A NEUROLOGICAL TEST FOR STUTTERERS.*

By

ROBERT WEST, WISCONSIN.

INTRODUCTION.

THE psychological and medical worlds are now fairly generally aware of the theory that dysphemia† (stuttering) is often caused by an experience or series of experiences that produce an emotional set or feeling-pattern, usually (a feeling) of social inadequacy. The appearance of the symptom of incoördination of speech in situations in which this feeling of social inadequacy is most strongly elicited has been regarded as good evidence as to the cause of the disorder. Plenty of cases of marked and definite 'inferiority-complex,' however, show no stutter at all. Many cases, also, show dysphemia without any discoverable inferiority feelings, or any other emotional problems or disorders clearly distinguishing them from the non-stutterer. It seems, therefore, as though there were another factor in the etiology of dysphemia in addition to these psychogenic conditions—another factor that may or must combine with these emotional habits to produce the dysphemia. The present writer has been attempting to secure an objective measure of this unknown. He presents statistics on 64 cases, with the suggestion that we have, by means of the test here described, at least a distant view of the organic or structural factors in the stutterers' problem. The direction of his study was partly suggested by the fact that certain cases of dysphemia (or what at least closely resembles it) brought on by an organic lesion (luetie) and disappearing with the cure of the infection, showed very sluggish movement of the muscles of the face and mouth. These muscles were definitely sluggish in non-speech movements as well as in articulation.

TECHNIQUE.

Working with this clue in mind, we arranged a test of the maximum speed to which these facial and mouth muscles could be forced in purely repetitive acts of a simple nature. A Morse key was connected to an electro-magnetic recording lever, whose writing-point was in exact vertical alignment with that of a chronograph recording fifths of seconds, and both levers were caused to write upon a moderately slow kymograph. The subject was first instructed to close the key with his jaw, holding the apparatus in his mouth like a sandwich. He was given a little practice to enable him to learn the simple trick

* From the University of Wisconsin Speech Clinic.

† I use this term out of deference to the recent report of the Committee on Terminology of the American Society for the Study of Disorders of Speech. Dysphemia is also recommended by J. M. Fletcher in his recent work, "The Problem of Stuttering."

of closing the key firmly with each closure of his jaw. Then he was told to exert every effort to produce maximum speed. The speed on this trial was recorded.

The instrument was then mounted in such a way that he could conveniently rest his eyebrow on the edge of the rubber disc handle of the Morse key. By the drawing downward of his eyebrow, he could then close the key. After preliminary practice, he was told to make these movements as fast as possible. The speed on this was recorded. A combined rating was made by simply adding the number of jaw movements per second to the number of brow movements per second (see Tables I, II and III for the data). The subjects were all adults from the ages of 20 to 40. Most of them were under 25. With these adults there was no correlation between age and the speed of muscle movement.

RESULTS.

Several rather interesting facts appear :—

1. The 21 normal males showed a greater spread or variation than the 18 normal females.
2. The normal males were 1.11 units faster than the normal females.
3. The normal males were 1.76 units faster than the 18 stuttering males.
4. The 18 normal females were 2.17 units faster than the 7 stuttering females. The difference between the normal and the stuttering females is within .41 units of the difference between the normal and the stuttering males.

We have as a check upon the reliability of these differences between the stutterers and the non-stutterers not only the low probable errors for these differences, but also the very significant parallel between the males and the females. The female stutterers not only differ from the female normals by about as much as the male stutterers differ from the male normals, but they differ *in the same direction*. The findings for one sex provide a convincing check upon the findings for the other, a check that is all the more impressive when we note that in the case of either sex the probable error of the difference is so low as to make the difference a matter of certainty.

To make the comparison in still another way: Note that the group of stuttering men overlaps that of normal men in 11 cases out of their combined total of 39 (see Table III). If there were a complete overlapping, we might safely say that our test is of no real significance; if there were no overlapping, we might say that we were testing the only significant factor in the problem of dysphemia. The overlapping in our data, however, is completely confined to the lower quartile of the normals and the upper quartile of the stutterers; the middle group of 10 cases among the stutterers and the middle group of 11 cases among the normals are mutually exclusive. Since the overlapping includes not more than a quarter of either group, we can at least say that the factor that we are testing is probably a more significant determiner of dysphemia than any other single condition. This contention is seen to be all the more

obvious when we note that, with respect to the overlapping in the case of the women, not a single stutterer falls within the range of even the middle 50 per cent. of the normal group.

On the basis of the combined evidence from the two groups, male and female, we may therefore assume that, after allowing for fundamental sex differences, sluggishness of response of certain facial and mouth muscles is either a cause of, or is related to a cause of, dysphemia.

Thus far we have drawn conclusions concerning our subjects as they may be arrayed in groups having certain demonstrable central tendencies. What can be said of the individual patient or of the individual normal subject with a low rating, about whose speech history we know nothing? (See Table III.) Patient No. 18 has a very low rating. Not a single normal male falls as low. We may fairly say of him that a certain quality or condition which marks the stutterer as different from the normals he possesses to a high degree. Patient No. 1, on the other hand, has a relatively high rating. Eleven normal males appear lower in the scale than he. We would say of him, therefore, that this certain quality or condition that characterizes dysphemia he possesses only to a slight degree. Other factors must be present to combine with this neuromuscular sluggishness to produce the symptoms of dysphemia. It is not unreasonable to suppose that prominent among these other factors is poor mental hygiene. Suffice it to say at this point that the case history of patient No. 1 reveals a family background that most mental hygienists would regard as distinctly unwholesome for the maturing personality. Normal subject No. 21 has a rather low rating; only three male stutterers fall below him. We can only say of him, that, in spite of his low rating, the combined effect of all the factors predisposing to dysphemia is still not sufficient to produce it; and that, if thorough mental hygiene is necessary to prevent the average person from stuttering, his must have been doubly thorough.

DISCUSSION.

There are probably about 10 male stutterers per thousand in the normal population of America, or in other words the average male has one chance in 100 of being a stutterer. Whether or not this is an accurate ratio is not important here. What does concern us is how a given man's rating on this test relates itself to his normal chance of escaping this disorder. In our artificial sampling we have 39 males, 18 of whom are stutterers—a ratio of 462 cases of stuttering per thousand. From an analysis of Table III we see that, of the 10 male subjects rating 7 or below, eight are stutterers, or that their ratio is 800 per thousand. Of the 18 subjects rating 8 or below, 13 are stutterers, showing a ratio of 722 per thousand. Those rating 9 or below exhibit the ratio of 16 in 27, or 592 per thousand. Those rating 9 or above show a ratio of 1 in 13, or 77 per thousand. We say, therefore, that a subject rating 7 or below has almost twice the normal chance of being a stutterer; a subject rating 8 or below has about 1.5 times the normal chance of being a stutterer;

a subject rating 9 or below has 1.4 times the normal chance of being a stutterer ; and the subject rating 9 or above has exactly one sixth of the normal chance of being a stutterer. The stutterers as a class differentiate themselves from the rest not so much by their low ratings as by their mediocrity. To have a low rating does not so much increase the subject's chances of stuttering as to have a high rating decreases it. To have a tendency to dysphemia may be normal, and not to have such a tendency may be the abnormal or supernormal condition. From that point of view our test, as applied to a given stutterer, would be more positive as a diagnostic index if it showed a moderately high rating than if it showed a moderately low one. The interpretation from the former case would be that the stuttering was probably not due to neuromuscular sluggishness but to other causes, while in the latter case one could be sure of nothing. A *very low* rating, of course, would be strongly presumptive of a neuromuscular etiology of the case of dysphemia under study ; and a very high rating would probably never be obtained from a stutterer.

THE TAPPING TEST.

A great deal of work has been done with the tapping test, timing the rate of movements of the muscles of the arm and hand. It is generally agreed that men are, as a class, faster than women in this test. Most workers with this test seem to regard the rate as basic, dependent upon more or less fixed neurological conditions, and not to be increased by training. If this be true of the movements of the jaw and eyebrow also, we need not look to the training of the muscles of the jaw and face as a cure for dysphemia. We have been unable so far to demonstrate any increase in speed on training. In the "double-tonguing" of a cornet tone we have a simple repetitive movement analogous to the jaw movement. Cornetists state that a beginner at this movement attains a maximum speed at the start, although control, regularity, and prolongation are acquired by practice.

On this point Ream* in his work with hand-tapping states : "The extended practice experiment of the present study seemed to indicate that the test measures fundamental basic abilities, since improvement was on the whole conspicuously lacking. The inference is that the motor neural set, undoubtedly an important condition of such basic ability, is inherited."

What is this condition or quality that we are studying by means of our jaw-brow tapping test ? Let us take as an analogue the simpler and better known hand-tapping test.

Clearly one of the factors limiting the speed of the repeated performances is that of the check or arrest of movement of one group of muscles and the starting of the movement by their antagonists. The speedy functioning of this reciprocal innervation depends partly upon the rapid routing through the cerebral cortex of the kinæsthetic impulses from the tendons and joints of the

* The Tapping Test, Psychological Monographs, Vol. XXXI. No. 1, 1922.

members involved in tapping. Cerebral inhibition in this case is but a matter of so routing the afferent impulses from any muscle group that the very act of contraction will furnish its own immediate inhibitory check, and also the excitatory impulse for contraction of antagonistic groups of muscles. The tapping test, therefore, is partly, it may be largely, a test of the efficiency of the cerebral mechanism for shifting inhibition. Evidently this efficiency increases during childhood, if one may judge from a few cases of children whom we tested. A more complete study of this development of tapping speed during childhood is given by Ream. He shows an increase for boys from less than 4 taps per second at the age of five to more than 6 taps per second at the age of 10, as over against about 9 per second for adult males. The maturing of the central nervous system, therefore, is accompanied by an increase in this inhibitory control.

The question now arises: why is it possible to develop so much more speed with movements of the hands and arms than with the masticatory and facial muscles? There are two possible answers: (1) That muscles of the arms and hands are supplied entirely with crossed nerve fibres. All their nerve connections are with the opposite side of the brain. The facial and masticatory groups, however, are supplied both with crossed and ipsilateral connections. Two sides of the brain are involved. In the complete coordination of both sides more synapses are involved. The passage through synapses involves time. This was partially brought out in our investigations by the finding that in alternate tapping of the right and left hands either hand moved about two-thirds as rapidly as when it alone is used in the tapping. This delay is probably a measure of the time involved in the synaptic connection between hemispheres in the process of coordination between the two sides. This rate of the right hand (in alternation with the left) is about that of the jaw. It is well known that the muscle groups having the greatest ipsilateral nerve supply are those of the upper part of the face. Accordingly we find these muscles slower in their rate of repeated contractions than those of the jaw. That, however, there are here involved other factors than the varying amount of ipsilateral nerve supply, is evident when we notice that many movements of the articulatory muscles are performable no faster than those of the upper face. We tried, for example a movement puckering or pursing the lips so as to extend them forward, while holding the jaw set and immobile; a movement retracting the angles of the jaw by means of the risorius muscle; a movement of the mandible from side to side; a movement of the palate opening and closing it against the emerging air-stream, while keeping the lips closed. These movements are slower than those of the masticatory movements and not demonstrably faster than those of the upper face. We must look, therefore, for another factor determining the speed of the reactions of these articulatory muscles, a factor that is clearly lacking in the set-up for the musculature of the hand and arm.

(2) A second guess, a very possible one, as to the situation that determines or limits the speed of these movements, is based upon the more direct and intimate connection of the musculature of the face, mouth, and throat with subcortical centres for the control of innate synergic vegetative and emotional reaction patterns. I refer to such centres as those for breathing, in the medulla; for coughing, sneezing, vomiting, yawning, gagging, and swallowing, partly mediated in the medulla (probably); and for crying, laughing, sobbing, frowning, smiling, etc., in the thalamus and striate bodies. These centres give off a profuse supply of upper neurones to the anterior horn cells of the lower motor fibres supplying the innervation for all of the musculature concerned in the processes enumerated above. These centres, on the other hand, have relatively few direct connections with the musculature of the arms and hands. It is probably this difference that is most highly a determining factor causing a difference in the speed with which inhibition may be shifted from one muscle to another. In the shift of inhibition from the extensor to flexor group of the arm, the only limiting factor (aside from the conduction time of the nerves and the latent period of the muscles) is the time involved in a reciprocating synaptic arc through one hemisphere of the cortex; while in the shift of inhibition from the risorius to the orbicularis oris muscle the limiting factors include all those involved in movements of the arm, plus the time involved in synaptic connections with the opposite hemisphere, plus the time involved in releasing the muscles concerned from the control exercised over them by subcortical centres. This process of releasing involves additional synaptic connections and is probably responsible for a large part of the difference in time between the movements of the face and those of the arm.

In short, our test may be largely a measure of ability to maintain an efficient cerebral control over the lower motor neurones to the face, mouth, and throat in opposition to the subcortical control of these same neurones. This explains why not a few postencephalitics and paretics stutter. This intermittent dysphemia may be regarded as an evidence of a comparatively even conflict between the cerebral and subcerebral centres for the control of the lower motor neurones. In rugged, sound speech that is seldom thrown out of rhythm, even by the greatest emotional upset, the cerebrum is clearly dominant; while in the spastic, scanning speech of the postencephalitic and of the bulbar paralytic the balance of power in the conflict for the control of the lower motor neurone is in subcerebral centres. Dysphemia is that condition of 'hair-trigger' balance between the two controls such that certain emotional conditions can intermittently shift the dominance from one to the other. This shift of dominance is characterized by the tonic and clonic spasms that we know as stuttering.

ETIOLOGY.

The difference between men and women in our test of the musculature of mouth and face is probably to be regarded as a rather fundamental sex difference. That it is not much related to speech is evident when we remember

that the incidence of dysphemia among men is much greater than among women. In comparing the two sexes from the point of view of speech we must conclude that the specific rate is not the significant factor in the disturbance of cerebral control but rather the difference between the individual's rating and the basic rate for his own sex.

With our 64 adults we found no correlation between age and speed of muscle movement. If this speed is linked up with the developmental history of the child, it is evident that it reaches a static point before maturity. The few children whom we have studied thus far show distinctly slower rates in our tests than adults. We are inclined for two reasons to assume tentatively that these cases have given us a safe lead as to the differences between adults and children in our test (this matter is now being verified). In the first place, with respect to sex differences, our results with the 'jaw-brow' test parallel the results obtained by various workers with the hand-tapping test; and, secondly, these investigators have also found children distinctly slower than adults. As in the case of women, we should not regard the specific rate as being a significant factor predisposing to dysphemia, but should refer the articulatory spasms to a disparity or lack of normal balance among the nervous centres concerned with the control of the speech organs, a thing measurable only by a comparison between the patient's tested rate and the normal for his age and sex.

Speaking generally as to etiology, we can say that two types of imbalance are responsible for this neuropathology predisposing the subject to dysphemia: (1) the interference with the inhibitory function of the cerebrum over lower centres through vice of one or both of the hemispheres or of their connection with the lower centres; (2) the abnormally heightened activity of subcortical centres causing their impulses to break through the cerebral inhibition. This hypertonic condition may be referable to toxic conditions systemic in nature, or to specific stimulation of the centres, as in chorea. Speaking generally as to the possibility of a remedy for this basic neuropathology predisposing to dysphemia, we can say that, if the disturbing condition is the result of disease, any exercises of the muscles of the face, mouth, and throat that increase the efficiency of their voluntary control are to be recommended. Just as, after many diseases paralysing arms or legs, judicious exercising will restore some degree of function by regenerating nerves and developing other tracts for those completely destroyed, so it is often possible to remedy pareses of the speech apparatus. Results of treatment in cases of this type lead us to make them the exception to the general rule that stutterers should not be given articulatory exercises. (It should be said, however, that these cases are few.) If, however, the predisposing factor is not a result of disease, but of inheritance of the brain structure and of the distribution pattern of the motor nerves, it seems quite likely that it is irremediable. In all probability exercises of the articulatory muscles will avail nothing.

SEX DIFFERENCES.

In the explanation of the comparatively greater incidence of dysphemia among men than among women (quoted by various authorities as from 4 to 1 to as low as 2 to 1) some importance must be attached to the greater variation of the normal males as against that of the normal females in the rate of jaw movement and in the rate of brow movement. In each of these tests of the functioning of facial and mouth muscles, the mean deviation for the males is approximately one and one-half times that of the females, while in the tapping test it is almost twice that of the females. Nature seems inclined to experiment more widely in the proportions in which the various elements are mixed in the male make-up. In this wider range of proportion the possibilities for imbalance among the brain centres is increased. To set up a statistical analogue : arrange 50 cards numbered 21 to 70 (series A) ; arrange 50 other cards bearing even numbers from 2 to 100 (series B). Series B, having the greater range and the higher average represents the variety of coördinational elements out of which nature selects a combination for each male ; series A represents the range of nature's choice for the component elements of the female. At random choose two cards from series B and two from series A. This is as though nature were constructing first a boy and then a girl. The two cards from series B may be 98 points apart. The two cards from series A cannot be farther than 49 points apart. Suppose we assume arbitrarily that the point at which dysphemia will appear in either sex is when the difference between the two cards drawn is 40 or more. In series B 465 possible combinations will produce a difference of 40 or more ; in series A there are only 55 such combinations. In each series there are 1,225 possible two-card combinations.

If these combinations are selected by chance, and the cards returned to the pack after each drawing, 10,000 drawings from series B, determining the inheritance of boys, will, in our simple analogue, produce 3,800 stutterers ; while 10,000 drawings from series A, determining the inheritance of girls, will yield only 450 stutterers. On some such disparity of combination-possibilities the greater incidence of stuttering among men may depend. Of course the combination is probably not of two variables, but of many.

Many writers have attempted to explain the greater incidence of dysphemia among boys on the basis of the difference of social demands made upon the two sexes. The sexes may be regarded as having different social environments, and the environment in which the boy is placed is less hygienic. Perhaps in answering the question as to why either sex stutters at all, we should in the future emphasize more than we have in the past these predisposing neurological factors. These conditions render the speech co-ordination so liable to interruption by muscle spasm that whenever the social situation is even slightly upsetting the patient begins to stutter.

CONCLUSIONS.

On the basis of our data, pending further investigations, the following conclusions seem warranted :

(1) Some stutterers present such a serious neurological problem that they should not hope for a 'cure.' To attempt to remedy such a case of dysphemia by probing for some psychic trauma is not only futile but likely to produce in the patient a morbid introspection.

(2) Some stutterers offer not neurological but psychological problems and should react favourably to mental medicine.

(3) The adequate handling of any case of dysphemia should involve a differential diagnosis separating the neurological problem from the psychological.

TABLE I.

RATING OF SIXTY-FOUR SUBJECTS.

- (1) Combined rate of movement of the jaw and brow.
(2) Hand-tapping rate.

Number of cases.	1		2	
	Means	Probable Error of means	Means	Probable Error of means
21 males, normal ...	9.26	.262	7.98	.159
18 males, stuttering ...	7.50	.172	6.93	.126
18 females, normal ...	8.15	.148	7.21	.88
7 females, stuttering ...	5.98	.295	7.53	.258

NOTE.—The hand-tapping rate was taken to check our technique by comparison with other studies.

The probable error was found by : P.E. of M. = .8453 M.V.

$$\sqrt{N}$$

TABLE II.

DIFFERENCES IN THE JAW-BROW TEST.

Between	Difference	Probable error of difference	D/P.E.	Probability of a real difference
Normal and stuttering males ...	1.76	.313	5.62	9999.2 in 10000
Normal and stuttering females	2.17	.33	6.58	10000 in 10000
Normal males and normal females	1.11	.30	3.70	9937 in 10000
Stuttering males and stuttering females ...	1.52	.341	4.45	9987 in 10000

NOTE.—The P.E. was calculated by : P.E. of D. = $\sqrt{P.E.^2 M_1 + P.E.^2 M_2}$.

The probabilities were derived from Table 45 on page 200 of "Mental and Social Measurements," by Thorndike.

TABLE III.

DISTRIBUTION OF THE SIXTY-FOUR SUBJECTS.