Stress and Rhythm in Speech.

NOTWITHSTANDING the steady advance of knowledge concerning the physics of speech, with regard to certain of the most fundamental speech-phenomena a lush upgrowth of theory has yielded a very small crop of ascertained facts. Especially is this true concerning speech-rhythm. The reasons are several. Too frequently investigators have failed to formulate their problem with precision and have obscured it with terms of undetermined connotation, such as 'stress,' 'accent,' 'quantity,' even the word 'measurement' being very loosely used; most serious, however, has been their failure to appreciate or apply

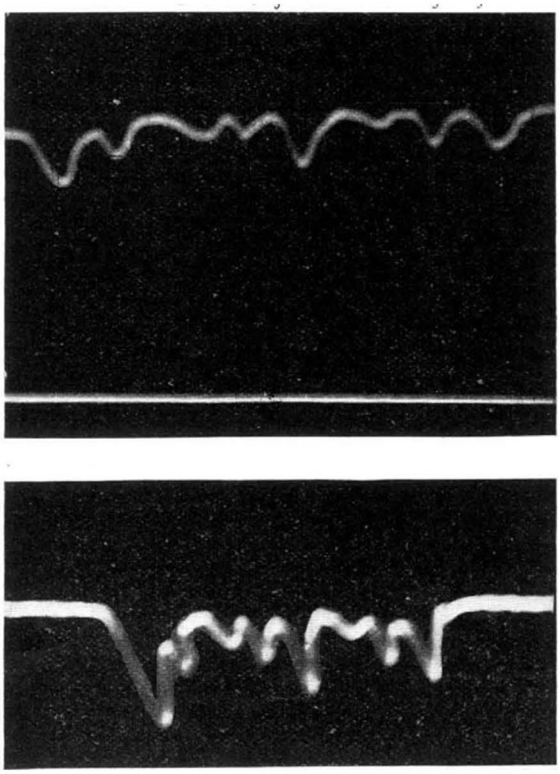


FIG. 1.—Direct photographs of jaw-movement. The lower curve was recorded some months after the upper, but by the same speaker. All the characteristics of the first curve are reproduced in the second, but the latter is more compressed laterally owing to slower movement of film.

when compelled to leave a *graphical* record upon a surface moving with known speed, *i.e.* when time had thus been replaced by its spatial presentment, alone susceptible of measurement. Let the metrician consider the principle involved. Behind the acoustic record of rhythmical sound, the true amplitudes of which were difficult of discovery, the physiologist was interested in the muscular actions, themselves presumably rhythmical, by which it was generated, and he addressed himself to the direct recording and measurement of these, incidentally presenting the metrician with an instructive but neglected example.

Experiments which I have been enabled to carry out during the past few years in the Physiological and Phonetics Laboratories at University College, London, indicate that even a crude adaptation of the physiologist's method yields valuable data as to the nature of 'stress,' and the distribution along the time-line of speech of its moments of maximum incidence. Fig. 1. exhibits the track marked on a photographic film, moving with uniform velocity, by an electric spotlight fixed rigidly between the lower incisor teeth of a speaker who, in profile to the camera and in darkness, recited the line: "I cannot see what flowers are at my feet." It represents, therefore, the rise and fall of the jaw during utterance. I can discuss here only one or two of the problems and conclusions suggested by this and very numerous similar experiments. It seems surprising that previous investigators should have neglected to examine this most evident factor in normal speech—the opening and closing of the mouth. The movements involved can scarcely be adjudged *a priori* superfluous and insignificant, since every depression of the jaw, effected by the combined work of numerous muscles and more particularly of those attached to the hyoid, provokes, as anatomists are fully aware, very special pivotings and displacements of the thyroid cartilages supporting the glottis, and consequently special tensions and special modifications of the resonant cavities of mouth and pharynx. These modifications are strictly conditioned by the number of muscles brought into play and the speed and vigour with which they are contracted. Hence the tracing executed by the moving jaw is a valuable index of the whole process of phonation, and this tracing reacts characteristically to every variation of stress, pitch, and vowel quality (timbre). The stressing (emphasising) of any particular vowel involves increased vigour of jaw-movement, and for each timbre characteristic degrees of descent of the jaw and characteristic expenditure of time.

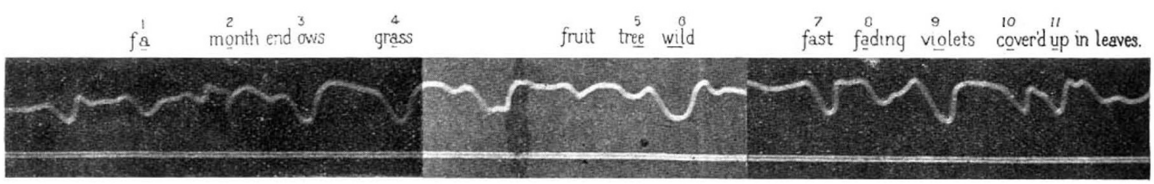


FIG. 2.—Excerpts from a continuous film of jaw-movement: "Wherewith the favourable (*sic*) month endows The grass, the thicket, and the fruit-tree wild," "Fast fading violets covered up in leaves." 1 and 8: characteristic semi-circular trough for *a* in f*a*ding and f*a*vourable. 2, 10, and 11: peaked trough for vowel ʌ in m*o*nth, c*o*vered, *u*p. 4 and 7: characteristic right-hand ascent of trough representing ɑ in gr*a*ss and f*a*st. 3, 6, and 9 large diphthong troughs in end*ow*s, w*i*ld, v*i*olets. 5: compare trough of i in fruit-tr*ee* with that of i in s*ee* (Fig. 1).

the methods evolved by other sciences for solving kindred problems.

Physiological research during the past half-century has shed complete light upon certain rhythms and, in so doing, elaborated characteristic and efficacious methods. A typical case is that of the heart-beat, which presented itself primarily as an *audible* rhythm, but could be subjected to accurate mensuration only

In Fig. 1 the vowels occupy the wave-troughs, and it will be realised that the lowest point of each trough, *i.e.* the point of maximum stress, corresponds to a unique position of the vocal apparatus, achieved by increasing muscular contractions on the descent and unmade by reversal of these contractions on the ascent. A 'pure' vowel apparently consists of symmetrical phases of approach and recession about a characteristic quality and pitch at the bottom, the slowest and most audible portion, of the trough. Asymmetry results in diphthongisation and appears as the result of overstress.

Fig. 2 shows some striking examples of the characteristic troughs traced out by vowels of different quality.

Fig. 3 exhibits a different kind of tracing. Instead of the direct photograph of jaw-movement we have here (*a*) an inscription made by the lever of a Marey-tambour fitted with an extremely elastic soft rubber diaphragm and hermetically connected with a bulb carried on a plate under the speaker's chin in such a manner as to eliminate the influence of all head-movements other than those of the jaw, the latter being recorded in terms of air-pressure. The figure contains the inscription of two recitations of the French Alexandrine, "Le vrai peut quelquefois n'être pas vraisemblable." The total time taken by each recitation is $2\frac{1}{3}$ seconds between the lowest point of the first vowel trough lE and the lowest point of the last, vraisemblAble. It will be observed that the same intricate curve is reproduced with scrupulous fidelity, and, as this reproduction postulates the identical performance of many highly complex and varied acts by a synergy of numerous muscles, it is difficult to believe that this fine accuracy subserves no practical purpose. It is interesting to observe the different depth and shape of trough corresponding to the vowel *ai* (e) in vr*ai* and in vr*ai*semblable, that is, in circumstances of strong and weak stress respectively. The inscription of jaw-movement is accompanied by simultaneous records (*b*) of sound vibrations, registered by the usual phonetic tambour, and (*c*) of the vibrations of a tuning-fork (100 per. sec.). Clearly by synchronising these three tracings we can determine to what phase of jaw-movement each sound corresponds and the time relations between the points of maximum stress. Most of the records thus synchronised have been registered on surfaces moving at a rate of about 10 in. per sec. and permit of accurate time measurements to within a 200th of a second.

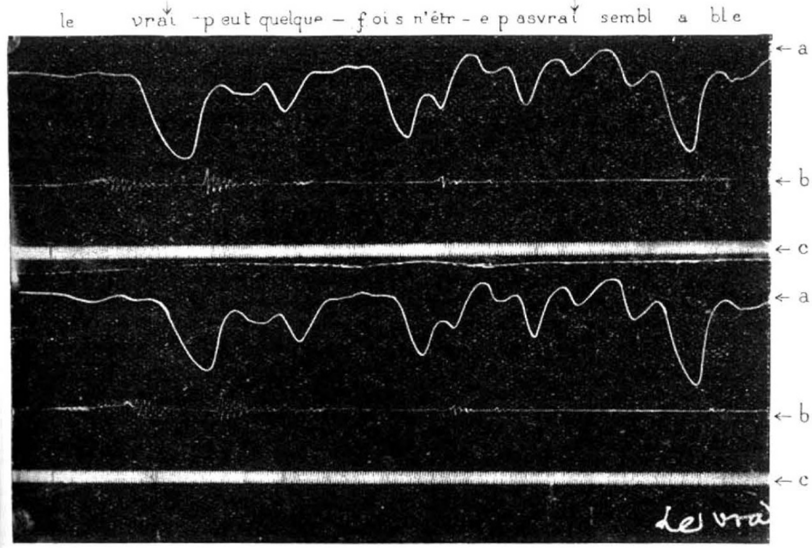


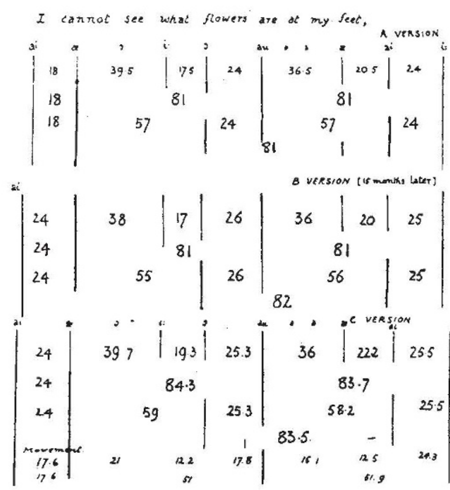
FIG. 3.—Two recitations of "Le vrai peut quelquefois n'être pas vraisemblable." (*a*) Jaw-movement; (*b*) sound record; (*c*) time record (tuning fork, 100 vibrations per sec.).

Detailed study of these curves soon reveals a host of unsuspected phonetic data of which the mere summarisation would require more space than is here available. The consonants, according to their nature, can occur only at very definite places on the curve; the stressing of the vowel to which they are contiguous profoundly modifies the conditions under which they are articulated and controls their duration and degree and quality of contact. In fine, the observer is able to watch in operation those very factors that have proved so profoundly influential in the historical evolution of speech-sounds.

The utility of the curves for the mensuration of poetical rhythm, a subject of greater interest to the general reader, can be more succinctly exemplified. We give below two sets of figures typical of those obtained from the mensuration of many experimental tracings of the kind described. To guard so far as possible against chance numerical coincidences, each experiment has been performed in duplicate or triplicate, *i.e.* the speaker has repeated his lines two or three times. In more than one case, after the corrections necessitated by the slight variations in speed of the best-regulated kymograph had been made, the recitation-curves, complex though they were, were found to be absolutely superposable; in others they had been systematically and proportionately varied and reflected slight alterations in the speaker's *tempo*.

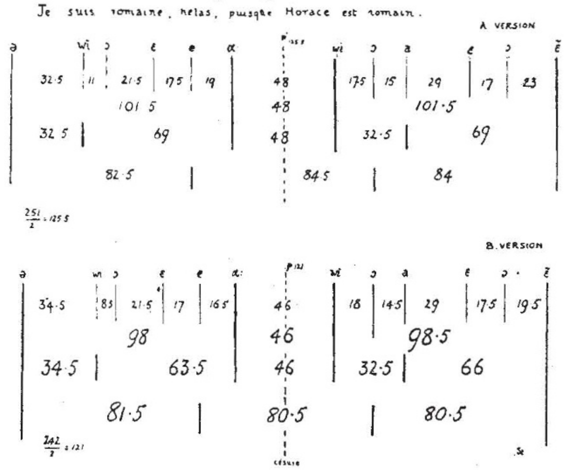
In the following tables each vertical line must be supposed drawn through the lowest point of the trough of the vowel of which the symbol figures at the top of that line; the numbers give the time, in 100ths of a sec., taken by the voice in passing from lowest point to lowest point.

I. Three recitations of the line, "I cannot see what flowers are at my feet."



It is scarcely requisite to insist upon the constant evidence of orderliness displayed by these figures. Excluding the initial interval, the time falls into two equal groups—equal beyond the metrician's dream—delimited by two prominent stress-maxima; each of these groups is again symmetrically subdivisible. The very weak stresses (as may be judged from Fig. 1) show no measurable maxima.

II. Two recitations of the French Alexandrine, "Je suis romaine, hélas, puisque Horace est romain."



Here in each recitation the addition of intervals results in a central symmetry of identical design (apparently the normal organisation of the isolated Alexandrine); a possible trimetric division is obtainable by utilising the less prominent stresses. It must be noticed that in the A recitation the time between the initial and final stress maxima is 251 hundredths of a second. Dividing this by 2 we have 125·5 and on synchronising this point with the voice record we find it to coincide with the closure of the p in *puisque*. The same holds true for B version, total 242; that is to say, the 'cæsura,' though not itself a stress-point, is situated exactly midway between the first and last stress-maxima. This twin experiment is particularly interesting as revealing (*a*) a stress-organisation of French verse; (*b*) the manner in which a reciter while reducing his total time expenditure by 9 in 251 hundredths of a second, yet accurately apportions the reduction so as to maintain the same organic rhythmical structure.

In this preliminary account of a few among a very large number of experiments, I have been compelled to choose only short examples, and to give of these a very summary interpretation. I may, perhaps, add that more extended records, notably those embracing a complete stanza, yield time-forms of beautifully elaborate and accurate symmetrical structure.

J. W. JEAFFRESON.

Dutch Pendulum Observations in the Atlantic and the Pacific.

By Dr. J. J. A. MULLER.

THE voyage of Dr. Vening Meinesz announced in NATURE of June 5, 1926, has almost been completed. The latest information by letter was from Honolulu; a cablegram reported the arrival at Amboina on November 25.

H.M. Submarine *K XIII.* left Helder on May 27 on a calm, sunshiny day, but the weather soon changed and after leaving the channel it was impossible to make any observations above the slope to the deep sea. A few days before sailing the ship had taken in much cargo, especially liquid fuel, and the trim was not known, which made it inadvisable to submerge for the first time in a very rough sea. The first observation was made June 2, and nearly every day after this date while at sea the pendulum apparatus was used in the submerged ship; on several days more than one and sometimes so many as four observations were made. As on his former voyages, Dr. Vening Meinesz also measured the intensity of gravity in every harbour where the submarine called.

The new apparatus has fully answered to expectations; the pitching of the ship causes no troublesome disturbance, and sliding of the pendulums need not be feared. This apparatus can be used in circumstances in which that used during the former voyage would have failed. A rolling of 3°·5 to both sides was no hindrance to the making of observations. This was a great advantage, as in the Atlantic, at a depth of 20 and more metres, the rolling sometimes reached as much as this. The strong swell in the Atlantic and the Pacific destroyed the hope that it might be possible to make observations at the surface of the sea.

Unfortunately for the deep sea soundings, the senders of the underwater clock signals were placed too high in the shipboard, in the wave zone. The echo was not a definite sound, and consequently the echo method could not be used for soundings at the surface of the sea; in the submerged vessel the place of the senders caused no trouble. The sonic depth-finder, which had been received only a few days before departure from Helder, has been of no use. Before San Francisco was reached, again and again Commander van der Kun and Dr. Vening Meinesz when trying to detect what was wrong, thought at first it was due to the relay; at length it appeared to be a defect in the construction, which only the maker in London can put right. It is a disappointment that owing to these two circumstances the voyage will contribute in only a limited manner to our knowledge of the depth of the sea on the track. For the determination of the interval of time between the production of the sound and the perception of the echo, a stop-watch of the Royal Navy was used indicating a hundredth part of a second.

The time signals used were at first those of Bordeaux, which were audible so far as Mona Passage, and afterwards those of Annapolis, which could be perceived for some days after leaving San Francisco. The use of the signals of Balboa and San Diego could be dropped, and the Naval Observatory at Washington was informed that these stations need not be controlled. In the whole Pacific the time signals of Lembang, given by the powerful radio station of Malabar (Java) can be used; these were clearly audible in Curaçao. The Nardin chronometers were the same as were used on the voyage in 1925; the regularity of the run of both was marvellous. For the comparison of the chronometers with the rhythmic time signals, Dr. Vening Meinesz intercalates the interrupter of the mean time chronometer in the telephone circuit and observes the appearance and the disappearance of the time signals; in this way the personal equation is almost entirely eliminated.

After taking an observation, the film was as a rule immediately developed; often it was directly measured and the preliminary result computed. Only when the temperature was too high was the developing put off until the next harbour was reached. Dr. Vening Meinesz estimates that the difference between the preliminary results will not exceed 0·005 cm./sec.^{2}; the isostatic reduction, however, will produce much greater differences. In this connexion it will be wise not to arrive at far-reaching conclusions immediately with regard to the prevailing theories