Proceedings of the 7th Triennial Conference of European Society for the Cognitive Sciences of Music (ESCOM 2009) Jyväskylä, Finland
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Psychological and Physiological Influences in Chord Progression Including the Prohibitions

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ABSTRACT

Harmony is one of three major elements in the music. Harmonics are the basic theory of composition. There are several kinds of prohibitions in relation to the chord progression in the rules of Harmonics. When composers compose music pieces, they pay attention not to contain these prohibitions. The prohibitions are empirically- defined with giving the musical expressions to melody processes by try and error. Even so, there are few studies that are quantitatively examined the perceptual effect of the prohibitions. Therefore, the authors have investigated the perceptual effects of the prohibition quantitatively. The present study deals with the psychological tests and the physiological measurements using electro-encephalograph (EEG) in listening of the chord progressions. When subjects listened to the chord progression including the consecutive chord with one of the prohibitions, how subjects perceive to the consecutive chord by the method of paired comparisons test and how the chord progression induces "P300" by EEG in physiological experiment. Psychological results suggest that subjects can distinguish the consecutive chord with one of the prohibitions. P300 was elicited by the prohibition in the physiological experiment. These results suggest that there is a different response of listening to the consecutive chord with the prohibition.

I. INTRODUCTION

Recently, the development of technology to observe the brain function has been active in research and understanding of the brain activity. However, the "fMRI" and other instruments emit a loud noise during operations, and their characteristics have low time resolutions. Therefore, most researches in the brain functions have been actively conducted in related to visual and tactile senses and the researches on auditory sense are few. Especially there are very few researches on hearing of music, because the information from music is far more abstract and ambiguous than the language or the figures.

Tempo, melody and harmony are basic elements in the compositions of music. In previous works, the emotional changes and the brain activity depend on the variation width in melody in hearing of music (Hirai et al., 2006; Mito et al., 2003). There are some different auditory responses that depend on hearing of either a monotone or a chord (Kuriki et al., 2006). Some studies reported that the concordant or the discord gives different changes in auditory responses (Shiba et al., 2003). There is a significant response in hearing the chord changes (Tamaki et al., 2007). Various studies have been conducted to understand the effect of the music.

The music contains a chord which is formed to support the melody. The chord progressions are formed by combine the chords. Even so, there are some chord progressions which have the prohibitions in music. There are a few types of prohibitions in music. The consecutive quint is progressed in the quintuplet of two voice parts. This prohibition disrupts the balance of the sound in music. When composers compose their music pieces, they pay attention not to contain the prohibitions. However, it is very difficult even for musicians to distinguish the chord progression with the prohibition or without the prohibition. As the prohibitions are defined, it is considered that the prohibitions would give some effects for listeners. Nevertheless, there are few studies that have examined the perceptual effect of the prohibitions quantitatively. Therefore, the perceptual effects of the prohibitions in hearing of music have been investigated in this study quantitatively.

This study consists of two approaches by psychological and physiological experiments. Psychological experiment is conducted by the method of paired comparisons in hearing the chords, and physiological experiment is conducted by measuring the brain waves (EEG) in hearing the chord progressions. Analysis of the EEG is proposed by several kinds of methods. The auditory evoked potential has greater effects by the consonant than discordance sounds (Shiba et al., 2004). It is reported that the β wave is remarkably increased by listening to music (Nakamura et al., 1999), and the appearance of β wave has varied with music pieces (Mori et al., 2006). Analysis of the brain waves is conducted by the frequency analysis and the auditory evoked potential.

II. MATERIALS AND METHODS

A. Psychological Experiment

Twelve subjects (21 to 23 years of age; nine males and three females) participated in the psychological experiment. They were university students and all right-handed. All subjects had not received lessons or training in musical instruments except for music courses in elementary school and junior high school.

Auditory stimuli of piano chords were generated with a software synthesizer. The presented timing of stimuli to the subjects was controlled by a program. Two consecutive chords are created in C major. An example of the score is shown in Figure1. These stimuli of two chord progressions randomly presented to the subjects with the sound pressure level of 60-65 dB in the audio proof room. Subjects were asked to judge which chord progression was beautiful.

B. Physiological Experiment

Three males (21 to 23 years of age) participated in the physiological experiment. They were university students and all right-handed. All of the subjects had not received lessons or training in musical instruments except for music courses in elementary school and junior high school. The subjects participated in this experiment gave the informed consents after explanation of EEG recordings.

Auditory stimuli of piano chords were generated with a software synthesizer. These presented timing of stimuli to the subjects were controlled by a program. Two consecutive chords are created in C major.

Four kinds of the chord progressions are divided four test sections, and each chord progression was presented to the subjects at 2 second interval in each listening test. About 5%of different chord progression mixed in a series, and the subjects were instructed to count the number of stimuli that have emerged different chord progressions as "Oddball issues". Original contents of this Oddball task are to watch the brain activity when the stimulus appeared different, but in this experiment used as a dummy Oddball issue.

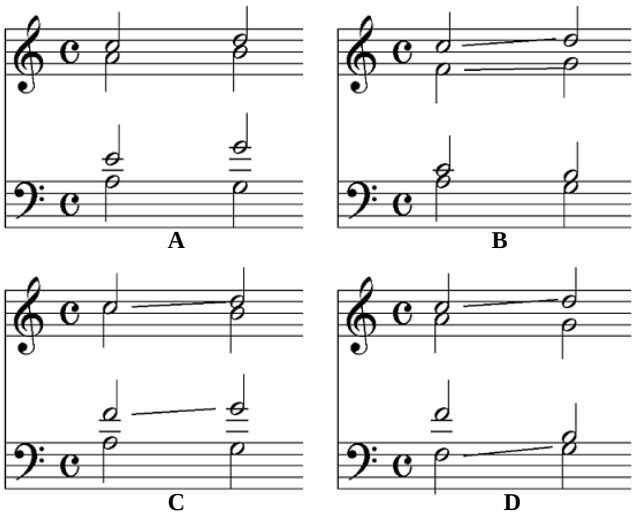


Figure 1. An example of chords. "A" is acceptable and other chords with the prohibition.

Experimental conditions for measuring the brain waves are sampling at 200Hz with a high pass filter 1.6Hz, a low-pass filter 100Hz and a hum filter set to 60Hz, and the sound pressure level of 60dB.

Until the chord progression as a target was presented to the subjects 50 times, the data of the brain waves were measured. Subjects keep eyes closed during this measurement at rest (resting state of closed eyes). The EEG analysis system for these data was developed using the MATLAB system.

The EEG 10-20 system diagram for measuring the brain waves is shown in Figure 2. The brain waves near the part of the auditory cortex (F4, C4, F8) were measured and the average processing of 50 times was done for each subject' data, and the value of RMS (root mean square) of evoked potential was compared with each stimulus. Frequency analysis was done during 500msec interval when the chord with the prohibition appeared in the test.

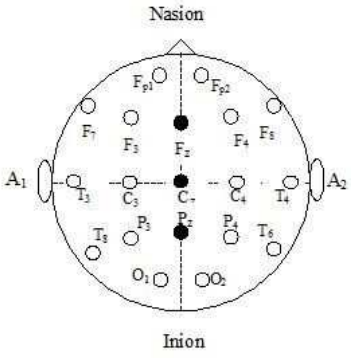


Figure 2. EEG 10-20 system diagram for brain wave measurement

III. RESULTS

A. Psychological Experiment

Two chord progressions randomly presented to the subjects. All subjects judged that the chord progression without the prohibition was most beautiful. Other three chord progressions with the prohibition are a little difference. But this difference was little compared with the chord progression without the prohibition. These results are shown in the Figure 2. Here the capital letters A, B, C, D show the stimuli of the chord progressions, and the locations on the line are the relative distances from the evaluation tests.

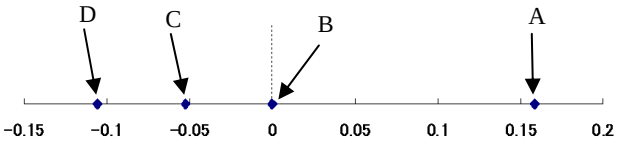
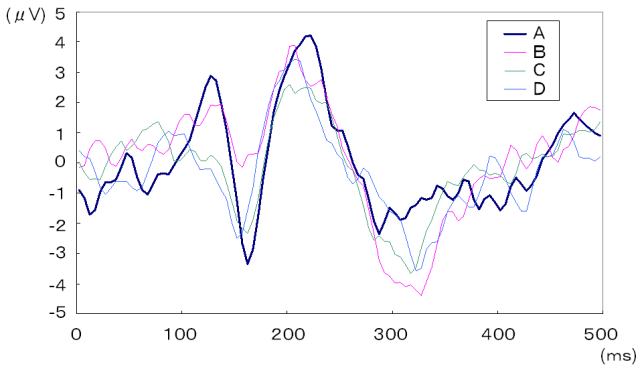


Figure 3. Relative distances among stimuli from the evaluation test

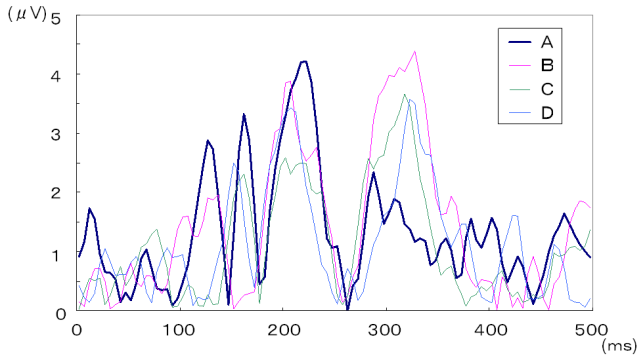
B. Physiological Experiment

By averaging the data from the EEG measurements, the auditory evoked potential occurs notably from the moment when the subjects heard a chord to 100 ~ 400msec of the latency in all section (shown in Figure 4a). The results from these values of RMS show that a stronger response occurs at the latency of around 300ms when subjects hear the chords with the prohibition (shown in figure 4b). The powers at 250 ~ 350ms of latency were calculated to compare with response of hearing the chord progressions (shown in Figure 4c). The results show that the power in hearing the chord progression with the prohibition is greater than the power in hearing the chord progression without the prohibition.

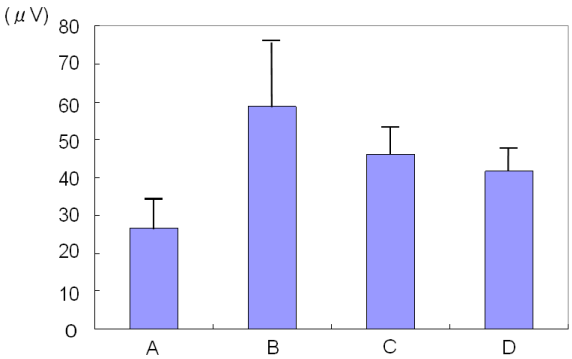
Here at the 1-way ANOVA test, a significant difference was recognized ($F(3, 8) = 4.95$; $p < 0.05$). As ANOVA shows a significant difference in the test, Post-hoc Schaffer test was done and the result shows that there is $p < 0.08$ significant difference between the power in hearing the chord without the prohibition and the power in hearing the chord with the prohibition.



(a)



(b)



(c)

Figure 4. (a) EEG average increment. (b) RMS values of EEG. (c) Powers of around 300ms latency

It is showing that the content rate of β wave in hearing the chord without the prohibition is greater than that with the prohibition by frequency analysis of the data from the EEG measurements(shown in Figure 5). Here at the, 1-way ANOVA test, the significant difference ($F(3, 8) = 7.93$; $p < 0.05$) was recognized. As ANOVA shows a significant difference in the test, Post-hoc Schaffer test was done and the result shows that there is $p < 0.10$ significant difference between the content rate of β wave in hearing the chord without the prohibition and that in hearing the chord with the prohibition.

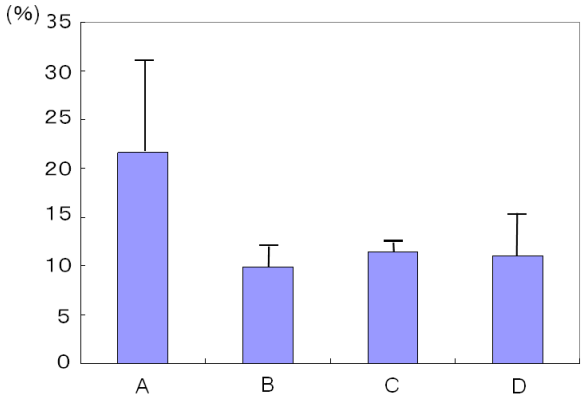


Figure 5. Content rate of β wave

IV. DISCUSSION

The power of response at the latency around 300msec amplifies when subjects hear the cacophony. When the prohibition occurs in hearing the chord progression, the power of response at the latency around 300msec also amplifies as well as the results in the earlier study. From these results, it is considered that the sound of the chord with the prohibition causes the similar response to the auditory dissonance.

The β wave appears in the mind of excitement, so the results suggest that the chord progression without the prohibition a greater influence on the state of human mind than that with the prohibition. The β wave is amplified in listening to music, which suggest that most of the musical information exists in the harmonic progression.

V. CONCLUSION

In this paper, the authors conducted a study on the auditory response when the prohibition occurs in the chord progression of functional harmony. We considered influences of the chord progression with and without the prohibition from psychological tests by the paired comparisons and from the physiological experiment by measuring the brain waves.

The result in psychological experiment shows that the chord progression without the prohibition keeps the beautiful impression of sound from the result of paired comparison.

The results of physiological experiments by measuring brain waves show that the response of auditory dissonance occurs when subjects hear the chord progression with the prohibition and the content rate of β wave increase when the prohibition appears, thus the sound of the chord progression without the prohibition would be preferable to human hearing.

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