis, etc., can be obtained as surely and accurately as one of diabetes or chronic nephritis from a urinary analysis.

I may be permitted to say that these researches form part of a larger scheme for studying the manifestations of nervous and mental disease in various ways. The variations in speech, which are studied by means of records, show similar results to those recorded here.

(1) Nadler, "Reaction Time in Abnormal Conditions of the Nervous System," *Studies Yale Psychol. Lab.* (Scripture), 1897, vol. iv, p. 1.—(2) Nadler, as before.—(3) Clark and Scripture, "The Epileptic Voice Sign," *New York Med. Record*, 1908.

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