SOME DATA ON VOICES OBSERVED IN THE WAVE MODES OF BODY-SURFACE VIBRATION

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Introduction

It is necessary to know what are, and what do mean the speech sounds to us. The speech sounds stand for communicational objects. We understand the speech sounds as communication signals to be impressed on the transmission circuits. We must study the physical structure of the speech sounds, because they have to be transformed, transmitted and reproduced by telecommunication systems; they are treated, in the procedure of transmission, as some physical concrete substances with some physical energies. The physical analysis of speech sounds has been executed from the view point just has mentioned above. But it is also important to know what is meant by speech sounds. It is because, so long as they stand as a communicational object, the speech sounds must represent the two sides, expression and comprehension, both of which belong to the domain of psychology.

We have to make research for these reasons, to search for the relationship between speech sounds and voices. As Prof. Ochiai and his group have shown already in this Research Report, the conceptional analysis for such matter is naturally a most difficult. Therefore, it is also desirable to find out another experimental method which correspond to the conceptional analysis.

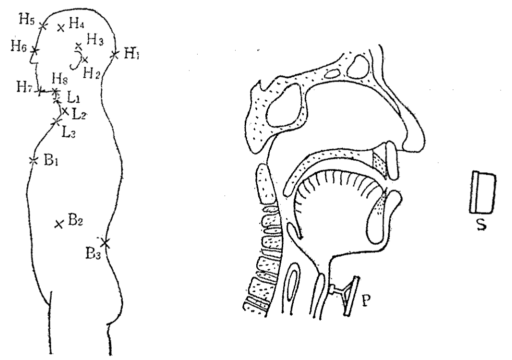
The voice phenomena can be searched on the body surfaces where the vibration of voice thereby may be transmitted in more primitive form and by more direct route than the vibration in the air off mouth. There is another profit for searching the vibration forms directly at the proximity of its source which is situated so deeply in the body that we can not approach it by any other procedures. Though we know a little of the mechanism of the bone and soft tissue conduction of sound, yet we can obtain some informations of voices.

On Procedure of Observation

The wave forms of the body-surface vibrations picked up are observed by the Brown tube equipment under various voicing conditions. As the pick-up of vibration, the conduction type based on piezo electric principle is used, and the pick-up positions on the body surface are illustrated in Fig 1.

(1) *Voicing condition*

The observation is done only of the male voice of a single individual whose vocal tone belongs nearly to baritone. He has neither defect in phonation nor dialect in pronounciation. Instruction on voicing conditions must be given clearly



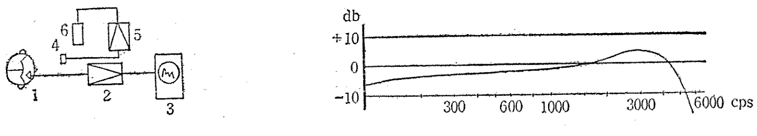
(*A*) (*B*)

FIG. 1 (*A*). Pick-up positions
H_1: protuberantia occipitalis externa
H_2: processus mastoides
H_3: linea temporalis
H_4: tuberantia os frontale
H_5: linea saggitalis regio frontalis (Metopion)
H_6: vomer (Rhinion)
H_7: protuberantia mentalis (Mentale)
H_8: corpus ossi hyoid
L_1 : prominentia laryngis
L_2 : tubercrum thyreoideum superius
L_3 : fossa suprasternalis
B_1 : corpus sternii
B_2 : costa IX
B_3 : vertebra lumbalis III
FIG. 1 (*B*).
S: supervisory microphone
P: pick-up microphone

as possible. The vocal technique such as *tremoro* and *vibrato* are avoided. The voice pitch is controlled by tuning with a certain given musical pitch, heteronomous method being thus adopted. As to the controlling of voicing levels, the ordinary utterance in natural breathing is chiefly adopted. But in case of necessity, an unnatural voicing in strained breathing is also tested, where the uttering subject is forced to voice his vowels always consulting the readings of supervisory VU meter. Level matching procedure executed here are as follows. Microphone set in front of the voicing subject at the distance of 50 cm is connected to the VU meter. And the subject is requested to adjust his voicing so as to keep steady the deflecticn of meter for all vowels (for level test) and besides for all pitches (for pitch test).

(2) *Apparatus used for measurement*

The block diagram in Fig. 2 (*A*) shows the whole arrangement in this observation, and the total acoustic frequency characteristics of the apparatus used is shown for reference in Fig. 2 (*B*). (The vibrational frequency characteristics of the set necessary for conduction type pick-up are not obtained.) In case of the observation of wave forms, the output waves of the amplifier for recording are inspected by the Brown tube equipment. And, on the other hand, the measure-



(*A*) (*B*)

FIG. 2 (*A*) Schematic diagram of the observing apparatus, 1. Pick-up, 2. Amplifier for recording, 3. Brown tube, 4. Microphone, 5. Amplifier for super vision, 6. VU meter.

FIG. 2 (*B*). The total freq. characteristics of the pick-up (1) with the amplifier (2).

ment of the crest values, is carried out by measuring the maximum heights in millimetre of output waves on the Brown tube.

Effect of Poition on Body-Surface Vibration

So long as the vowels are voiced in *piano*, the wave forms themselves are generally a little influenced by the kind of vowels and also by the difference of pick-up positions. And the maximum heights of wave crests depend both on the pick-up positions and on the kind of vowels. In accordance with the increase of voicing levels (i.e., increasing gradually from *mezzo forte* up to *forte*) the crest amplitudes undergo different increases every one vowel, and by and by, the differences of the wave forms of five vowels become also remarkable enough to distinctify. However, the difference of wave forms due to the variety of head and face part vibration is not very remarkable, as shown in Fig. 3. There the wave forms are inspected on the parts of the *tuberantia os frontale* (H_4) and the *protuberantia mentalis* (H_7). The vibration of the upper neck parts such as the laryngeal parts (L_1 and L_2), however, has generally stronger crest values than any other, and the conspicuous difference due to the kinds of vowel is also found in their wave forms. But these characteristics disappear rapidly in the lower part of neck. By using the single-sweep oscillograph, five photographs in Fig. 4 are taken from the part of the *fossa suprasternalis* (L_3), where five vowels are voiced in *mezzo forte* at 150

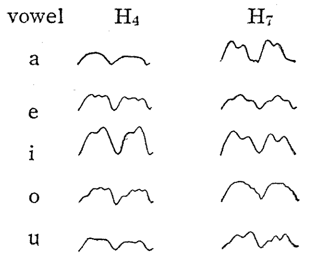


FIG. 3 (*left*). Inspected wave forms at the *tuberantia os frontale* (H_4) and the *protuberantia mentalis* (H_7) are copied, in every cases, vowels are uttered at c pitch in *mezzo forte.*

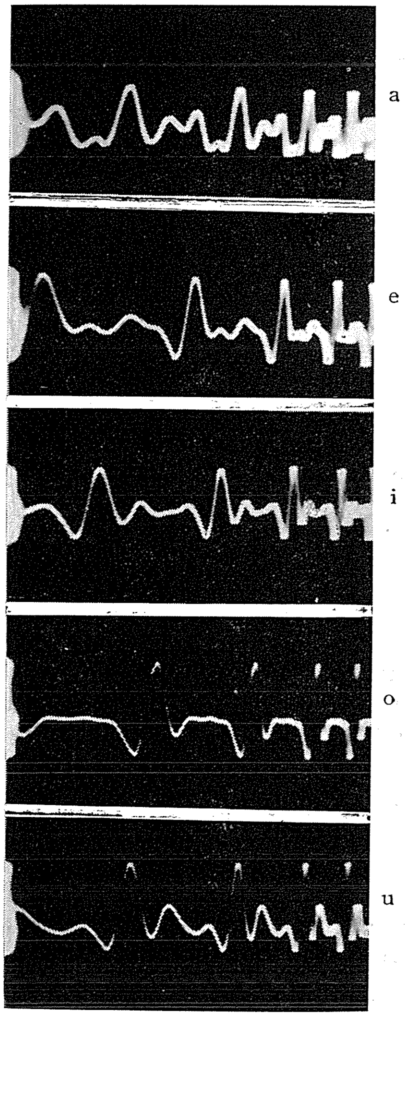


FIG. 4 (*right*). Oscillograms of five vowels, voiced in *mezzo forte*, in natural breathing at 150 c.p.s. pitch, on (position of) *fossa suprasternalis* (L_3), taken by the single-sweep oscillograph.

c.p.s. pitch in natural breathing. As the graphs show, there are little differences both of the wave forms and of the crest values due to the kinds of vowel.

On Level Effect

As we have already shown, the amplitude of the wave crest grows large generally with the increase of the voice level. And with the increases of the levels, the wave forms themselves come to show some changes, as Fig. 5 shows. In *mezzo forte* and *forte*, we can see some differences in wave forms. But there is

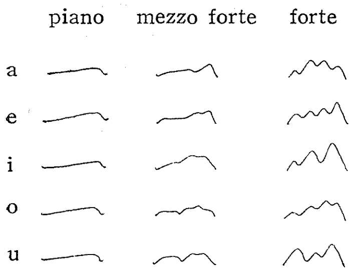


FIG. 5 (*left*). Wave forms of 5 vowels voiced in strained breathing on the *fossa suprasternalis* (L_3) at three levels are copied by inspection.

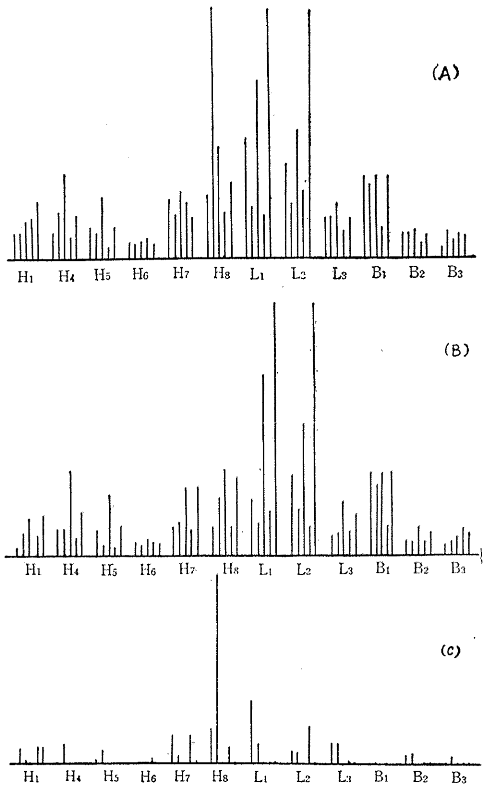


FIG. 6 (*right*). Maximum amplitudes of the output wave forms in natural breathing (A), in strained breathing (B) and their differences at each position (C), in every cases vowels are uttered at *c* pitch in *mezzo forte*, and arranged in the order "a, e, i, o, u" at each position.

little difference due to the kinds of vowel at the same level. The wave form in the duration of one period at the *fossa suprasternalis* (L_3) is traced. The results of the measurement of output amplitudes in natural breathing are shown in Fig. 6 (A) for each position. Furthermore, in comparison with the case of natural breathing, the case of strained breathing for level matching is also tested as shown in Fig. 6 (B). The difference between (A) and (B) of Fig. 6 produces the results shown in Fig. 6 (C).

On Pitch Effect

To inspect the pitch effect on body-surface vibration, we tested here only the case of strained breathing which is necessary for cancelling its level rises in accordance with pitch rising. The results obtained are as follows: wave crest amplitude decreases on the head, breast and back positions with the increase of pitch in a variety of vowels. The vibrations on the laryngeal part, on the contrary, present the reverse relation. The front and lower parts of the face, however, do not show such unidirectional tendency; the order of the magnitude of amplitude in pitch rising, and thereby the directions of tendency of the phenomena become out of order because of its changes of position and of its vowels. The maximum amplitude of the wave form corresponding to each pitch is measured in millimetre and shown in Fig. 7, and the tendency of the changes of maximum amplitudes with the pitches are shown in Fig. 8. There are three classes in this tendency, the first is upward, the second is downward and the third is somewhat horizontal.

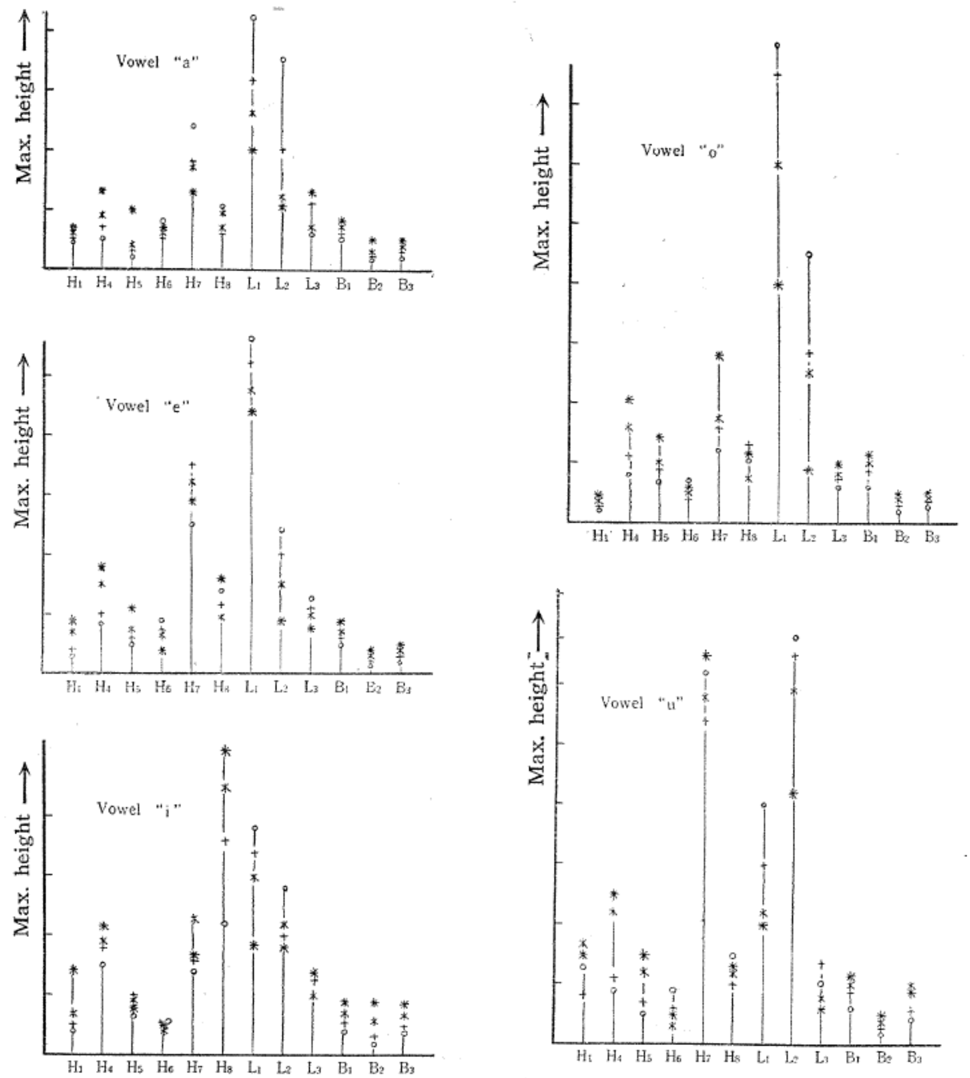


FIG. 7. These show the max. amplitudes of each vowel corresponding to 4 pitches at 12 positions; ※ (G), ⁎ (c), + (e), ○ (g).

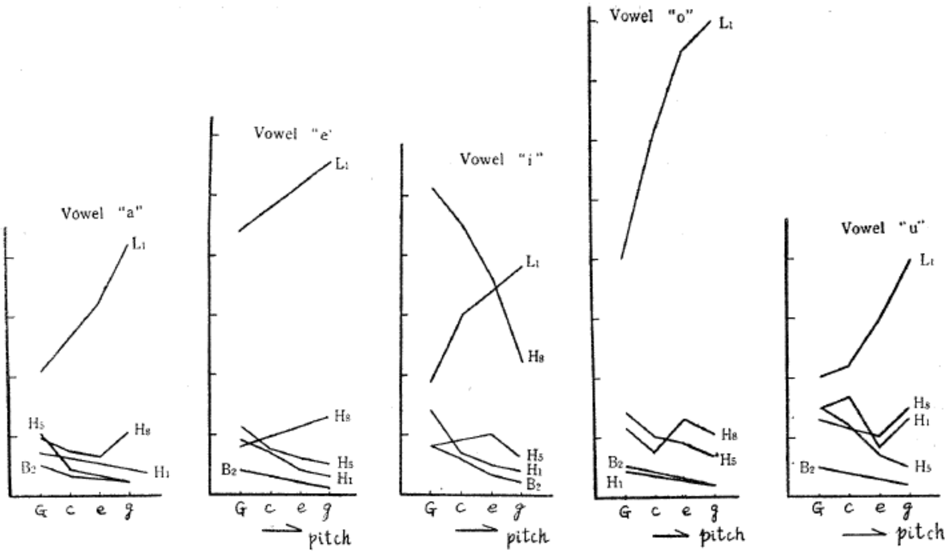


FIG. 8. Tendency of the changes of max. amplitude with the pitch change, for each vowel, having certain positions as parameter.

The examples at *prominentia laryngis* (L_1) and the *tubercrum thyreoideum superius* (L_2), are included in the former, and those at the *corpus sternii* (B_1), and the *costa IX* (B_2) and the *vertebra lumbalis III* (B_3) are in the second, and *fossa suprasternalis* (L_3) and H_8 is in the third. At these positions the tendencies appear considerably distinct, but at the others obscure. The wave crest amplitudes at G and g pitches are measured, as shown in Fig. 9 (*A*). Fig. 9 (*B*) is obtained as the difference of these two quantities. The most remarkable difference of amplitude takes place at *prominentia laryngis* (L_1) and *tubercrum thyreoideum superius* (L_2), and in these parts the most prominent difference is observed evidently in vowel "o."

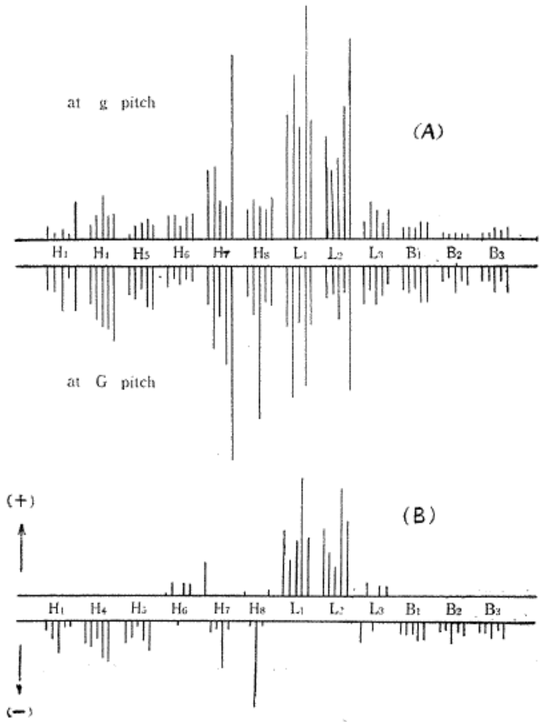


FIG. 9. Max. amplitudes of 5 vowels at 2 pitches (G, g) on 12 positions are shown in (*A*), of which the upper part is at g pitch and the lower at G pitch. (*B*) correspond to their differences showing the directions of increase or decrease. In the figures, the vowels voicing in unnatural on each position are arranged in the order "a, e, i, o, u."

Conclusion

We have treated here some problem of voice by the systematic observation of the body-surface vibration. Though the response characteristics of pick-up equipment are considered not perfectly, and also the mechanism of bone conduction are not clear enough, and though the voicing condition is not perfectly controlled, yet we can obtain some informations of voicing phenomena. But we must not be in a hurry for our conclusion. All that we can do first is to collect the data based on the systematic observation which is carefully planned in accordance with our clear purpose. We have reported, with reserve, only on some conspicuous effects which seem important to us, because the quantitative measurement is prospective hereafter by the help of these precautions given here.

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