Pitch perception factors of harmonic complex sounds with varied spectral tilt

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February 9, 2010

Keywords: pitch, harmonic complex sound, spectral titl, Multi Dimensional Scaling (MDS), perceptual space.

Generally pitch is strongly related to fundamental frequency. However, we experience different pitch when we listen to sounds, produced by different musical instruments, which has the same fundamental frequency. It is conceivable that the pitch is not only determined by fundamental frequency. It was reported that by E. Zwicker and H. Fastl (1999) the second harmonic influences the pitch perception. Roelf J. Ritsma (1967) showed that the lower harmonics had an influence on pitch. These studies showed that pitch of harmonic complex sounds was affected by higher harmonics. However, these researches did not show relations between the strength of harmonics (spectral tilt) and pitch in detail. Therefore, we investigate pitch perception of complex sounds with spectral tilt. This thesis confirms that pitch is different depending on change of spectral tilt. This thesis also investigates physical correlates of pitch perception in addition to the fundamental frequency. We used two groups of stimuli to investigate existence of pitch perception change depending on spectral tilt, and to investigate the factor of pitch perception.

In experiment I, we investigate the pitch perception varying with fundamental frequency. Our purpose is to arrange stimuli which are seven complex sounds having flat spectral tilt and varied F0s in pitch.

In experiment I, we used seven complex sounds having flat spectral envelope and varied F0s from 144 to 156 Hz at 2-Hz steps. These stimuli are the harmonic complex sounds having seven harmonics from the fundamental frequency. Listening tests were conducted in the soundproof chamber with nine subjects. We adopted Scheffe's Paired Comparison for the tests the subjects heard a pair of stimuli, and compared their pitch. The subjects were asked to answer which stimulus of the paired complex sounds is lower than the other in five grades, the former is low, the former is slightly low, same, the latter is slightly low, or the latter is low.

This result showed that pitch perception of these stimuli was strongly related to fundamental frequency.

The purpose of experiment Ⅱ is to investigate pitch sensation of stimuli which have different spectral tilts. We confirm that pitch is different depending on change of spectral tilt. We present stimuli consisting of spectral tilt according to pitch.

In experiment Ⅱ, fundamental frequency of the stimuli is 150 Hz. These stimuli are the harmonic complex sounds including seven harmonics from the fundamental frequency. We use the stimuli that eight kinds of spectral tilt are different. Listening tests were conducted with ten subjects (nine participated in experiment I and one additional subject). All other experimental procedures were the same as experiment I.

The stimuli with the different spectral tilts were presented according to pitch. As for this pitch perception, there probably are strong relationships among the peak, the slope or the center of gravity of spectral tilt.

Each of two group stimuli were presented depending on pitch in experiments I and Ⅱ. Therefore we tried an experiment to compare pitch, using the all stimuli. However, it was very difficult to compare the pitch of all stimuli. This shows possibility that the pitch perception factors of each stimulus group are different. The proof of this supposition is important.

We investigate possibility that the pitch perception factor in experiment I is different from that in experiment Ⅱ. In addition, we examine physical correlates of pitch perception varying with spectral tilt. We build perceptual space based on psychological distance of the stimuli to conduct this investigation.

The purpose of experiment Ⅲ is to investigate the psychological distance

of stimuli.

In experiment Ⅲ, we used all the stimuli of experiment I and experiment Ⅱ. Listening tests were conducted with ten subjects who were the same as the participants of experiment Ⅱ. The equipments and experimental procedure are the same as experiment I and Ⅱ. The subjects are asked to how similar the paired complex sounds is with six grades, the former is very similar, similar, slightly similar, slightly different, different, very different. To prove that the pitch perception factors of the stimuli used in experiment Ⅱ is different from that of the stimuli in experiment I, we adopted a multiple regression analysis with a result of MDS analysis in experiment Ⅲ and the results of experiment I and Ⅱ.

This result showed the possibility that pitch perception factors of two stimuli groups was different. This result is regarded as the reason why it was difficult to compare all the stimuli.

We investigated the possibility that the pitch perception factor in experiment I is different from that in experiment Ⅱ. In experiment I, we considered that pitch perception factors of the stimuli was fundamental frequency. In experiment Ⅱ, we considered that the pitch perception factor of the stimuli was not fundamental frequency. Based on the result of experiment Ⅱ, we expected that the physical correlates of the pitch was the peak of spectral tilt, the slope of spectral tilt and the center of gravity of spectral tilt. We adopted a multiple regression analysis with a result of MDS analysis in experiment III and the physical correlates. We applied the result of the multiple regression analysis to perceptual space that we built based on MDS. These physical correlates were calculated in a logarithmic frequency scale to match it with auditory perception. These results showed that the peak of spectral tilt, the slope of spectral tilt and the center of gravity of spectral tilt were physical correlates of pitch which changes depending on a change of spectral tilt. In this pitch perception, the center of gravity of spectral tilt was the best for physical correlates.

In this study, we used two groups of stimuli to investigate pitch perception changing depending on spectral tilt, and to investigate the factor of pitch perception. The first group is stimuli consisting of same spectral tilt having different fundamental frequency. The second group is stimuli consisting of the same fundamental frequency having different spectral tilt. In

each condition, we presented each stimuli according to the pitch. We built perceptual space with psychological distance of all stimuli by performing MDS analysis. We took a multiple regression analysis with the results of experiment I and Ⅱ. We applied these results to perceptual space built by MDS. The result showed the possibility that pitch perception factors in each two groups was different. In the stimuli consisting of the same fundamental frequency and different spectral tilt, we took a multiple regression analysis of some physical values. It suggests that center of gravity of spectral tilt was quantity of physics that is most strongly related to this pitch perception.