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A Correction Method of Uncertainty of Tone in Singing

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This paper deals with a correction method for tone deafness from the basic study of mechanism of tone deafness. First, the conditions of uncertainty of tones in singing by the tone deafness were analyzed and most of the causes were thought to be their disability to extract pitch from complex sounds.

An instrument having a function of extracting pitch was made, examined on the capability to correct the condition of tone deafness. In some cases, it was found to be effective.

1. Introduction

We found out a method by using the computer to correct tone deafness, the condition of uncertain tone in singing[1]. This may be applied to other sensory handicapped conditions.

In singing a song, we have to express by our voice all factors which are written in the score. For this action, our sense must discriminate the factors. The factors are pitch, sound level, duration of tone, rhythm, timbre and etc.[2]. Of these factors, the decisive one leading to tone deafness is height of tone. And, when the range of difference of frequency between the tone and the correct one exceeds a threshold[3],[4], the condition or the person is said to be tone deafness.

The vocalization is controlled by Feed Back loop as shown in Fig. 1. A melody led from ears is memorized in brain and vocalized corresponding to the memories, and the frequency is checked by feed back voice caught by ears. The cause of tone deafness is thought to lie in the route of melody acquisition (A) or in vocalizing process route(B). The condition by A is sensory, and one by B is motorial.

We watched various kinds of difference between normal people and the tone deaf. First, the accuracy of vocalizing and tuning of musical scale was examined on both groups. Secondly, the accuracy of height of tone was examined, which the subject presented trying to equalize pitch to the previously presented standard tone.

From these results and others, the cause of tone deafness is supposed to be the incapability of extracting fundamental frequency from a complex tone. From this supposition,

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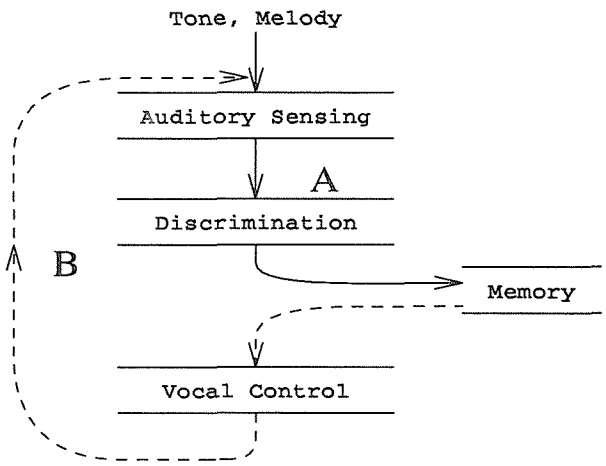


Fig. 1 The control loop of vocal system.

a new method to substitute the function of extracting pitch for tone deafness was attempted. It was very effective to improve tone deafness tendency.

2. Presentation of musical scale

Because the condition of tone deafness is observed in singing a song, we adopted a musical scale as a sample of melody, and asked subjects to vocalize the scale. For reference, the subjects are asked to tune up key board sounds to correct scale. The groups of subjects are divided into two groups, normal and tone deaf based on self-declaration. The used musical scale is an equal temperamental and major one.

Fig. 2 shows frequency error rate(E) in vocalized musical scale. The error rate is defined as follows:

$$E = (f_1 - f_0)/f_0 \times 100 \quad (\%)$$

f_0 = (f_0: next frequency calculated from vocalized tone)

f_1 = (f_1: frequency of vocalized tone)

Fig. 2 (a) shows the results of errors of 2 members in the normal group, and Fig. 2 (b) shows those of the tone deaf group respectively. The latter has about twice the errors of the former. The results of all members are plotted on Fig. 3. This shows the relation between the average of the error rate and the standard deviation. The plot distribution of the two groups is different in range. The average points and standard deviation line are drawn. This map shows obvious difference between the two groups.

Fig. 4 (a), (b) show similar results by an experiment of composing a musical scale on a key board of the computer. The selected 8 keys are programmed to have a function to output frequency-tunable sound when pushed. The subjects are asked to tune up the

key output sounds to the musical scale until they feel it correct. For reference, the errors got by a vocal experiment are shown by the dotted line.

Fig. 5 is the result of this experiment shown as the relation between the average error rate and its standard deviation. The obvious difference between the two groups is also found in this plot. But, it is unknown when these errors were implanted in subjects, because the same errors can be got if a wrong music scale is taught when a subject is very young.

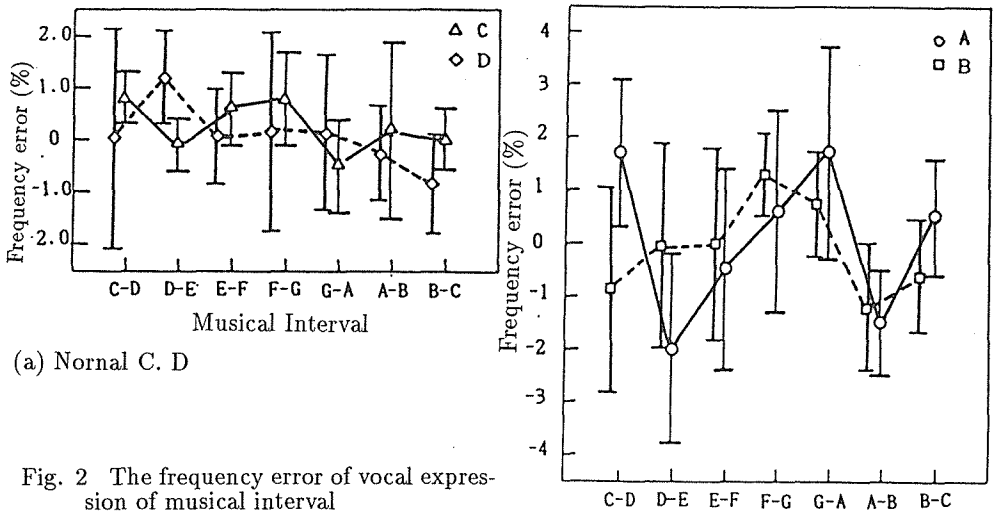


Fig. 2 The frequency error of vocal expression of musical interval

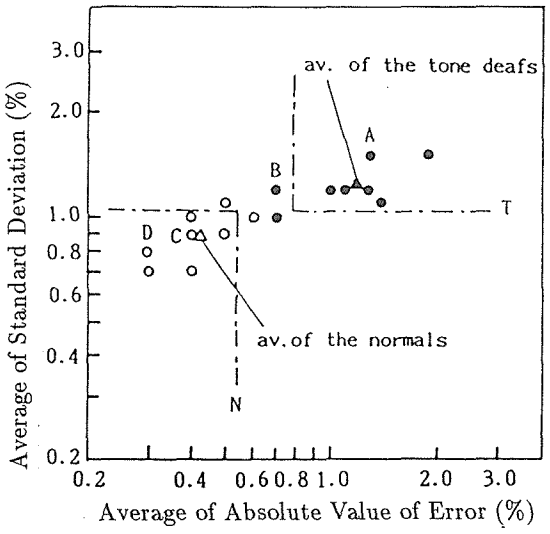
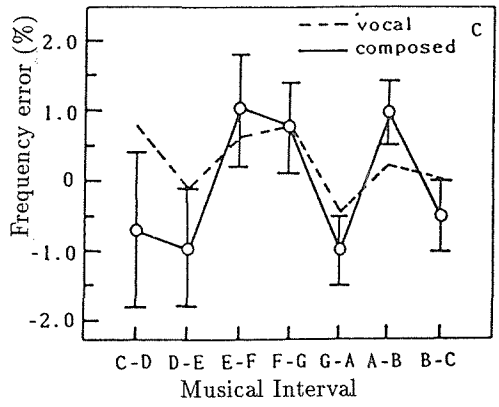
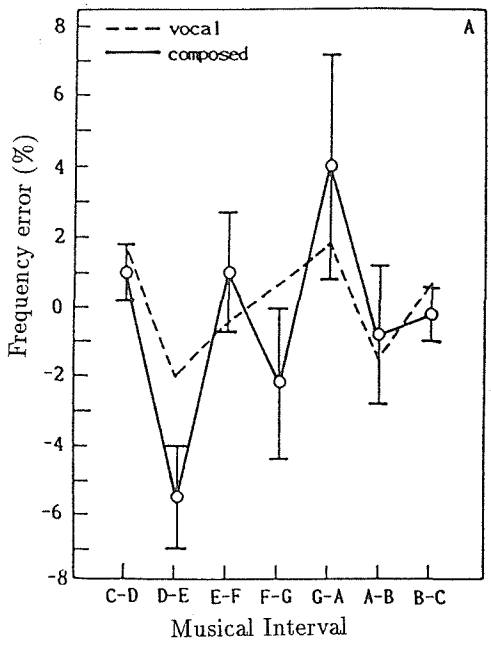


Fig. 3 The average of standard deviation vs. the average of absolute value of frequency error for vocal expression of musical interval.



(a) Normal C



(b) Tone deaf A

Fig. 4 The frequency error of composed musical interval.

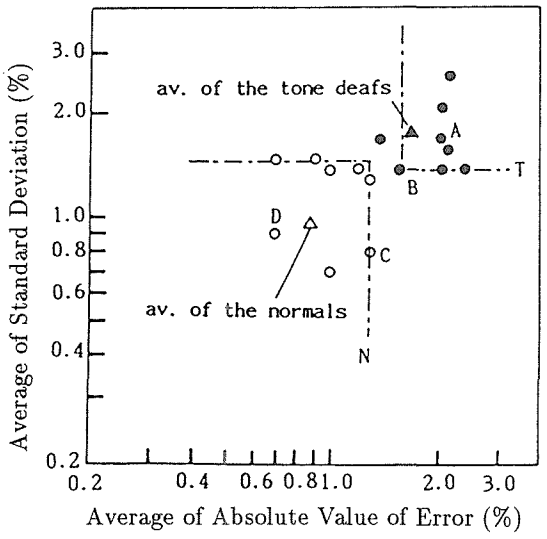


Fig. 5 The average of standard deviation vs. the average of absolute value of frequency error for composed musical interval.

3. Error in vocalizing single tone

After listening to a pure tone, subjects were asked to vocalize /a/ at the same pitch frequency as the pure tone. The Error found by this test is defined as follows:

$E_1 = (f_2 - f_3)/f_2 \times 100$ (%)

f_2: frequency of presented pure tone

f_3: pitch frequency of vocalization

Fig. 6 is the results of this experiment. And also, we can see a great difference between the two groups. This tells that the tone deaf condition is in the subjects even now. And the tone deaf can't simulate the heard pure tone by vocalization at the same pitch.

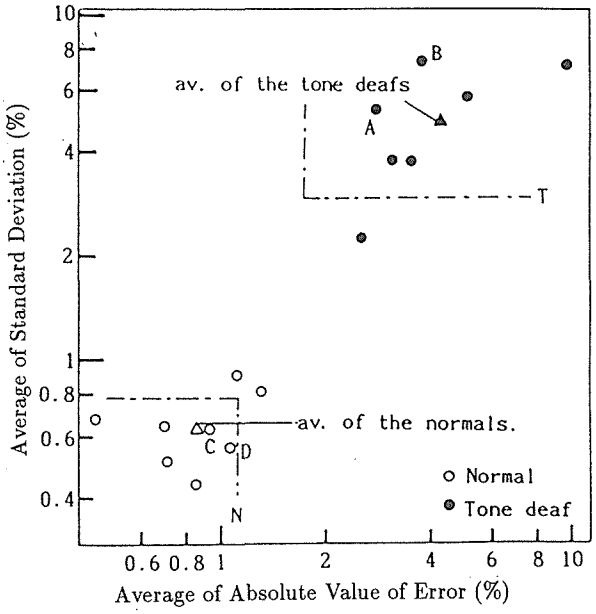


Fig. 6 The average of standard deviation vs. the average of absolute value of frequency error.

4. Error in tuning single tone

To know which process the cause of tone deafness lies in, in a vocalization process or in an auditory process, the subjects were asked to tune up a tone from an oscillator to another tone which had been presented before tuning. This test doesn't include the vocalization process above-mentioned. In this experiment, presented tones were pure ones(single frequency) and square wave form ones(including multi frequency).

Fig. 7 shows the relation between average errors and its standard deviation. In this test, the presented tones are the same as tuned tones. Unlike the previous tendency, there is no difference of errors between the two groups. Fig. 8 also shows the relation

between the average errors and its standard deviation in the case in which the presented tone is square wave form tone and tuned tone is pure tone. We can see again a great difference between the two groups.

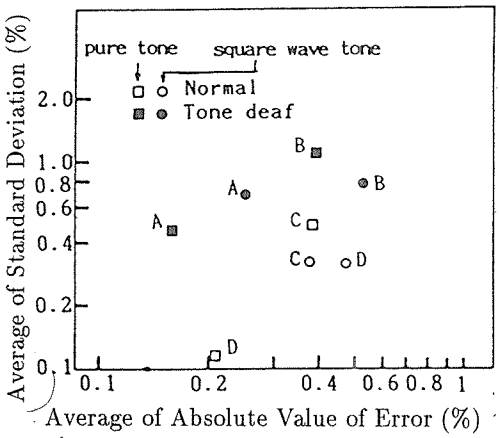


Fig. 7 The average of standard deviation vs. the average of absolute value of frequency error adjusted tone.

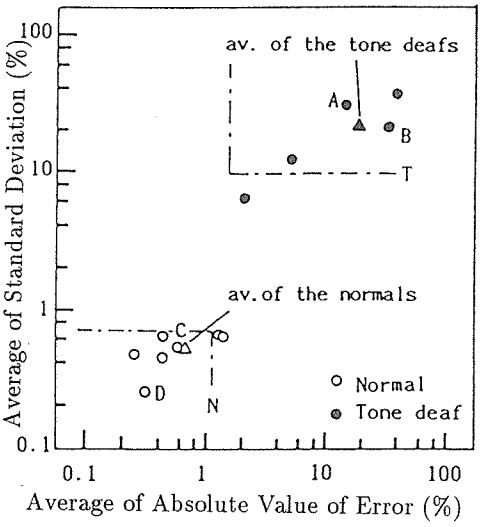


Fig. 8 The average of standard deviation vs. the average of absolute value of frequency error of adjusted pure tone.

5. Estimation of the mechanism of tone deafness

By this experiments, the following facts are revealed. For the tone deaf,

I. To vocalize a melody with small errors is difficult.

II. To tune up a melody with small errors is difficult.

III. To tune up their voices to a pure tone previously presented is difficult.

IV. To tune up a tone to the tone of the same kind tone presented before is easy.

V. To tune up a pure tone to the complex tone presented previously is difficult.

From these results and the fact that a vocal tone is also a complex tone, tone deafness is supposed to come from incapability to extract fundamental frequency from a complex tone. Namely, in the fact III and V, one of tones in presenting and tunning is complex. And maybe, the tones by which they learned music scale differ from their voice or pure tone they tuned. But, the fact IV shows the easiness of tunning up the same complex

tone. In this test, they were supposed to tune it up by timbre of the sound or to make errors in the same tendency. These results also show that tone deafness we are concerned with are sensory.

6. A trial of correction

From these experimental results, we can suppose that tone deafness can be corrected if the function of pitch extraction is substituted by a system. The system is constructed on the personal computer(NEC 9801UV21). The pitch is detected from a voice of the tone deaf and the pure tone of the pitch frequency is sent to auditory input of the person in 10ms. The tone deaf were asked to vocalize as high as the pure tone presented previously. Fig. 9 shows the result. They showed remarkable improvement in accuracy as the decrease of error rate and its standard deviation. But the effect is not perfect and there may be other causes of tone deafness.

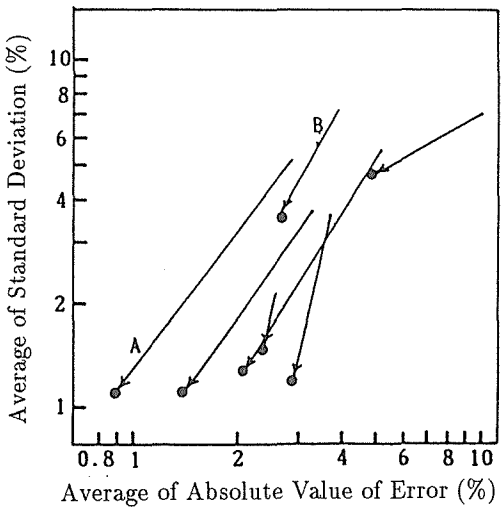


Fig. 9 The average of standard deviation vs. the average of absolute value of frequency error with pitch tone feed back.

7. Afterword

The mechanism of deafness was studied and a correction method based on the results was tried using the personal computer. The effects of correction are shown only during the use of the correcting system now. We suppose that the training of extracting pitch from their own voices by using this system will cure the condition of tone deafness.

References

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