Proceedings 2003 IEEE International Symposium on Computational Intelligence in Robotics and Automation July 16-20, 2003, Kobe, Japan

A Musical Communication between a Player and a Listener and its Model

Tomohito YAMAMOTO, Norimasa FUJII, Yoshihiro MIYAKE

Computational Intelligence and System Science,
Dept. of Interdisciplinary Graduate School of Science and Engineering,
Tokyo Institute of Technology
Yokohama, Japan
tyama@myk.dis.titech.ac.jp, hujii@myk.dis.titech.ac.jp, miyake@dis.titech.ac.jp

Abstract

In this paper, to analyze the mechanism of the communication between a player and a listener, the relation between the time course of acoustic level and the time course of physiological level of a live performance were analyzed at the same time. The results revealed that (a) where scatter of note was low, music rhythm of a player and handclap rhythm of a listener were likely to synchronize, and where scatter of note was high, both respiration rhythms were likely to synchronize, (b) where scatter of note was high, the coupling between acoustic level and physiological level became strong. To interpret these results, we hypothesized that where scatter of note is high, a player and a listener have to anticipate the timing of sounding, and proposed the new communication model between a player and a listener.

1 Introduction

We sometimes feel the difference between music of CD and music of a live performance. Generally, the visual and auditory information of a live performance have been focused on as the reasons [1][2]. However, we consider a live performance as a musical communication, and focus on the interaction between players and listeners.

Up to now, a musical communication has been researched from two aspects. One is from acoustic aspect. For example, R.A.Rasch [3] researched the synchronization between players when they played music at the same time. Y.Horiuch [5] researched the mechanism of playerís synchronizing way with the other player in a cooperative performance.

The other is from physiological aspect. For example, S.Inoguchi [6] researched the relation between tension state of a player and that of listeners by measuring the heart rate and skin potential of them. I.Koura [7] researched the synchronization of respiration between players in playing the guitar. This research suggested that when player playing difficult music or when armature playing music, respiration rhythms were likely to synchronize.

Weíve already researched the relation between a player and a listener from both of aspects[8]. This research suggested that there was an interaction between a player and a listener, and there was a mutual entrainment between respiration rhythm and music rhythm. However, weíve only analyzed it statically, and not analyzed the mechanism of the interaction. Therefore in this paper, to investigate the mechanism of communication between a player and a listener, we analyze the relation between the time course of acoustic level and the time course of physiological level of a live performance at the same time. To investigate the mechanism, we measure respiration of a player and a listener as a physiological index and measure musical rhythm of a player and handclap rhythm of a listener as an acoustic index.

2 Method

2.1 Measurement Procedure

The players were two graduate students who had 15 years experience of playing the piano (Male, 25,27). The listeners were three graduate students (Male, 22-23). 3 of music were used for experiment.

Music A: Praeludium C dur (Composed by J.S.Bach, Music Length: about 145sec)

Music B: Energy Flow (Composed by Ryuich Sakamoto, Music Length: about 95sec)

Music C: Ely my love (Composed by Keisuke Kuwata, Music Length: about 120sec)

These three of music have each tempo pattern. Music A

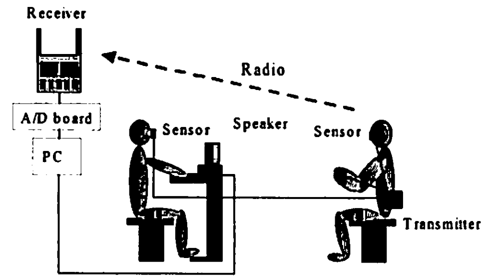


Fig.1 Measuring system

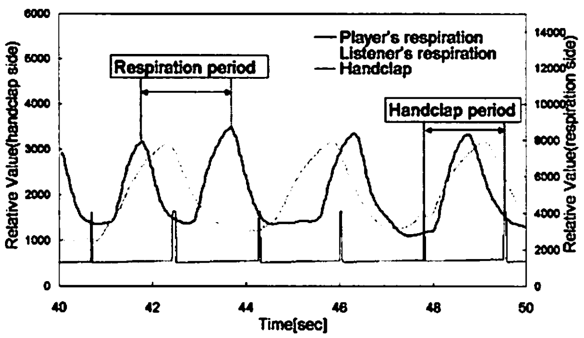


Fig.2 Respiration and handclap waves

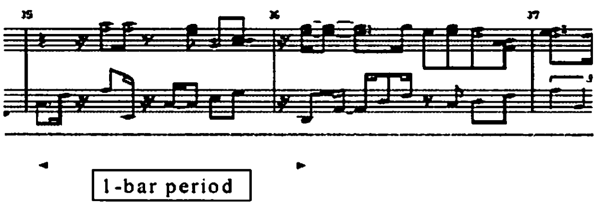


Fig.3 MIDI data of player's performance

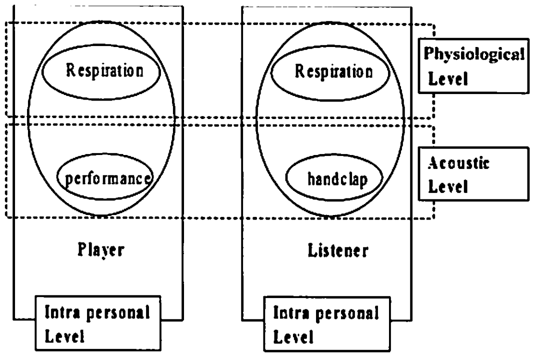


Fig.4 Shematic view of analysis

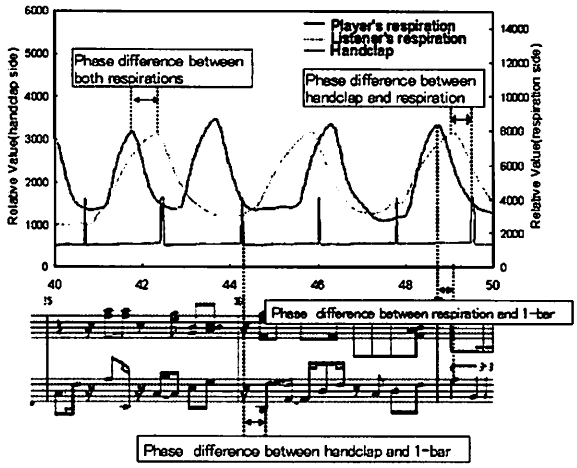


Fig.5 Definition of phase difference

has monotones tempo pattern. Music B has changing tempo pattern only in bar:16-19 and bar:35-38. Music C has complicated changing tempo pattern.

Measurement procedure was that firstly, each listener listened the played music without handclap, and next, each listener listened the played music with handclap at first and third beat. This procedure was repeated three times in each music.

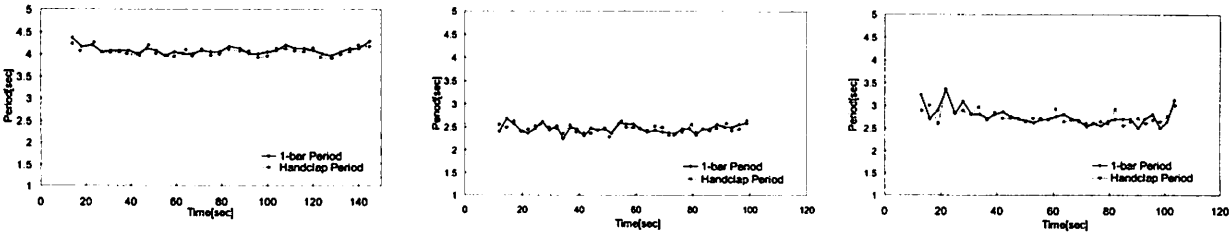
2.2 Measurement System

Fig.1 shows measurement system. Musical Performance was performed with the electrical piano (Roland: RD-600), and sound was presented by the speaker (ONKYO: GX-R3). There were 2m between a player and a listener. Performance of piano was recorded by the MIDI sequencer (emagic: Logic Audio platinum Ver.3.5). Respiration of a player and a listener was measured by an attached thermistor sensor (NIHON KODEN:TR-511G) at nasal cavity (Therefore singing and humming is restricted). Handclap of a listener was measured by electrode attached at the palm. Measured data were sent to receiver (The same:WEB-5000) from transmitter (The same:XB-581), and those were carried to PC (Intel Pentium II 450Mhz) through A/D converter (Interface:IBX-3119) with 100Hz sampling rate and 12bit resolution. Measurement accuracy of music is 0.04sec, and that of respiration is 0.02.

2.3 Analysis Procedure

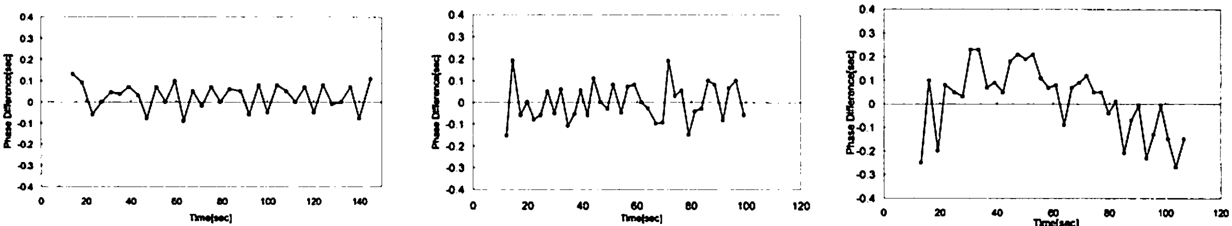
Indices of a player for analysis are respiration rhythm and 1-bar rhythm, and indices of a listener are respiration rhythm and handclap rhythm. Fig.2 shows an example of measured handclap data, and Fig.3 shows recorded MIDI data. Respiration period is calculated by the time difference between two high peaks. Handclap period is calculated by the time difference between two rectangle waves. 1-bar period is calculated by the time difference of first note of a bar to first note of a next bar.

Fig.4 shows all of the indices that are used for analysis in section 3,4. In section 3, phase difference of acoustic level and physiological level are focused on, and the inter-personal relation is analyzed with them. Fig.5 shows the way of calculation of each phase difference. Phase difference between handclap rhythm and 1-bar rhythm is calculated by the time difference between first note of a



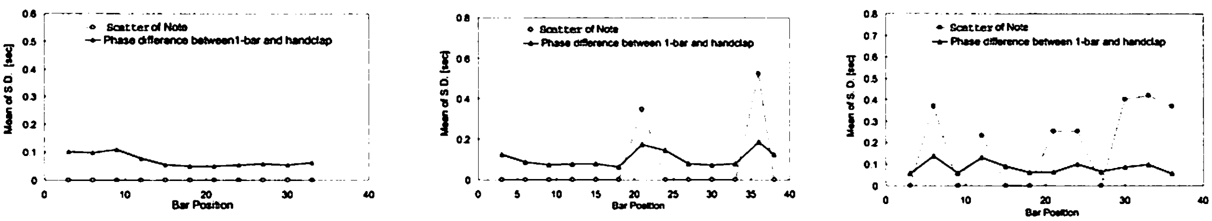
(a) **Music A** (b) **Music B** (c) **Music C**

Fig.6 Time course of 1-bar and handclap period



(a) **Music A** (b) **Music B** (c) **Music C**

Fig.7 Time course of phase difference between respiration rhythm and handclap rhythm



(a) **Music A** (b) **Music B** (c) **Music C**

Fig.8 Mean S.D. of mean phase difference between 1-bar rhythm and handclap rhythm and scatter of note

bar and a rectangle wave. Phase difference between respiration rhythms is calculated by the time difference between high peaks of a player and a listener.

In section 4, phase difference between respiration rhythm and 1-bar rhythm of a player and phase difference between respiration rhythm and handclap rhythm of a listener are focused on, and the intra-personal relation is analyzed with them. Phase difference between 1-bar rhythm and respiration rhythm is calculated by the time difference between first note of a bar and a high peak. Phase difference between handclap rhythm and respiration rhythm is calculated by the time difference between a rectangle wave and a high peak.

In this paper, scatter of note of music score is used as score information. The way of calculation is that a quarter note is converted to 1, a eighth note to 0.5, a whole note to 4, and its standard deviation value through 3 bars is calculated. If this value is low, musical rhythm is stable and if this value is high, musical rhythm is unstable.

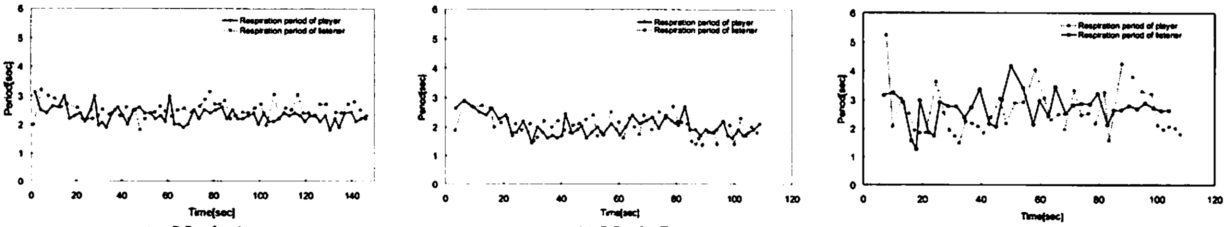
3 Analysis of inter-personal relation

3.1 Relation between music rhythm and handclap rhythm

In this subsection, the relation between a player and a listener in acoustic level is analyzed. Fig.6a-c show one example of the time course of 1-bar period and handclap period of Music A,B,C. As figure shows, each music has each period. Fig.7a-c show the phase difference between 1-bar rhythm and handclap rhythm shown in Fig.6a-c.

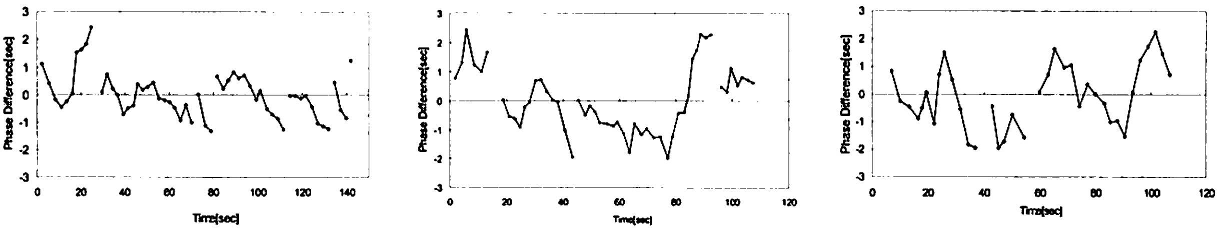
To investigate the characteristic of the time course of the phase difference, some calculation was performed. At first, S.D. of each three bars of phase difference was calculated, and mean value of all trials (18 case) was calculated. As mentioned in subsection 2.3, scatter of note of each song are introduced as the characteristics of music. Fig.8a-c show their pattern. Scatter of note of Music A has flat pattern. Scatter of note of Music B has two peaks, and Music C has more complicated pattern.

As shown in Fig8a,b, where scatter of note is relatively high, mean S.D. of phase difference is high, and where is scatter of note is relatively low, mean S.D. of phase



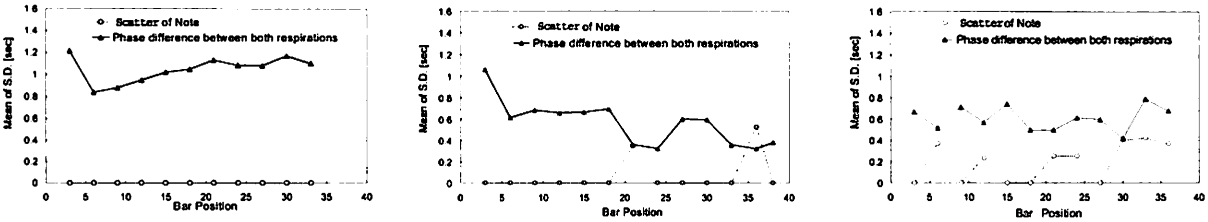
(a) Music A (b) Music B (c) Music C

Fig.9 Time Course of respiration periods



(a) Music A (b) Music B (c) Music C

Fig.10 Time course of phase difference between respiration rhythms



(a) Music A (b) Music B (c) Music C

Fig.11 Mean S.D. of phase difference between respiration rhythms and scatter of note

difference is low. In Fig.8.c, the cross correlation between mean S.D. of phase difference and scatter of note is 0.389 ($p<0.05$). This result means that Music C has same tendency to Music A.B.

These results suggest that where scatter of note is low, handclap rhythm and music rhythm is more likely to synchronize.

3.2 Relation between playerís respiration rhythm and listenerís respiration rhythm

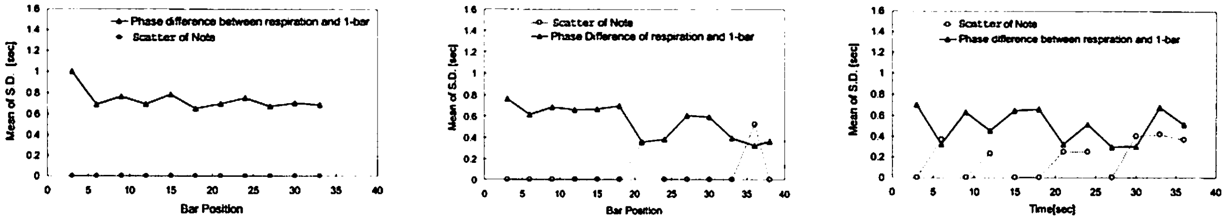
In this subsection, the relation between a player and a listener in physiological level is analyzed. Fig.9a-c show one example of the time course of the playersí and listenersí respiration period of Music A,B,C. Fig.10a-c show phase difference of respiration shown in Fig.9a-c. Fig.11a-c show scatter of note and mean S.D. of phase difference of respiration, as same as Fig.8a-c. As Fig.11a,b shows, where scatter of note is high, mean S.D. of phase difference of respiration is low, where scatter of note is low, mean S.D.. of phase difference of respiration is high. In Fig.11c, the cross correlation between mean S.D. of phase difference and scatter of note is -0.360 ($p<0.05$). This result means that Music C has same tendency to Music A.B.

These results suggest that where scatter of note is high, respiration rhythms between a player and a listener is likely to synchronize. These results are opposite to results of 3.1.

4 Analysis of intra-personal relation

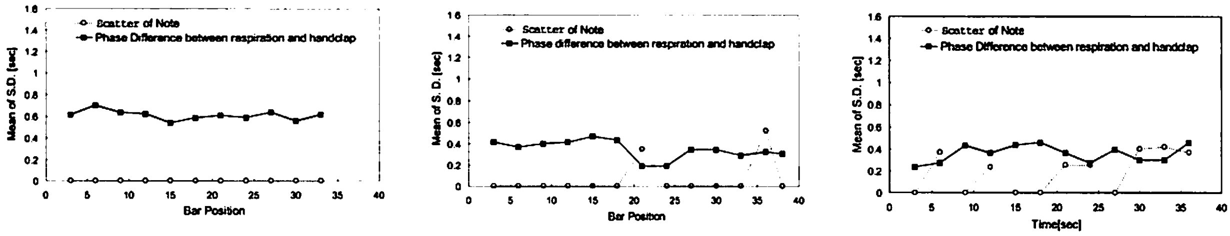
In section 3, inter-personal relation was analyzed. In this section, to investigate the intra-personal relation, the relation between 1-bar rhythm and respiration rhythm of a player, and the relation between handclap rhythm and respiration rhythm of a listener are analyzed.

Fig.12a-b show mean S.D. of the phase difference between 1-bar rhythm and respiration rhythm of a player, Fig.13a-b show mean S.D. of the phase difference between handclap rhythm and respiration rhythm of a listener. As Fig.12a,b and Fig.13.a,b show, where scatter of note is high, both phase differences are low, and where scatter of note is low, both phase differences are high. In Fig.12a, the cross correlation between two phase differences is -0.400 ($p<0.05$), In Fig.13a, the cross correlation between two phase differences is -0.311 ($p<0.05$). This result means



(a) Music A (b) Music B (c) Music C

Fig.12 Mean S.D. of phase difference between respiration rhythm and 1-bar rhythm and scatter of note



(a) Music A (b) Music B (c) Music C

Fig.13 Mean S.D. of phase difference between respiration rhythm and handclap rhythm and scatter of note

that Music C has a same tendency to Music A,B.

These results suggest that where scatter of note is high, 1-bar rhythm and respiration rhythm of a player was likely to synchronize, and handclap rhythm and respiration rhythm of a listener was also likely to synchronize.

5 Discussion

In section 3, to investigate the mechanism of the interpersonal relation, the relation between 1-bar rhythm and handclap rhythm, and the relation between playerís respiration rhythm and listenerís respiration rhythm were analyzed. In subsection 3.1, it was suggested that where scatter of note was low, handclap rhythm and 1-bar rhythm were more likely to synchronize. In subsection 3.2, it was suggested that where scatter of note was high, respiration rhythms between a player and a listener were more likely to synchronize. That is to say, where 1-bar rhythm and handclap rhythm relatively synchronize, both respiration rhythms do not synchronize, conversely where 1-bar rhythm and handclap rhythm relatively do not synchronize, both respiration rhythms synchronize.

In section 4, to investigate the mechanism of the intrapersonal relation, the relation between 1-bar rhythm and respiration rhythm of a player, and the relation between handclap rhythm and respiration rhythm of a listener were analyzed. The results suggested that where scatter of note is high, 1-bar rhythm and respiration rhythm of a player were likely to synchronize, and handclap rhythm and respiration rhythm of a listener were also likely to synchronize. To interpret these results, at first, we hypothesize that where scatter of note is high, a player and a listener have to anticipate the timing of sounding. Next, some researches are cited [8] [9]. These researches revealed that respiration rhythm and musical rhythm were coupling, therefore it is suggested that 1-bar rhythm and respiration rhythm of a player, and the handclap rhythm and the respiration rhythm of a listener are coupling.

With this hypothesis and the suggestion, the results are interpreted as follows; where a player and a listener have to anticipate the timing of sounding, the coupling between acoustic level and physiological level become strong and both rhythms synchronize. Where a player and a listener do not have to anticipate the timing of sounding, the coupling between them become weak and both rhythms do not synchronize.

We propose the communication model (Fig.14) between a player and a listener with this interpretation. There are acoustic interaction between a player and a listener whether scatter of note is high or low. Where scatter of note is

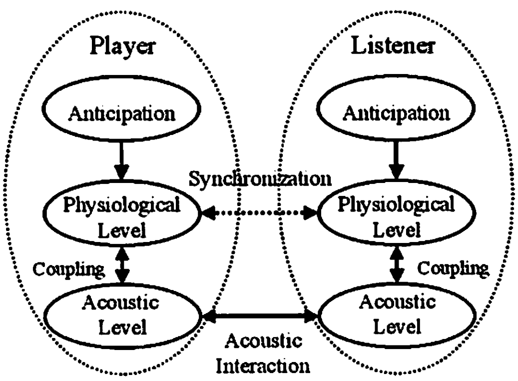


Fig.14 Model of interaction between a player and a listtener

high, it is difficult to synchronize the timing, therefore in acoustical level, handclap rhythm and 1-bar rhythm do not synchronize. However a player and a listener have to anticipate the timing of sounding in such the part, and the coupling between acoustic level and physiological level become strong. As a result, in physiological level, both respiration rhythms synchronize. Where scatter of note is low, it is easy to synchronize the timing, therefore in acoustical level, handclap rhythm and 1-bar rhythm was likely to synchronize. In such the part, a player do not anticipate the timing of sounding so much, the coupling between acoustic level and physiological level become weak, and as a result, in physiological level, both respiration rhythms do not synchronize.

Based on this model, it is suggested that respiration is an interface between anticipation that is high degree function of brain and physical rhythm that generate musical rhythm. In future works, we will investigate the relation the anticipation and respiration in dynamics level to verify the hypothesis, and to construct fine model.

6 Conclusion

In this paper, to analyze the mechanism of the communication between a player and a listener, the relation between the time course of acoustic level and the time course of physiological level of a live performance were analyzed at the same time. Firstly, it was suggested that where scatter of note was low, handclap rhythm and music rhythm were likely to synchronize, and also suggested that where scatter of note was high, respiration rhythms between a player and a listener were likely to synchronize. Secondary, where scatter of note was high, 1-bar rhythm and respiration rhythm of a player were likely to synchronize, and handclap rhythm and respiration rhythm of a listener were also likely to synchronize. To interpret these results, we hypothesized that where scatter of note was high, a player and a listener had to anticipate the timing of sounding, and proposed the new communication model between a player and a listener that was composed of acoustic level, physiological level and anticipation level.

Reference

[1] K.Ohgushi. How Are the Playerís Ideas Conveyed to the Audience?, Music Perception. 4(4):311-324. 1987.

[2] T. Yokota, T. Seimiya, S. Sakamoto and H. Tachibana. Difference in acoustic effect of sound diffusers due to room shapes. J. Acoust. Soc. Jpn.(E). 21(5):283-285

[3] R.A.Rasch. Synchronization in Performed Ensemble Music. ACUSTICA.43:121-131.1979

[4] Y.Kobayashi. and Y.Miyake. New Ensemble System based on Mutual Entrainment. Proc. of 2002 IEEE International Conference on Systems, Man, and Cybernetics. Hammamett. Tunisia. MP1J1 pases 1-6 2002

[5] Y.Horiuchi. K.Sakamoto.A.Ichikawa. Estimating the Model of Human Performance in Ensemble (in Japanese), J. of IPSJ. 43(2):260-267. 2002

[6] H.Tsutada,H.Kato,A.Kimura,H.Katayose,T.Kanamori. S.Inoguti . A Physiological Analysis of Tensity of Performer and Audience in Interactive Art. JVRSJ, 2(2):9-16 1997

[7] I.Koura. "Iki ga au"(in Japanease). Kitaouji-shobo,1990

[8] T.Yamamoto and Y.Miyake. Analysis of Interaction in Musical Communication and Its Modeling, Proc. of 2000 IEEE International Conference on Systems, Man, and Cybernetics. pases 763-768. 2000.

[9] F.Haas,S.Distenfeld and K.Axen : Effects of perceived musical rhythm on respiratory pattern.J. APPL. PHYSIOL.. 61(3) pp.1185-1191. 1986.

[10] R.R.Bechbache and J.Duffin. THE ENTRAINMENT OF BREATHING FREQUENCY BY EXERCISE RHYTHM.J.Physiol. 272:553-561. 1977.