The Clinical Measurement of Fatigue. PART I.—*The Measurement of Mental Fatigue.* By WILHELM SPECHT, of Tübingen University. (From Prof. Kraepelin's Psychological Laboratory in the Heidelberg Lunatic Asylum.) With twenty-four figures in the text. Authorised Translation from the German, revised by THOMAS JOHNSTONE M.D.Edin., M.R.C.P.Lond.

(*Continued from p.* 570, *Vol.* LII.)

The Measurement of Fatigue in Traumatic Neuroses.

WE have already pointed to the great practical importance of the measurement of fatigue in traumatic neuroses. It is particularly important for our purpose because, as we have already observed, exaggerated fatigue is always present in this disease, and so it gives the best opportunity of testing the general applicability of our method to the clinical measurement of fatigue.

Many years ago Gross (1) and Röder (2) measured fatigue in traumatic neuroses by the method of continuous addition. They made use of periods of work lasting half an hour, half an hour's addition without any pause being done daily for several consecutive days. Gross calculated the amount of fatigue from the diminution of the work done in the second quarter of an hour, stated as a percentage of the work of the first quarter of an hour, and also from a comparison of the first quarter of an hour of the second day with the second quarter of an hour of the first day. By comparing the work values of his patients with the corresponding work values of a large number of healthy subjects, Gross discovered that his patients' liability to fatigue considerably exceeded the "limits of health," and also that the absolute amount of work performed by them was far below the normal values. These results were afterwards confirmed by Röder, who applied the same method to a larger number of patients.

Gross himself was conscious of the error inherent in his method of calculating the amount of fatigue. Yet it cannot be denied that the method has a certain utility, especially if the amount of work done in each separate section of five minutes is recorded. In cases where the liability to fatigue is

extraordinarily great, it will make itself known in a continuous decrease in the work performed. We recognised the significance of such a course of work when discussing the experiments made by Oehrn and Weygandt. On the other hand, we are fully persuaded that experiments with a pause form the only means by which anything like a satisfactory measurement of fatigue is possible.

The patients we employed in our experiments were kept under observation for a considerable time, partly in the Insane Hospital and partly in the Medical Hospital of Heidelberg, and were found to be suffering from traumatic neuroses, free from all complications. The following brief accounts are taken partly from the hospital notes made on these patients and partly from my own observation:

P—, (3) æt. 64, belt-maker and clerk to the Guardians of the Poor. Formerly perfectly healthy. In 1897 was in a railway collision. Slight external injuries. Great fright, much excited, fainted. Has been changed ever since. Very forgetful, depression, monotonous train of thought, hasty temper, very loquacious. Reduced capacity for work at his business. Highly exaggerated liability to fatigue. Examined by Gross in 1898; the same disturbances. Practically unchanged in 1903.

B—, æt. 56, grinder. Luetic infection in 1867; always healthy in other respects. Accident, 1891, open wound on forehead. Not unconscious. Wound healed well. Subsequently neuralgic pains radiating from the scar, especially on physical exertion. Almost entire incapacity for work in consequence of this. Change of character since that time. Irritable to the point of fits of wild rage, sullen, mentally indolent, weak of will. Increased liability to fatigue. Numerous hysterical symptoms. Practically no improvement in capacity for work so far.

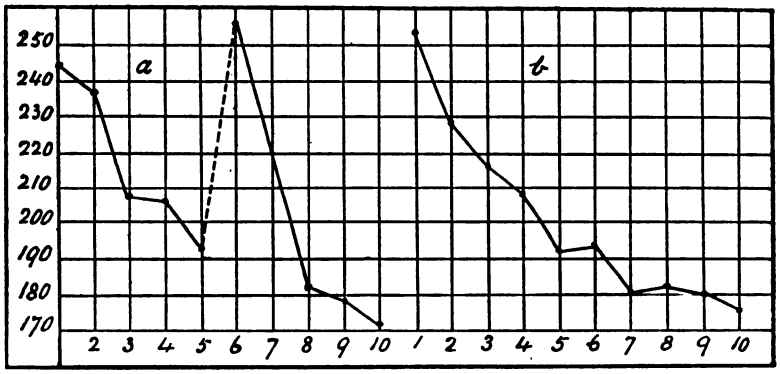
Pf—, æt. 42, whitewasher. Formerly healthy. Fell on his head in 1900, unconscious for a short time. Open wound, soundly healed. Able to work in a few days. Changed ever since. Felt tired, was irritable, and apathetic, grew worse a year later. Giddy feeling, hysterical attacks. Left off working, was very quiet, lived "as if in a dream." Difficulty in comprehension, timidity, increased liability to fatigue, great reduction of mental and physical capacity for work. Practically no improvement since.

J—, æt. 48, carter. Insane heredity, formerly healthy. Struck by lightning and thrown to the ground in 1902, not unconscious; paralysed on right side. Quick recovery from paralysis; very timorous since then; afraid of thunderstorms. Quiet, shy disposition, feeling of incapacity, hypochondriacal direction of thoughts. Capacity for work at occupation reduced, increased liability to fatigue.

T—, mason, æt. 49. Lungs at one time transitorily affected healthy in other respects. A series of accidents since 1886 some resulting in considerable external injuries; never unconscious; capacity for work only temporarily impaired; last accident in 1901; broke some bones in the face; not unconscious. Numerous nervous troubles since then; depressed and tearful mood, irritable, timorous, taking no interest in those around him, quite devoid of will-power; capacity for work completely lost; increased liability to fatigue; hysterical symptoms.

M—, vintager, æt. 48. Formerly healthy. Ill health since 1899. Fall in a cellar on his left side in 1900. No external injuries; severe dyspnœa, attacks of pain since then in the region of the heart, with giddiness, breathlessness, and a "feeling of annihilation." Depressed, irritable, tearful. Hypochondriacal loss of will-power; incapacity for any mental or physical occupation; increased liability to fatigue. Hysterical tachypnœa up to 52 respirations a minute. Numerous other hysterical stigmata.

Fig. 18.



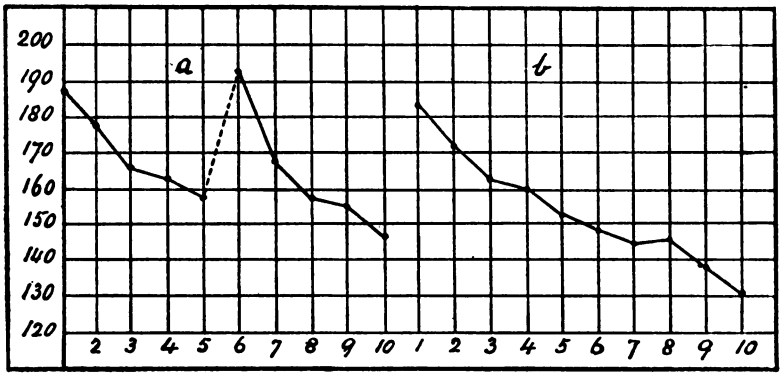
Work-curves of Patients.

SUBJECT P—.—In its general course, curve *a* much resembles that of Subject 17, who was so very liable to fatigue. The rate of work decreases continuously from the first minute to the pause. But while in Subject 17 there were obvious signs of impulse in the first and fifth minutes, it is hardly possible to discover in P— any influence of an exertion of the will in the amount of work done. Only from the third to the fourth minute does the curve show a less abrupt fall. Even here the subject is unable to increase his performance of work by the exertion of his will. After the pause the rate of work is higher at first than at any previous time. As the course of the curve seems to show that the work of the sixth minute was not affected by impulse, we may assume that the fatigue so far disappeared during the pause, that the persistent effect of practice prevailed at first over the effect of the fatigue remaining. From the comparatively high starting-point after the pause the curve falls very abruptly, and by the eighth minute the rate of work is lower than at any time before the pause. Thus the pause has at first had a purely favourable influence on the course of the work through its restorative effect, but the restorative effect itself has been extremely fugitive.

Curve *b* falls abruptly from the first to the fifth minute without changing its general course. It rises a little in the sixth minute, then falls again and follows a more horizontal course until the tenth minute. Curve *a* also shows a change of direction, which takes place at the eighth minute. It is probable that the work done in these last sections of the course was partly influenced by impulse, but we cannot attribute the more horizontal course of both curves in the last few minutes, especially the course of curve *b* from the sixth minute onwards, exclusively to this cause. We knew that the exertion of the will can only be kept up for quite a short time, and that it seldom lasts for more than a minute, but the more horizontal course of curve *b* continues for several minutes. We must rather explain the course of this curve, which changes its direction from the fifth minute onwards, by supposing that the fatigue of the subject increased very quickly at the beginning of the work, but reached a point in the fifth minute beyond which it increased only slowly.

Co-efficient of practice = 235 ~ 257 = + 11·1 *per cent.*
Additions in I 5′ ~ Additions in II 5′ (with pause)
= 1083 ~ 1007 = − 7·1 *per cent.*
Additions in I 5′ ~ Additions in II 5′ (no pause)
= 1110 ~ 913 = − 17·9 *per cent.*
Difference = 10·8 *per cent.*
5′ ~ 6′ (with pause) = 192 ~ 257 = + 33·8 *per cent.*
5′ ~ 6′ (no pause) = 191 ~ 192 = + 0·5 *per cent.*
Difference = + 33·3 *per cent.*
Co-efficient of fatigue = − 25·8 *per cent.*
Total additions = 2193.
2′ ~ 10′ = − 24·1 *per cent.*

FIG. 19.



SUBJECT B—.—Both curves resemble those of Subject P— in their general course, but the difference in the absolute performance of work must be noticed. Curve *a* sinks continuously from the first minute until the pause, and there are no signs of impulse. In the first minute after the pause the rate of work is higher than at any previous time. Here, too, the persistent effect of practice prevails over the effect of the fatigue remaining. But by the second minute after the pause the values have fallen again considerably. The influence of impulse in the sixth minute is excluded, if we consider the fact that in the whole course of both curves, with the exception of the very slight rise in the eighth minute of curve *b*, there are no signs of an effort of the will to be found. As in Subject P—, the amount of work done after the pause is far less than that of

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the work done before it, as the result of great fatigue. Here, too, the pause has at first had a good effect on the work, through its restorative action, but the subject has not recovered from his fatigue sufficiently for the persistent effect of practice, even though reinforced by fresh practice acquired during the second half of the experiment, to prevail over the effect of fatigue. With the exception of the trifling rise in the eighth minute, curve *b* never alters its direction, a fact pointing to great susceptibility to fatigue in the subject. It is remarkable that this curve starts from a rather lower point than curve *a*. As the experiments in which the work is done without a pause come a day later than the experiments with a pause, we should have expected them to have a higher starting-point, as the result of the advance of practice, as is the case with all the other subjects. We must suppose that this subject had little capacity for retaining practice.

Co-efficient of practice = 179 ~ 193 = + 7·8 *per cent.*

Additions in I 5 ~ Additions in II 5′ (with pause)
= 852 ~ 821 = − 3·7 *per cent.*

Additions in I 5′ ~ Additions in II 5′ (no pause)
= 831 ~ 709 = − 14·7 *per cent.*

Difference = 11·0 *per cent.*

5′ ~ 6′ (with pause) = 158 ~ 193 = + 22·1 *per cent.*

5′ ~ 6′ (no pause) = 153 ~ 148 = − 3·3 *per cent.*

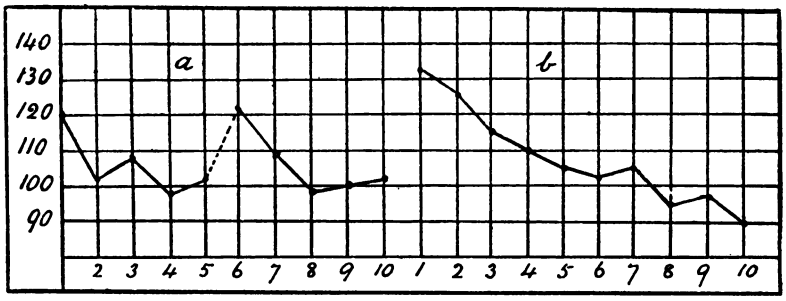
Difference = 25·4 *per cent.*

Co-efficient of fatigue = − 20·8 *per cent.*

Total additions = 1683.

2′ ~ 10′ = − 24 *per cent.*

Fig. 20.



Subject Pf—.—The absolute performance of work is extraordinarily small. Curve *a* shows fluctuations which must be

interpreted as signs of impulse. The subject said himself: "I tried again and again to add together more figures." It is hard to tell how far the difference between the performances of the first and second minutes was affected by a greater exertion of the will in the first minute. In curve *b* there are no signs of impulse in the first minute. It is possible that the subject set to work in a different way, according to whether the experiment was to be made with or without a pause, and that the prospect of a speedy ending led him to a greater exertion of his strength. The work was certainly influenced by impulse in the last minute before the pause. On the other hand, the uniform downward direction of curve *a* from the sixth to the eighth minute does not favour the supposition that the subject worked with a special effort of the will after the pause.

Co-efficient of practice = 103 ~ 121 = + 17·4 *per cent.*

Additions in I 5′ ~ Additions in II 5′ (with pause)
= 528 ~ 529 = + 0·1 *per cent.*

Additions in I 5′ ~ Addition in II 5′ (no pause)
= 584 ~ 491 = − 16·0 *per cent.*

Difference = 16·1 *per cent.*

5′ ~ 6′ (with pause) = 102 ~ 121 = + 18·6 *per cent.* (too small)

5′ ~ 6′ (no pause) = 116 ~ 113 = − 2·9 *per cent.*

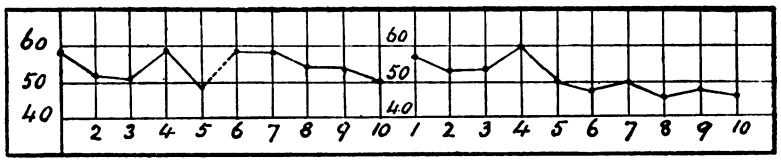
Difference = 21·5 *per cent.*

Co-efficient of fatigue = − 28·1 *per cent.*

Total additions = 1112.

2′ ~ 10′ = 124 ~ 90 = − 27·5 *per cent.*

FIG. 21.



SUBJECT J—.—We have only an eight-day series with Subject J—. As the increase of practice gradually diminishes in the course of the experiments, and is, therefore, greater on the first than on any subsequent day, we must remember, in dealing with the average values, that they may be more influenced by the effect of practice than those obtained from a twelve-day series of experiments.

If we calculate the reduction of work done in the second five minutes of the individual days without a pause as a percentage of the work done in the first five minutes, we arrive at the amount 6·8 *per cent.* less on the second day, 13·5 *per cent.* less on the fourth day, 12·7 *per cent.* on the sixth day, and 19·1 *per cent.* on the eighth day. From this we see that the diminution of work in the second part of the experiment has, on the whole, increased from day to day. This deterioration is to be explained by the circumstances that the fresh gain of practice diminishes with the increase of the amount already gained, and that the effect of fatigue is thus more able to make itself felt. If the experiments had been continued for twelve days, the effect of fatigue would presumably have been still more evident.

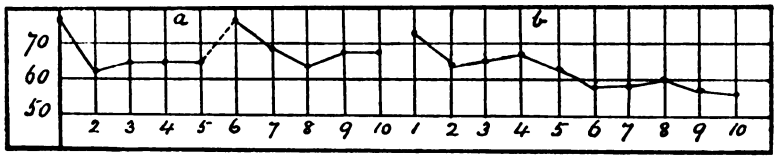
Both curves show a very horizontal course on the whole, the highest and lowest performances of work in the individual minutes differing only by fifteen additions. But we must bear in mind that the absolute performance is extraordinarily small, and that the smaller the number of figures added up in a minute the smaller will be the absolute amount of the fluctuations. It is only from this point of view that we can judge the fluctuations of the curve correctly. Curve *a* falls from the first to the second minute. We must not suppose the fall to be an expression of fatigue; it is more likely that the work-value of the first minute and also that of the fourth minute are affected by an effort of the will. There are no signs of impulse to be found in the fifth and sixth minutes either on the days with or without a pause.

The total performance of the first five minutes of all eight days amounts to 542 additions. It appears from the list of experiments that the performance of the first five minutes was about the same from the sixth to the eighth day. Seventy-one additions were made on the sixth day and seventy-four on the eighth day. The better to compare the absolute performance of this patient with that of the other subjects of experiment, it will be well to add to the performance of the first eight days the amount of work that would presumably have been done in the four days that are missing. Assuming that the subject would have made an average of seventy-four additions in the first five minutes of each day, the total performance for twelve days would have amounted to about 840 additions.

Co-efficient of practice = 53 ~ 59 = + 11·3 *per cent.*

Additions in I 5′ ~ Additions in II 5′ (with pause)
= 271 ~ 276 = 1·80 *per cent.*
Additions in I 5′ ~ Additions in II 5′ (no pause)
= 271 ~ 235 = − 13·3 *per cent.*
Difference = 15·1 *per cent.*
5′ ~ 6′ (with pause) = 49 ~ 59 = + 20·4 *per cent.*
5′ ~ 6′ (no pause) = 50 ~ 47 = − 6·0 *per cent.*
Difference = 26·4 *per cent.*
Co-efficient of fatigue = − 21·9 *per cent.*
2′ ~ 10 = 54 ~ 46 = − 14·9 *per cent.*

FIG. 22.



SUBJECT T—.—The absolute performance is even less than that of the patient J—, amounting to an average of only twelve additions in a minute. The curves take a horizontal direction. The fall from the first to the second minute in both curves, and again the fall immediately after the pause, make a strong contrast with this horizontal course. How are these falls to be explained? In the first place, they might depend on impulse at the beginning of the work. In that case the patient must have begun work with a great exertion of will, for the reduction of work in the second minute amounts to 19·3 *per cent.* of the work done in the first minute. Now, the patient's whole mental behaviour during the experiment was in contradiction to the idea that his work could be influenced by a strong effort of the will. He was very slow and clumsy in his movements, apathetic, languid, and devoid of all initiative. Again, if the patient had begun his work with a great exertion of his will, we should have expected that other obvious signs of impulse would be found, but there are none to be seen. The sinking of the curves might also be a result of fatigue. But if the fatigue had reached so high a degree in the second minute as to cause a deterioration in the work to the amount of 19·3 *per cent.*, the curve must at least have shown a further fall in its general course. This is not the case, for it is almost horizontal.

To explain the remarkable course of the curve, we may appeal to experiments made with this patient on the ergograph. With the object of measuring the fatigue caused by physical work, the patient was told to make a series of pulls of 5 kilograms at regular intervals of one and a half seconds. The first pull was quite successful, but the second pull raised the weight a considerably smaller distance than the first, and subsequent pulls had hardly any effect. The weight, which was raised about 3·5 cm. by the first pull, only rose about 1 cm. at the third. But instead of the patient's showing a still further loss of strength, all his subsequent pulls had about the same result as the third, and he made thirty more attempts without the occurrence of any material change in the height of the lift. All the encouragement to lift the weight higher given him by the conductor of the experiment was without effect. A fresh experiment was made after a pause of thirty minutes, beginning with a weight of 4 kgm., with almost exactly the same result. The weight was lifted the full height at the first pull, while at the second the height of the lift diminished to precisely the same extent as in the first experiment, and remained at about the same level afterwards. Eventually we reduced the weight to 1 kgm., but still with a repetition of the results of the first experiment.

There can be absolutely no doubt that the nature of the patient's work on the ergograph was not determined by physical fatigue. If the reduction in the lift from 3·5 cm. to 1 cm. during the first three pulls had been due to the effect of fatigue, that would have implied the exhaustion of the muscles, and the patient would not have been able to continue his work as he did. That the work always deteriorated in the same way, independently of the size of the weight, also shows that the deterioration was not due to fatigue. We must rather suppose that we have to deal with a severe disturbance of a mental nature which affected the patient's capacity for work. We might explain this disturbance, to a certain extent, by saying that, following the sense of exertion which belongs to the first stroke of work, a hampering sense of incapacity springs up and destroys, or very greatly impairs, the capacity for work. The feeling of incapacity may exist from the first, when the work will be feeble from the very beginning, or it may be increased by the sense of exertion, and then the performance of work

will decrease and adapt itself more or less exactly to the degree of capacity which the patient still feels that he possesses.

In the same way we may explain the patient's mental work-curves by a sense of impediment. The poor initial performance points to the presence of the impediment from the first. But the sense of impediment is increased by the exertion of adding up, and the work performed is reduced to the amount of which the patient still feels capable. As extraordinarily little work is done, there is no occasion for any great results of fatigue to make themselves felt; the pauses between the separate additions are so long that the patient always has time for recovery. On the other hand, even this small amount of work, if continued for a considerable time, may produce a degree of fatigue that will have some effect, especially in a person very liable to fatigue. The sense of fatigue may at first increase the feeling of impediment only to a certain degree, in which case the work-curve will fall at first and then follow a horizontal course for some time after, or if the fatigue increases continuously, it may produce a continuous increase in the feeling of impediment, and in that case the amount of work done will decrease continuously.

Curve *b* takes an almost horizontal direction from the second to the fourth minute, then falls until the sixth minute, and remains at about the same height from that point to the end. It is quite possible that the impediment is increased by the sense of fatigue and that the subject settles to the rate of work of which he still feels capable. From this point of view we might assume that the decrease in the rate of work for the second five minutes of the days without a pause is due to the effect of fatigue. But it is questionable if the difference between the two work-values immediately before and after the pause can be employed to estimate the amount of the fatigue. Curve *a* is almost horizontal from the second minute to the pause, and such a course gives no indication of fatigue. The rise in the curve after the pause might be explained by supposing that the feeling of impediment, so far as it had been increased by the work done in the first minute, disappeared during the pause, so that the patient went on again with the same rate of work as at the beginning. We found, in the case of his work on the ergograph, that the weight was raised considerably higher by the first pull after the pause than by the last pull

before the pause, although this difference in the height of the lift did not depend on the effect of fatigue.

As the patient's capacity for work was influenced permanently and in a high degree by the effect of the impediment, we should, of course, expect the other influences that usually act on the course of work to make but little impression on the work done by him, yet we cannot fail to recognise that he has made some advance in practice during the experiments. While he made 45 additions in the first minute on the first day, he made 56 on the twelfth day. The average daily advance in practice, however, only amounted to 0·8 additions.

As the decrease in the rate of work for the second five minutes on the days without a pause is apparently due to fatigue, we may use the difference between the work-values of the two sections of five minutes to help us in estimating the effect of the fatigue. But here, too, we must remember that the rate of work was influenced by the effect of the mental impediment, and that the fatigue was, therefore, felt only in a slight degree. But for the result of the impediment, the effect of the fatigue would probably have been very much greater. For the reasons already given, none of the other work-values are of any use for the measurement of fatigue.

Co-efficient of practice = 63 ~ 78 = + 23·8 *per cent.*

Additions in I 5′ ~ additions in II 5′ (with pause)
= 337 ~ 337 = ± 0 *per cent.*

Additions in I 5′ ~ additions in II 5′ (no pause)
= 329 ~ 286 = − 13·1 *per cent.*

Difference = 13·1 *per cent.*

5′ ~ 6′ (with pause) = 65 ~ 78 = + 20·0 *per cent.*

5′ ~ 6′ (no pause) = 62 ~ 57 = − 9·6 *per cent.*

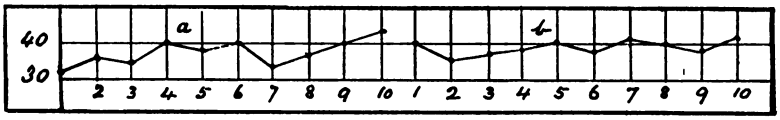
Difference = 29·6 *per cent.*

Co-efficient of fatigue = − 29·0 *per cent.*

Total additions = 664.

2′ ~ 10′ = − 12·5 *per cent.*

FIG. 23.



SUBJECT M—.—A ten-day series of experiments. The work-

curves of this patient may be considered parallel to those of the patient T— in their general character. The features common to both are the extraordinarily small absolute performance of work and the horizontal, sinuous course of the curves. But while in the case of the patient T— the rate of work falls considerably from the first to the second minute and from the fifth to the sixth minute, and then remains on the same level in the experiments with a pause, but gradually sinks still further in the experiments without a pause, both the work-curves of the patient M— show that the performance of work improved continuously, in however slight a degree, during the experiment. The work-values of the sixth minute of the experiments with a pause and the first minute of the experiments without a pause are, however, rather higher than the corresponding values of the seventh and second minutes. Whether the fall has the cause that we assumed in the case of the patient T—, or is due to accidental influences, must remain uncertain. At any rate, the general direction of these two curves is upward. The amount of the absolute performance of work, which is even smaller than in the case of Patient T—, shows that the patient's capacity for work is reduced to a minimum. Here, too, we must assume an impediment of mental origin as the cause of the reduction. The impediment, which increases still further during the work in the patient T—, is greater here at the beginning of the work than in its subsequent course. It does not disappear, but its effect on the course of the work is weakened by the action of practice in facilitating the work and possibly by that of momentum. The patient made an average of about eight additions a minute. With this small performance of work, fatigue had no effect, or so slight an effect that it was more than covered by the opposite effect of practice. The effect of practice also appears in the improvement in the rate of work from day to day. Thirty-seven additions were made in the first five minutes on the first day and forty-three on the tenth day. The average daily increase of practice was equivalent to 0·6 additions, or 1·6 *per cent.* of the performances of the first day.

As both work-curves are free from signs of fatigue, we cannot determine the amount of its effects, even approximately, from the work-values of the patient. Neither can we form any idea of the patient's capacity for practice. The result of practice

can indeed be seen, but here, too, we must assume that it is hidden to a great extent by the effect of the impediment. In order to compare the amount of this patient's absolute performance directly with the performance of the other patients, it will be well to count up the additions which he would presumably have made on the eleventh and twelfth days. In the first five minutes of the eighth, ninth, and tenth days he made 43, 40, and 43 additions. If we assume that he would have made about 42 additions on the eleventh and twelfth days, we obtain 455 additions as the total performance in the first five minutes of all twelve days.

In order to present the peculiar course of the work, determined as it is by the effect of the impediment, in an arithmetical statement, we have calculated the patient's work-values. The only figures that we can apply to our particular purpose are those of the total number of additions and of the average daily advance in practice.

Co-efficient of practice = 35 ~ 38 = + 8·7 *per cent.*
Additions in I 5′ ~ additions in II 5′ (with pause)
= 180 ~ 193 = + 7·2 *per cent.*
Additions in I 5′ ~ additions in II 5′ (no pause)
= 190 ~ 202 = + 6·3 *per cent.*
Difference = 0·9 *per cent.*
5′ ~ 6′ (with pause) = 38 ~ 39 = + 2·6 *per cent.*
5′ ~ 6′ (no pause) = 40 ~ 39 = − 2·5 *per cent.*
Difference = 5·1 *per cent.*
Co-efficient of fatigue = − 1·9 *per cent.*
2′ ~ 10′ = 35 ~ 41 = + 17·1 *per cent.*

Comparison of the Work-Values of Healthy Subjects and of Patients.

Comparison of the results of our experiments on healthy subjects showed that the amounts of the work-values of which we could avail ourselves for the measurement of fatigue were extraordinarily different in different people. If we should speak of the "bounds of health" in reference to the highest and lowest work-values of healthy subjects, we might place Subjects 2 and 3 upon the upper boundary and Subjects 12 and 16 on the lower. (4) The work-values afforded by Subject 17 differ but little in amount from those of the healthy subjects most liable to fatigue. We may conclude from this that the liability

of healthy subjects to fatigue varies within wide bounds, and that it may reach a degree not far removed from the highly-exaggerated susceptibility to fatigue seen in Subject 17. This subject felt himself so much affected by his extreme liability to fatigue as to be incapable of strenuous mental work, even for a short time. As the liability of Subject 17 to fatigue must be regarded as morbidly exaggerated, and yet this subject is placed, with respect to his work-values, at the upper limit of the bounds of health, it does not seem to be unconditionally necessary that patients who complain of great susceptibility to fatigue should be far removed from the upper limit of the bounds of health. We may rather assume that here, as everywhere else, the transition from health to disease is not fixed, but that there are all sorts of gradations between the liability to fatigue of healthy and morbid subjects.

In Table III we have collected the work-values we obtained from all the healthy subjects, from Subject 17, with his great liability to fatigue, and also from the patients; 1 to 11 are twelve-day series, 12 to 16 eighteen-day series. In Column *j* the figure above the line gives the performance in the first five minutes of the first day, and the figure below the line gives the total performance in the first five minutes of all twelve days. The figures in Column *k* show the amount of the average daily acquisition of practice as a percentage of the performance in the first five minutes of the first day.

In Column *a* the highest values within the bounds of health are + 25·4 and + 22·9. Both these values are affected by impulse and have come out too high. The highest value uninfluenced by impulse, as far as we can tell, is the + 17·8 of Subject 3. Subject 17, who is very liable to fatigue, has the figure 20. Hence the figure 33·8, belonging to the patient P—, goes considerably beyond the limits of health. In Column *b* the values are quite irregularly positive or negative. But even if we neglect the error due to impulse in all the subjects, including the patient P—, he shows by far the greatest difference in Column *c*.

In Group *d*, the values fluctuate in Subjects 1 to 17 between − 0·4 and + 12·3. In Subject 2 we found that the reduction in the performance of work after the pause indicated great liability to fatigue. Here P— comes far below the worst values of the healthy subjects, with − 7·1. On the days without a pause

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TABLE III.*

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*
Subject.	5′ ~ 6′. With pause.	5′ ~ 6′. No pause.	Difference.	I ~ II. With pause.	I ~ II. No pause.	Difference.	Co-efficient of practice.	Co-efficient of fatigue.	2 ~ 10. No pause.	Total additions.	Advance in practice.
1	+ +25·4	−1·4	26·8	+ 1·3	− 7·0	8·3	+ +10·3	+ −13·2	−14·4	119/2366	+ 8·4
2	+ +22·9	−2·7	25·6	− 0·4	− 8·9	8·5	+ +11·1	+ −17·95	−13·9	201/3112	+ 4·7
3	+17·8	+ +3·1	14·7	+12·3	− 0·5	12·8	+17·8	−15·52	* −8·5	111/2781	+15·1
4	+ +19·3	+ +1·5	17·8	+ 3·9	− 5·0	8·9	+ 9·3	−13·4	* −4·3	242/4087	+ 6·3
5	+ +17·4	−0·5	17·9	+10·3	− 0·8	11·1	+ +12·5	+ −11·73	− 1·7	234/4127	+ 6·3
6	+16·5	−0·7	17·2	+ 5·8	− 6·2	12·0	+11·1	−15·51	−11·3	185/4348	+10·1
7	+13·4	+ ±0	13·4	+ 3·3	− 4·1	7·4	+ 9·7	−12·5	− 6·3	233/4083	+ 5·5
8	+10·0	−3·8	13·8	+ 2·4	− 7·3	9·7	+ 5·3	−11·8	* −6·6	177/3545	+ 8·9
9	+ 9·0	+ +0·2	8·8	+ 5·6	− 2·4	8·0	+ 9·0	− 8·8	* +0·9	213/4039	+ 7·6
10	* +4·9	−2·6	7·5	+ 1·9	− 5·1	7·0	+ 3·7	− 8·3	* −0·5	296/4412	+ 2·7
11	* +3·5	+ +2·1	1·4	+ 2·5	− 6·3	8·8	+ 6·8	−12·1	* −2·0	116/2003	+ 6·9
12	+ 9·1	−1·7	10·8	+ 3·3	− 1·2	4·5	+ 6·2	− 6·8	− 2·6	313/5749	+ 7·3
13	+13·3	−2·7	16·0	+ 3·4	− 6·5	9·9	+ 3·4	− 9·4	− 6·6	222/4344	+ 8·0
14	* +6·1	±0	9·9	+ 7·8	− 2·1	9·9	+ 5·1	− 7·7	* −3·0	87/3488	+29·6
15	+15·9	−1·1	17·0	+ 6·3	− 4·7	11·0	+ +14·9	+ −17·0	* −2·2	177/3797	+12·0
16	+10·0	+ +1·5	8·5	+ 0·9	− 2·5	3·4	+ + 7·9	+ − 9·5	* −1·7	254/4298	+ 5·0
17	+20·0	+0·7	19·3	+ 2·4	−11·1	13·5	+ 7·9	−16·6	* −13·0	198/4076	+ 8·4
P.	+33·8	+ +0·5	33·5	− 7·1	−17·9	10·8	+11·1	−25·8	−24·1	169/2193	+ 1·4
B.	+28·4	−3·3	31·7	− 3·7	−14·7	11·0	+ 7·8	−20·8	−24·0	129/1683	+ 1·5
Pf.	* +18·6	−2·9	21·5	+ 0·1	−16·0	16·1	+17·4	−28·1	−27·5	89/1112	+ 1·6
J.	+20·4	−6·0	26·4	+ 1·8	−13·3	15·1	+11·3	−21·9	−14·9	55/840	+ 4·0
T.	+20·0	−9·6	29·6	± 0	− 13·1	13·1	+23·8	−29·0	−12·5	46/664	+ 1·7
M.	+ 2·6	−2·5	5·1	+ 7·2	+ 6·3	0·9	+ 8·7	− 1·9	+17·1	37/454	+ 1·6

* + = too high; * = too low. *Cf.* the separate descriptions of the work-curves.

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(Column *e*) Subject 2's performance of work has fallen 8·9 *per cent.* and Subject 17's 11·1 *per cent.* below their performance in the first five minutes. With these compare P—, with his enormous reduction of 17·9 *per cent.* In Column *f*, Subject 17 shows the greatest difference, with 13·5 *per cent.* P—, with 10·8 *per cent.*, would seem, at first sight, to come within the limits of health, but we have shown that in this case we cannot judge of the amount of the fatigue from the amount of the difference. The difference in the rate of work, according to whether there has been a pause or not, is comparatively small in the case of P—, because a considerable amount of fatigue remained even after the pause. P— did, however, recover to a great extent, as is shown by the increase in the value of his work in the sixth minute (Column *a*), and a large amount of his fatigue disappeared during the pause, but his recovery was only momentary. His rate of work was much reduced by the eighth minute—indeed, it was then below the rate of the fifth minute. It is because P— recovers far less from his fatigue during the pause than do the other subjects, and because the useful effect of the pause is far less in his case than in theirs, that the absence of the pause has not as bad an effect on the course of his work as it has on that of subjects whose fatigue disappears more completely during the pause. Moreover, as we have already shown, fatigue in his case reaches an extraordinarily high degree in the first five minutes, and its further advance takes place only slowly. Subject 17, in spite of his great liability to fatigue, always recovered so much better than P— during the pause, that the persistent effect of practice, reinforced by the practice freshly acquired, prevailed over that of fatigue. For this reason, the effect of the pause on the course of work made itself felt in a higher degree in his case than in that of the patient P—. That P—'s pure capacity for practice is no less than that of the other subjects is clear from the fact that in spite of his incomplete recovery during the pause, his work-values of the sixth minute are considerably higher than those of the second, and even of the first. Accordingly, we see that his co-efficient of practice is of normal amount. It is possible, indeed, that it may have come out too low, as the work done in the sixth minute may still have been affected by fatigue. Even so, the co-efficient of fatigue which we have calculated for P— with the help of his co-efficient of practice, is very

much higher than that of Subject 17, for all his liability to fatigue. P—'s great susceptibility to fatigue also appears very clearly in the difference between the work-values of the second and tenth minutes (Column *i*).

The absolute performance of the healthy subjects in the first five minutes of all twelve days varies from 2003 to 5749 additions. Their average performance is about 4000 additions. P—, with 2193 additions, shows a worse total performance than any of the healthy subjects but one, but his performance on the first day, amounting to 169 additions, is high compared with the work of those healthy subjects who also show a small total performance. From this we may conclude that P— made but little advance in practice in the course of the experiments. The average daily increase of practice, stated as a percentage of the performance of the first day, varies in the healthy subjects from 2·7 *per cent.* to 29·6 *per cent.*, the second greatest increase being 15·1. The extent of these variations is remarkably large, but it is explained by the facts that in Subjects 14 and 3 the first day's performance is unusually small—it is very likely that accidental influences have been at work here—and that the total performance of Subject 10 is extraordinarily great. Subject 10, at the time of the experiments, had for a long time been in the daily habit of solving arithmetical problems, and so began them with a high degree of practice; that is why his daily advance in practice comes out so small. P—, with his daily advance of 1·4, is far below the average values of the healthy subjects, a sign that his power of retaining practice was extraordinarily small.

Here it must be remembered that in P— the persistent effect of the practice in addition, that he had formerly had, both as a clerk and during the experiments made on him by Gross, cannot safely be left out of consideration. On the other hand, we must consider that he gave up his clerkship in 1897, and that Gross's experiments were made in 1898. At any rate, even if we cannot quite overlook the persistent effect of this practice, in spite of the length of time that has elapsed, it is not sufficient, by itself, to explain his small advance in practice. Even Subject 10, who had practised the solution of arithmetical problems up to the time when the experiments on him were begun, shows an average daily acquisition of practice equal to 2·7 *per cent.* of his performance at the beginning of the experiment.

The course of work shown by the patient B— is very similar to that of P—, but his work-values are on the whole rather smaller. They, too, fall quite outside the limits of health. The difference between the values shown in *d* and *e* is, again, smaller than in Subjects 5, 6, and 17, although the reduction in B—'s performance of work in the second five minutes on the days without a pause is considerably greater than the reduction in that of Subject 17. It would appear from the reduction in the performance on the days when there was a pause that considerable fatigue remained after the pause in this patient also. In spite of incomplete recovery during the pause, 4·8 *per cent.* more work was done in the sixth minute than in the first. Hence the capacity for practice does not seem to have been much impaired in B—.

Like his other work-values, B—'s co-efficient of fatigue indicates that his liability to fatigue was rather less than that of P—. Only in column *i* do both show the same reduction of work. The work of the first five minutes of the first day of experiment is within the limits of health and is greater than in four of the healthy subjects. The corresponding performance for all twelve days, however, is much smaller than that of Subject 11, who has the worst performance among the healthy subjects. The proportion between the performance on the first day and the performance on all twelve days points to only a small advance in practice. The average daily increase of practice is, in fact, only 1·5 *per cent.* of the performance on the first day. This shows the patient's small capacity for retaining practice.

In the patient Pf— the increase in the work of the sixth minute over that of the fifth minute on the days without a pause is smaller than in Subjects 1, 2, 4, and 17, but we were able to discover from his work-curves that the value of work in the fifth minute was increased by a final impulse. Consequently, the difference between the work of the fifth and sixth minutes does not give a correct picture of the patient's liability to fatigue. For the same reason the difference between the figures in columns *a* and *b* is valueless. In the five minutes after the pause (Column *d*) the performance improved a little, though only by 0·1 *per cent.* of the performance in the first five minutes; the effect of practice and the effect of the fatigue remaining very nearly balanced one another. On the days, how-

ever, when the work was done without a pause, it deteriorated even more than in the case of the patient B—. The dependence of the effect of the pause upon the degree of fatigue is very well seen in Pf—, as his performance after the pause was not subject to the same degree of fatigue as that of the two first patients. In spite of the fact that the reduction of work in the second five minutes is smaller than in P—, the difference shown in Column *f* is far greater. From this we may conclude that Pf— is unusually susceptible to fatigue, but is more capable of recovery than the two other patients. His co-efficient of practice has come out extraordinarily high, although we cannot discover any signs of impulse in the sixth minute. It is, however, conceivable that his performance in the second minute has come out too small because he began the work with an effort of will and then flagged in the second minute. We cannot be sure about this. The high co-efficient of practice has, of course, affected the co-efficient of fatigue, which may, perhaps, also have come out too high. Yet the high figures in Columns *f* and *i* also indicate that Pf— is extraordinarily liable to fatigue. The work of the first five minutes of the first day is about the same as that of Subject 14, but in that subject the work shows a great improvement from day to day, and a total performance of 3488 additions is finally reached, while Pf—'s total performance is considerably less than that of the patient B—. His capacity for retaining practice is very little greater than that of the two other patients.

The work-values of Patient J— are derived from an eight-day series of experiments. We have already pointed out that the effect of practice has a greater preponderance over that of fatigue in the first few days of an experiment than in the last. Consequently, the effect of fatigue is not so clear in the case of the patient J— as it would be in a twelve-day series. In spite of this, J— has higher figures in almost all the columns even than Subject 17. His performance of work on the first day and the total performance, which we have calculated for twelve days, are remarkably small. Both these values are considerably smaller than those of the patient Pf—. On the other hand, his average daily acquisition of practice is greater than that of any other patient or of Subject 10. Here too, however, we must remember that J— only worked for eight days, and that the improvement of his work by practice therefore shows up better

than that of the other subjects. At the same time, his acquisition of practice is less than that of any healthy subject, if we exclude Subject 10 for the reasons previously explained.

We have already expressed our opinion as to the impossibility of using the work-values of the patients M— and T— for the measurement of fatigue. We are not justified in inferring from these values the amount of the fatigue, because the course of work was principally determined by influences constituting an impediment. Only in the case of T— can we find signs of fatigue in the course of the work. Here the work deteriorates in the second five minutes, on the days without a pause, to the extent of 13·1 *per cent.* of the work of the first five minutes. This shows that T— was very liable to fatigue. On the other hand, we may regard it as certain that his real liability to fatigue was considerably greater than is shown by the course of his work, because the effect of the fatigue was concealed by that of the impediment. His absolute performance on the first day was even smaller than that of the patient J—. In the course of the twelve days of experiments it improved very little —only two additions a day.

Signs of fatigue are entirely absent from the course of work in the case of the patient M—. There were such long pauses between the separate additions that fatigue could have no effect upon the amount of work done. But while in T— the effect of the impediment increased as the result of the sense of effort, we can see from the work-curves of the patient M—that his rate of work improved a little under the helpful influence of practice and possibly also of momentum. This explains why he did more work in the second five minutes than in the first (Column *e*) even on the days without a pause. We can also point to a very small advance in practice during the whole series of experiments.

The patient's total performance amounts to 454 additions; that is to say that M— made an average of $\frac{454}{12 \times 5} = 7{\cdot}5$ additions a minute. Considering that the worst performance of the healthy subjects, that of a simple workman, amounted to $\frac{2003}{12 \times 5} = 33$ additions a minute, and the best to $\frac{5749}{12 \times 5} = 95$ additions a minute, we can easily see that M—'s capacity for work was as good as annihilated.

Briefly to sum up the results of those last experiments, we

have discovered, in the first place, that the patients P—, B—, Pf—, and J— are highly susceptible to fatigue. We had found that the liability to fatigue of Subject 17 only slightly exceeded the ordinary bounds of health, but nevertheless we had reason to suppose that it was morbidly exaggerated. Of the patients, J— comes nearest to Subject 17 in his work-values, yet there is a greater difference in their degree of susceptibility to fatigue between J— and Subject 17 than between Subject 17 and the most easily fatigued of the healthy subjects. We must also consider that J—'s work-values were taken from an eight-day series of experiments. The work-values of the other patients differ so much in their amount from those of healthy subjects, and even from those of Subject 17, that we are justified in assuming their liability to fatigue to be far greater even than that of the very susceptible Subject 17. With this extreme liability to fatigue is associated a diminished power of recovery. In all the healthy subjects, except in the single case of Subject 2, we have found that even great fatigue was so far recovered from during the pause, that the effect of practice could completely prevail over the remaining effect of fatigue. In contrast to this, the power of recovery of the patients P— and B— is extremely defective. In Pf— and J— the restorative effect of the pause was rather more favourable, but even in their case there was reason to assume that a great deal of the fatigue remained after the pause.

While the patients' pure capacity for practice does not seem to have been much reduced, it appears that their performance of work improved only very little from day to day. Their power of retaining practice must therefore be extremely small. Only in J— was the daily increase of practice rather greater, and even in his case it was less than in the case of those of the healthy subjects who showed least power of retention, if we neglect Subject 10, with whom no comparison can be made. Finally, comparison of the absolute amounts of work performed showed that the difference between the work of the first and second five minutes without a pause was always very much reduced in the patients.

In the case of the patients T— and M—, we were not able to estimate the liability to fatigue with any accuracy. The reduction of T—'s rate of work in the second five minutes (Column *e*) gave us grounds for supposing that he was very

easily fatigued. The true extent of his liability to fatigue may, however, have been far greater than appeared. In both patients the effects of fatigue were concealed by the effects of impediment. The absolute performance of T— and M— was so small, that we may conclude that their power of work was almost entirely lost.

The Detection of Intentional Simulation.

In dealing with our patients, we were able to exclude the possibility of intentional simulation or exaggeration of the disturbances of which they complained, because their clinical observation precluded all doubt as to the real existence of their illnesses. But even had this unfailing source of information not been available, there are other considerations which make it improbable that the patients tried to cheat in their experimental work. Complicated as are the influences which determine the direction of the work-curve, we have always been convinced that there are certain invariable laws regulating the course of work and the mutual relations of the figures obtained by the comparison of the work-values. We were never able to discover that our patients' continuous work had been done in a way which contradicted the results of our other experiments, or that the comparative values obtained from them were different in their mutual relations from the values obtained from healthy subjects.

To set the applicability of our method to patients suffering from the results of accidents absolutely beyond the reach of objection, we must be able to give a satisfactory answer to the question whether it is not possible for a malingerer simulating great fatigue to observe these invariable laws which govern the course of work so accurately as to escape detection.

To decide this question, which is one of extraordinary practical importance, we have had some experiments carried out in the wilful simulation of abnormal fatigue. Three of the four subjects of experiment were familiar with the behaviour of the work-curves, while the fourth, who was a young lady, entered on the experiments quite unprepared and without any previous knowledge of the course of work. Each series consisted of six daily experiments. For three of the subjects the arrangements were exactly the same as we have employed elsewhere, but in

two series of experiments, which I made myself, I altered the conditions to a certain extent. The arithmetic books are printed with ten vertical columns of equal length on each page, each column containing thirty-six figures. As each minute's work is marked off by a stroke of the pencil, it is not very difficult to compare the work of the separate minutes, as the experiment goes on, so as to form an approximate idea of the number of figures one has added up in a minute, and to add the number, more or less, which one has pre-determined in the following minute. If one knew exactly how the course of work must change from minute to minute to reproduce the changes which take place in the case of patients suffering with abnormal liability to fatigue, it is conceivable that the simulation might be successfully carried out by this means. In order to deprive myself of this means of comparison I struck out a piece of different length in each column. As I had expected, this made it impossible to measure the amounts of work done in each minute, even approximately, with the eye or to compare them with one another.

TABLE IV.

	1	2	3	4	5	6	7	8	9	10	11	12
Subjects.	With pause. 15 M. / 11 5 M.	No pause. 15 M. / 11 5 M.	1 M. / 5 M.	1 M. / 2 M.	With pause. 6 M. / 7 M.	No pause. 6 M. / 7 M.	With pause. 1 M. / 6 M.	No pause. 1 M. / 6 M.	With pause. 5 M. / 6 M.	No pause. 5 M. / 6 M.	No pause. 2 M. / 10 M.	Advance in practice.
P.	− 7·1	− 17·9	− 23·3	− 7·1	− 13·2	− 6·3	+ 4·8	− 24·5	+ 33·8	+ 0·5	− 24·1	+ 1·4
B.	− 3·7	− 14·7	− 16·2	− 5·7	− 13·7	− 2·8	+ 3·2	− 19·6	+ 28·4	− 3·3	− 24·0	+ 1·5
Pf.	+ 0·1	− 16·0	− 18·2	− 10·7	− 10·0	+ 2·9	+ 0·8	− 23·2	+ 18·6	− 2·9	− 27·5	+ 1·6
J.	+ 1·8	− 13·3	− 13·2	− 6·2	±0	+ 4·2	+ 1·7	− 16·1	+ 20·4	− 6·0	− 14·9	+ 4·0
Dr. B.	− 3·5	− 24·6	− 38·4	− 13·1	− 14·7	+ 3·3	− 2·6	− 31·1	+ 75·1	− 32·9	− 46·9	− 1·4
Dr. St.	− 8·3	− 10·4	− 33·6	− 24·9	− 25·5	− 1·6	− 7·1	− 25·3	+ 38·8	+ 13·1	− 22·8	− 2·1
Frl. S.	− 26·5	− 37·6	− 50·4	− 24·9	− 25·5	− 3·0	− 25·4	− 51·6	+ 52·5	− 5·6	− 52·0	− 8·8
Dr. Sp. *a*	− 9·2	− 18·0	− 28·3	− 11·5	− 13·0	− 1·2	− 6·3	− 28·1	+ 34·5	+ 3·5	− 25·5	+ 4·0
Dr. Sp. *b*	− 14·2	− 24·3	− 27·4	− 26·0	+ 9·1	+ 3·2	− 23·1	− 38·2	+ 59·7	+ 8·4	− 3·5	− 2·9

Table IV shows the results of the experiments, together with the corresponding work-values of the four patients P—, B—, Pf—, and J—. Columns 1, 2, 9, 10, 11, and 12 correspond to Columns *d*, *e*, *a*, *b*, *i*, and *k* in Table III.

We will first consider the work-values of the subject Dr. B—. In Column 1 the amount by which the work of the second five

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minutes, on the days with a pause, differs from that of the first five minutes, is stated as a percentage of the work of the first five minutes. In this column Dr. B— shows the value of — 3·5 *per cent.*, about the same diminution of work as is found in the case of the patient B—. But while the greatest reduction among the patients on the days without a pause was only 17·9 *per cent.*, Dr. B— shows a reduction of 24·6 *per cent.* The difference between the work-values of the patients and Dr. B— becomes still more striking when we consider their work-values in Columns 3, 9, 10, and 11. No further comment is necessary; the figures themselves show, beyond all question, that Dr. B— has greatly overacted his part. In the other columns also, *e.g.* in Columns 4 and 8, which show the difference between the work-values of the first and second minutes on all twelve days and the difference between those of the first and sixth minutes on the days without a pause, he has considerably higher figures than the patients, but the differences are not so pronounced here as in Columns 9, 10, and 11. While the work of the sixth minute on the days without a pause is only 6 *per cent.* less than the work of the fifth minute (Column 10) in the patient J—, Dr. B— shows a reduction about five times as great. The deception is also completely exposed by the fact that the rate of work does not improve from day to day, but grows worse (Column 12). The advance in practice in a genuine case is certainly small, but it can never be a negative quantity.

Dr. St— has not, on the whole, overacted his part to the same extent as Dr. B—, but this makes the want of proportion between the separate comparative values all the more striking. Considering that his work in the second five minutes, on the days with a pause, is 8·3 *per cent.* worse than the work of the first five minutes, the diminution in the second five minutes, on the days without a pause, is far too small. We should have expected to find a considerably higher figure in Column 2, while the reduction of work we see in Columns 3, 4, 5, and 9 is remarkably great. The disproportion between the comparative values is even more obvious in Column 10. In this column, in which the difference between the work of the fifth and sixth minutes, on the days without a pause, is calculated as a percentage of the work of the fifth minute, we should have expected the preponderance of the effect of fatigue over that of practice to result in a reduction of work in the sixth minute, or

if the patient worked with impulse here, to allow, at the very most, a trifling increase. The increase of 13·1 *per cent.* can only be explained as a falsification of the results. Finally, the work grows less from day to day in the case of this subject also, and even in a higher degree than in that of Dr. B—.

Dr. B— and Dr. St— were both acquainted with the laws regulating the course of work. The next subject, Fraülein S—, had no such knowledge. The results of her experiments are therefore, for obvious reasons, of special interest for the detection of wilful simulation. It may be added that she was a lady of unusual intelligence, and had carefully considered her plan of simulation beforehand.

The results of her experiments bear throughout the mark of the most extreme exaggeration, and there are also remarkable contradictions in the mutual relations of the comparative values. That the subject was very far from being able to observe the invariable laws which regulate the whole course of work is made particularly clear by the way in which the work varies from day to day. The work of the first five minutes on the six consecutive days amounts to 125, 95, 85, 82, 66, and 65 additions—that is, it deteriorates progressively from day to day by an average of 8·8 *per cent.* of the work done on the first day. The subject has entirely omitted to take account of the factor of practice in her work.

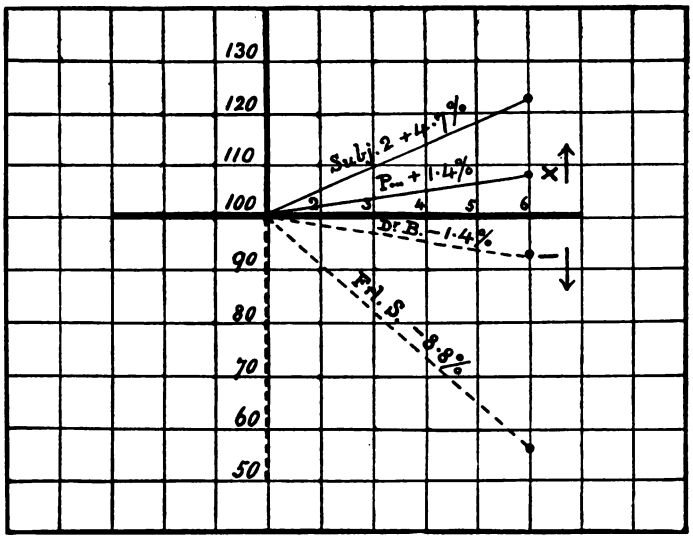
In the following figure (Fig. 24) we have tried to give a graphic representation of the gain or loss of practice simulated in wilful deception and its disagreement with the invariable relations found in patients and in healthy subjects.

The days of experiments 1 to 6 are marked on the horizontal line, and the daily increase of practice stated as a percentage of the work of the first day, is shown on the vertical line. If the point of intersection of the vertical and horizontal lines is connected with the co-ordinate points a straight line is obtained, representing a linear function, the angle of which is determined by the gain or loss of practice. In this way we have represented the advance in practice, or the reverse, of Subject 2, with an average daily gain of 4·7 *per cent.* of the work of the first day, of the patient P— with a gain of 1·4 *per cent.*, and of Dr. B— and Fraülein S— with a loss of 1·4 *per cent.* and 8·8 *per cent.* respectively. As P— shows the least advance in practice of all the patients, and Subject 2 the least of all the healthy

subjects, excluding Subject 10 for the reasons previously given, the curves of the other patients would fall between the curve of Subject 2 and that of the patient P—, and the curves of all the healthy subjects between that of Subject 2 and the vertical. In other words, they would rise considerably above the horizontal line. The curves of the subjects who have simulated abnormal fatigue fall, on the contrary, below the horizontal, thus departing from the necessary and invariable course of the curves. Thus the deception becomes obvious.

It is sufficiently proved by the experiments we have described

FIG. 24.



that not even an accurate knowledge of the nature and effect of the various influences governing the course of work can enable anyone to simulate abnormal fatigue without betraying his intention by extreme exaggeration and gross disproportions between the comparative values. If the attempt is to succeed at all, the subject must not only have an exact idea of the way in which the amount of work done changes from minute to minute in the special case of patients suffering from increased liability to fatigue, but must also be able to make the exact number of additions that he intended every minute. I knew myself, from my study of their curves, how the work that my patients did varied in every separate minute. I was therefore in a position

to calculate exactly, before the experiment, how many additions I must make in every minute in order to produce changes in the course of the work corresponding in all their details with those which occurred in the work done by my patients. The principal difficulty was this: I had in the first place to count the additions I made as I went on, and secondly, to estimate the time when the minute would come to an end. The first condition was particularly hard to satisfy, for, as I have explained, I had made it impossible to tell the number of additions I had made from the length of the columns. I therefore had recourse to marking the seconds by a regular movement, practised beforehand, of one of the fingers of my left hand, which was imperceptible to the person conducting the experiment, and tried to make the additions in time with this movement. As I had expected, I succeeded fairly well, after long practice, in marking the seconds correctly. It was more difficult to count the movements and make the additions simultaneously, but this, too, I practised for a considerable time.

It appears from the results set down in Table IV (Dr. Sp—, *a*) that my work-values corresponded fairly well with those of the patients, and that the advance in practice, in particular, was pretty well imitated. On the other hand, a closer inspection shows a disproportion between the comparative values. It seems unnecessary to point out that the employment of so complicated a method would hardly occur to any malingerer. Still, I thought it worth my while to take into account the possibility even of so elaborate an attempt at simulation.

I also made a second series of experiments to see what form the course of work would take when the subject was not able, as I had been, to compare the work of the separate minutes, and the use of my complicated method was impossible.

The work-value in the very first column (Dr. Sp—, *b*) shows that I exaggerated considerably, and the same conclusion must be drawn from the values in Columns 2, 3, and 4. Besides this, there is a gross contradiction between the values in Columns 3 and 4. If the reduction of work amounted to 26 *per cent.* between the first and second minutes, it must have been very much greater by the fifth minute. The falsification evident here also appears in the values of the following columns. In Column 5 we find a great reduction of work between the fifth and sixth minutes in the case of all the first three patients, and only in

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that of J— are the values equal. I ought to have had a minus quantity here, since the work should have decreased from the sixth to the seventh minute as the result of great liability to fatigue.

The last three work-values also are evidently falsified. In Column 10 P— shows the trifling increase of 0·5 *per cent.*, and that only because he worked with an effort of will in the sixth minute. The impulse could only produce a very small improvement in his work, because the effects of fatigue had already gained too great an influence over the course of the work. I, who seemed, according to my other work-values, to be even more susceptible to fatigue than P—, ought to have been able to make very little improvement, or none at all, in my values, even if I worked with impulse in the sixth minute. Finally, the slight reduction in my work from the second to the tenth minute is a gross contradiction of my other work-values, and the minus quantity in Column 12 is opposed to the principles which determine the growth of practice.

It is clearly and incontrovertibly proved by the results of these five sets of experiments that we are able to detect intentional simulation by our method. Even those subjects who are fully acquainted with the laws that regulate the course of work are betrayed at once by their extreme exaggeration of the susceptibility they would simulate, and by a disproportion between the comparative values.

There is still a possible mode of simulation which we must consider to complete our discussion of the subject. We have seen in the case of our patients P— and M— that the absolute amount of work they did was extraordinarily small, and that the number of additions hardly varied from minute to minute or from day to day. Although it is altogether improbable that anyone about whom there was a question of simulation would know the details of such a course of work as was performed by these two patients, the possibility cannot be excluded with absolute certainty. In such a case, it is conceivable that the malingerer might try to make his work resemble theirs—that is, to make about eight additions in every minute. The attempt would not be difficult to carry out in itself. But it must be observed, in the first place, that even the work of these two patients followed certain laws in its course, as is shown more especially by their regular advance in

practice. Secondly, and here is the difficulty, such a course of work as we met with in patients T— and M— is only possible when the work comes under the influence of a very severe impediment. Where an impediment of this kind is actually present, the general clinical picture is such as to leave no room for doubt about the reality of the morbid disturbances. From this it follows that, in the case supposed, there would not be the slightest difficulty in detecting the imposition.

Recapitulation.

The object of this work has been to discover a method by which it might be possible to measure fatigue clinically. The method itself is based on the results obtained by Kraepelin from his preliminary investigation of the influences determining the course of work. The accurate comprehension of the composition of the work-curve is an indispensable preparation for the use of the method of continuous work for the purpose of measuring fatigue. Our method has, therefore, been developed in close dependence on the work of Kraepelin and his pupils. To measure fatigue in our patients we had first to obtain comparative values from healthy subjects. With this object we carried out experiments, lasting for twelve or eighteen days, on a considerable number of healthy people. By this means we discovered that the amount of liability to fatigue existing in healthy people is very variable, and that the liability may reach an extraordinarily high degree even within the bounds of health. We have tested the usefulness of the method in the clinical measurement of fatigue by applying it to patients in whom greatly increased liability to fatigue is a regular symptom. Our comparison of the work-values of healthy subjects and of patients has brought to light the fact that the patient's liability to fatigue is considerably greater than that of the most susceptible healthy subjects. We were able to present the difference in a series of arithmetical statements. From all this we may draw the conclusion that the method has made good its claims, and, therefore, may be applied to the object of clinically measuring fatigue.

For determining the amount of the effects of fatigue we had a number of comparative values at our disposal in each individual case. The difference between the work-values of the fifth and sixth minutes, on the days with a pause, and the

difference between the differences in the work of the first and second five minutes, on the days with and without a pause, were particularly useful for our purpose. We had expected that these two comparative values would correspond to one another. In many cases they did not, but we were able to show from the work-curves that the amount of the values of the fifth and sixth minutes was affected by impulse in many people. We were also convinced that the amount of the effects of fatigue could not be discovered from the difference between the work on the days with and without a pause in the case of people whose work showed a diminution in the second five minutes, even on the days when there was a pause. The reason for this was that, in such people, great remains of fatigue persisted after the pause, and its useful effect was, therefore, unable to make itself felt to the same extent as if there were more complete recovery from fatigue. These two facts explained the apparent contradiction between the comparative values in an absolutely satisfactory way.

The fact that the amount of the difference between the differences in the work of the two periods of five minutes, on the days with and without a pause, cannot be employed in such a case to determine the amount of the fatigue does not particularly increase the difficulty of measurement. The great decrease in the work of the second five minutes, on the days both with and without a pause, points at once to great liability to fatigue. The error arising from impulse, which more or less affects the work-values of the fifth and sixth minutes, on the days with a pause, may also be neglected, as a rule. But where the separate comparative values are out of proportion to one another it will be as well to consider the possibility that the values of the fifth and sixth minutes may be influenced by impulse, and this can best be done by reference to the work-curve. Examination of the work-curve affords the best means of judging if the work has been affected by impulse.

Of the other comparative values we have employed for determining the amount of fatigue, the co-efficient of fatigue, as we have calculated it, is perhaps the least reliable. It is true that we found certain points of agreement to exist between it and the other comparative values, and that it was always greater in the patients than in the healthy subjects; but as it could only give an approximate and very inexact idea of the true amount of the

effects of fatigue, while the other comparative values have proved to be sufficient without it, one might give up calculating it. On the other hand, the value which we calculated from the difference between the work-values of the second and tenth minutes, on the days without a pause, has proved to be extremely useful.

The results we have obtained from our experiments are derived from series of twelve, or occasionally of eighteen, days. We continued the experiments for this length of time because, on first testing the method, it was important to obtain the most reliable average values possible and the least affected by accidental influences. Very probably shorter experiments, continued for a few days only, will be sufficient to determine the amount of the effects of fatigue in a perfectly reliable way.

The measurement of fatigue in traumatic neuroses in particular has shown that the patients' liability to fatigue is greatly increased, that they have very little power of recovery, and that their capacity for work is much reduced. Their capacity for practice does not seem to be much impaired, but the traces of practice disappear extraordinarily quickly, their power of retaining practice being very small.

In the case of two patients it was impossible to determine their liability to fatigue in arithmetical terms, but we were able to discover that their work was affected by a severe psychogenic impediment, which had practically destroyed their capacity for work.

Finally, the method has to the fullest extent made good its claim to be a means of detecting intentional simulation. We were able to prove with certainty that it was impossible, even with an accurate knowledge of the laws which govern the course of work, intentionally to alter one's way of working for the purpose of malingering so as to observe these laws without any contradictions. Intentional simulation is at once betrayed by its extreme exaggeration of the morbid disturbances it imitates and by the disproportions between the comparative values.

(1) Kraepelin's *Psych. Arb.*, vol. ii, p. 577.—(2) *Münchener med. Wochenschrift*, 1898, No. 49.—(3) *Cf.* Gross, *Ibid.* P— is the same patient in whom Gross measured fatigue.—(4) *Cf.* Table III.