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Analysis of F0 entrainment of singing voices in chorus

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1 Introduction

Music is one of the media to express human feelings in a similar manner as human communication or gesture. A great musical performance can touch the audience to the heart. Especially, chorus and orchestra can give a strong impression that cannot be achieved by a solo play. Of course, each performer's skill is important in a cooperative music. However, even if highly skilled performers play in a cooperative music, a great performance cannot be necessarily achieved. In a cooperative music, there should be an important factor on the relationship between the performers. Each performer fits his rhythm or fundamental frequency to that of the other performer. Focus of the previous studies has been mainly on synchronization of rhythms such as tempo and respiration. However, only a few researches focus on the synchronization of the fundamental frequency. If the fundamental frequency is not at all synchronized in a cooperative music, the musical performance may not sound very impressive. On the other hand, if the fundamental frequency is completely synchronized, it sounds like machinery, such as a computer-generated performance, which is less artistic. In this study, we investigate the relationship between the fundamental frequencies of the two singers who simultaneously sing a long tone.

2 Experiment of chorus

We carried out experiments on chorus by two singers. The experiments were conducted in a soundproof room. We recorded both EGG(Electro Glottography) signals and singing voices simultaneously. The singers could be classified into two groups: one consists of trained vocalists and the other consists of untrained vocalists. Each group had three males and three females. All combinations of the singing pair were examined in each group within the same gender. The subjects were asked to sing a long tone, which is composed of a single sustained note. Two situations were considered: one is a normal chorus by two singers and the other is a chorus in which one singer sings with a recorded voice of the other singer. As the chorus style, unison and major triad were considered.

The fundamental frequency was estimated from the EGG signal by using STRAIGHT-TEMPO that is a part of STRAIGHT. We represent the relationship between the fundamental frequencies of the two singers by using the absolute value of a frequency ratio , to clarify entrainment of the singing voices. It is assumed that, from the start of the singing, the frequency ratio decays in an exponential order of time. To characterize the entrainment property, we calculate a settling time which is defined as an interval during which the frequency ratio converges to a stable value. The stable value is defined the average value of the frequency ratio between 1.5-2.5 seconds after the start of the singing.

As the result, the settling time of two groups showed no significant difference, and the stable average of two groups showed significant difference. There is a possibility that the music experiences other than the singing affect an ability of adjusting the fundamental frequency to the partner's voice.

We compare the result of unison with the result of a chorus in which one singer sings with a recorded voice of the other singer. The settling time showed influenced by singer pair. The stable average in unison was closer to 0 cent than that in a chorus in which one singer sings with a recorded voice of the other singers. It showed that the synchronization of the fundamental frequency in the normal chorus by two singers was easier than that in a chorus in which one singer sings with a recorded voice of

the other singers.

3 Evaluation of artistic level

We evaluate an artistic level by subjective listening test and compare the artistic level with the settling time and the stable average. We carried out experiments by a method of the paired comparison. We calculate a rank of the artistic level. The subjects were four male who were not the singers in experiment of chorus. Two subjects were asked to evaluate an artistic level of recorded voice of male, other subjects were asked to evaluate an artistic level of recorded voice of female. The subjective listening test repeated three times.

The stable average contributes to artistic level compared with the settling time.

4 Conclusion

In this study, we investigate the relationship between the fundamental frequencies of the two singers who simultaneously sing a long tone. The frequency ratio of singing voice was compared between the trained vocalist and the untrained vocalist. Except for some cases such as the stable average in unison and chorus of the root and the major third, no systematic difference was found between the two groups. There is a possibility that the music experiences other than the singing affect an ability of adjusting the fundamental frequency to the partner's voice.

We evaluate an artistic level by subjective listening test and compare the artistic level with the settling time and the stable average. The stable average contributes to artistic level compared with the settling time.