Effect of a listener on a player in a musical live performance

Tomohito YAMAMOTO[1], Yoshihiro MIYAKE[1]

[1] 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 miyake@dis.titech.ac.jp

Abstract--**Listening to music at a live concert is different from listening to it with CD player. It is caused from not only sound facilities but also interaction between players and listeners. In this study, we investigated the relation between listener's respiration and player's 1-bar period to analyze interaction in a live performance. As a result, it was suggested that listener's respiration period was changed by music, and also player's 1-bar period was changed by a listener, and mutual entrainment occurred between 1-bar period and respiration period.**

***Keywords*: Respiration, Music, Interaction, Entrainment, Live Performance**

I. INTRODUCTION

We sometimes feel the difference between music of CD and music of a live concert, and feel the later better. From ordinary point of view, its reason comes from sound facilities or visual information. Therefore, to play music of CD as a live concert, multi-channel speaker or high sampling rate music devices are used. However, in this study, we focus interaction between players and listeners. In other words, when listening to music of CD, a listener listens to monotonous music, however, when listening to music of a live concert, listeners listen to music that was changed by players who are affected by listeners, and it makes music better.

We have already performed some experiments to investigate interaction between a player and a listener [1][2]. In these studies, 1-bar period of a player and respiration period of a listener were focused as elements of interaction. There are some studies that investigated the relation between players and listeners [3]-[6]. However, in those studies, how players' intention was transmitted to a listener was focused, and feedback from listeners was not considered.

Respiration when listening to music was investigated from early [7]-[10]. In those studies, it was suggested that respiration rate was changed by music, and its change correlated to music tempo. In this study, we assume that there is an interaction between player's music and listener's respiration and analyze it. Form results, we intend to extract essence of interaction between a player and a listener and gain a guidance to construct the system that realizes to play music of CD as a live concert.

II. METHODS

A. Procedure of experiment

All musical performances were performed by the electric piano. Players were 4 and they were students of music academies (20-23, female). Listeners were 6 and they were students of graduate school (23-25, male). Played music was "energy flow" (composed by Ryuichi Sakamoto, 4/4, 88 bars, piano solo, no lyrics, song length: about 260sec). An experiment was performed by the following procedure:

1. Measuring listener's respiration in rest 4 times (5min/once)
2-1. A player plays musical performance 6 times alone.
2-2. A player plays musical performance to 6 listeners (one listener by one listener).
2-3. Partition is placed between a player and a listener, and a player plays musical performance to 6 listeners (one listener by one listener).

Each player performed experiment 2-1 to 2-3 in a day (each player performed in each day), total number of musical performances was 18. Experiment 1 was performed on different day of experiment 2, but soon after experiment 2.

In this experiment, listener's respiration period and player's 1-bar period were measured. Listener's respiration was calculated as follows: plot measured data to x-axis and plot 0.8sec before measured data Y-axis, and move its center to the origin. Fig.1 shows measured respiration wave (the ascent means inspiration, the descent means expiration). Fig.2 shows transformed respiration wave. As Fig.2 shown, transformed wave is closed circle, and we can calculate its phase by connecting plotted point to the origin.

1-bar period was calculated by measuring length of first note of a bar to first note of a next bar.

Experiment 2-3 is verification that a player is affected by vi-

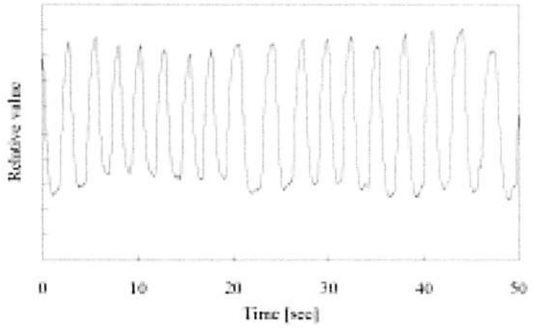


Fig.1. Respiration wave

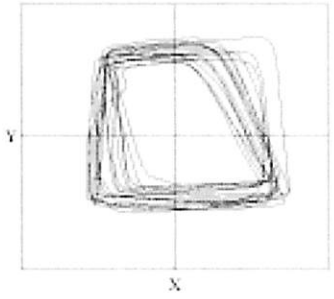


Fig.2. Tranformed respiration wave

sual information of a listener, if there is an interaction between them.

B. Measuring system

Experiment 1 was performed with the system shown Fig.3. Respiration was measured by an attached thermistor sensor (NIHON KODEN:TR-511G) at nasal cavity (Therefore singing and humming is restricted). 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. The room for measurement was 3.6m in breadth × 7.0m in length × 2.5m in height.

Experiment 2 was performed with the system shown Fig.4. The electric piano (Roland : RD-600) was used for musical performance. Sound was presented by a pair of speakers (MELCO : DIATONE DS-51). Other measuring devices and measuring environment are same as Fig.3. There is 2.7m interval between a player and a listener and 2m between speakers and a listener. When measuring, no other people were there without a listener and a player. Partition for experiment 2-3 was 125cm in breadth x 175cm in height. Musical performance was recorded by a MIDI sequencer (emagic:Logic Audio platinum Ver.3.5).

III. CHANGE OF RESPIRATION PERIOD AND 1-BAR PERIOD

A. Change of listeners' respiration period caused by listening to music

Fig.5 shows mean respiration periods of Listener_F in each condition, "In Rest", "Face to Face", "Partition". Mean value is calculated from 4 trials of each condition. As Fig.5 shows, mean respiration period of "In Rest" is different from that of "Face to Face" and "Partition".

Table 1 shows all listeners' (Listener_A,B,C,D,E,F) mean respiration period to each players (Player_1,2,3,4) in each conditions, and total mean ("Mean"), and standard deviation (S.D.). All units of table are "sec". Result of welch's test between "Mean" of "In Rest" and that of "Face to Face" is shown at second line from bottom, and result of welch's test between "Mean" of "In Rest" and that of "Partition" is shown at bottom line. ** means that there is a significant difference at level, $p < 0.01$, and * means $p < 0.05$. Results show that there is a significant difference between "In Rest" and "Face to Face", and between "In Rest" and "Partition" without "Partition" condition of "Listener_C".

The result above means that listeners' respiration period changed from "In Rest" to "Face to Face" and "Partition", however, this result dose not clarify whether its change depends on only listening to music or listening to music of each player. Therefore, to verify dependence of its change, we focus the rate between mean respiration period to each player and total mean. If all listeners' respiration periods are long to a player or short, it means that its change depends on listening to music of each player and vice versa.

Table 2 shows its rate. Table 2(a) shows "Face to Face", and Table2(b) shows "Partition". Result of ANOVA between play-

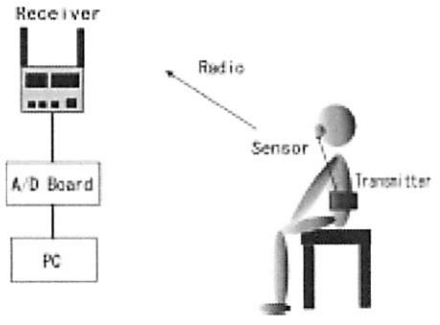


Fig.3. Measuring system of respiration

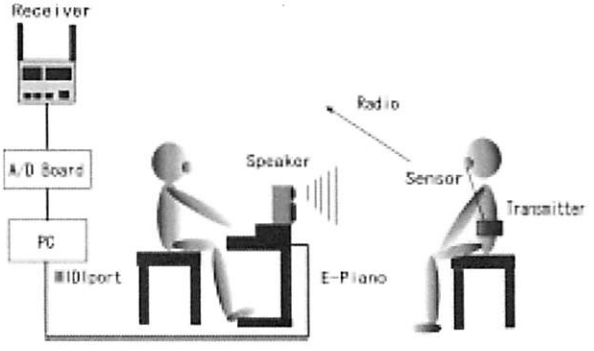


Fig.4. Measuring system of a live performance

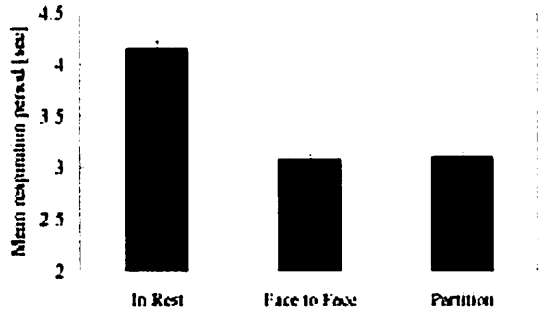


Fig.5. Mean respiration period of a listener

ers is shown at bottom line. * means that there is a significant difference at level, $p < 0.05$. Results shows that respiration period change of listening condition depends on listening to music of each player.

B. Change of players' 1-bar period caused by a listener

Fig.6 shows mean 1-bar periods of Player_4 in each conditions "Alone" ,"Face to Face", "Partition". Mean value is calculated from 6 trials of each condition. As Fig.6 shows, mean respiration period of "Alone" is different from that of "Face to Face". Table 3 shows all players' (Player_1,2,3,4) mean 1-bar period to each listeners (Playner_A,B,C,D,E,F) in each conditions, and total mean ("Mean"), standard deviation (S.D.). All units of table are "sec". Result of welch's test between "Mean" of "Alone" and that of "Face to Face" is shown at second line from bottom, and result of welch's test between "Mean" of "Alone" and that of "Partition" is shown at bottom line. * means that there is a significant difference at level $p < 0.05$, and if $p > 0.05$, p-value is shown. Results show that there is a significant difference between "Alone" and "Face to Face", and this indicates that a player changed his play when a listener was in front of him.

The Result above means players' 1-bar period changed from "Alone" to "Face to Face", however, this result dose not clarify whether its change depends on only listener's existence or each listener's existence. Therefore to verify dependence of its change, we focus the rate between mean 1-bar period to each listener and total mean. If all players' 1-bar period are long to a listener, or short, it means its change depend on each listener's existence and vice versa.

Table 4 shows its value. Table 4(a) shows "Face to Face", Table4(b) shows "Partition". Result of ANOVA between listeners is shown at bottom line. P-value of "Face to Face" is 0.126, and that of "Partition" is 0.925. These results indicate that 1-bar period change depends on each listener's existence.

C. Interaction between 1-bar period and respiration period

Fig.7(a) shows time course of respiration and 1-bar period of

Table 1
Respiration period of listeners

	Listener_A			Listener_B			Listener_C			Listener_D			Listener_E			Listener_F		
	In Rest	Face to Face	Partiton	In Rest	Face to Face	Partiton	In Rest	Face to Face	Partiton	In Rest	Face to Face	Partiton	In Rest	Face to Face	Partiton	In Rest	Face to Face	Partiton
Player_1	4.609	3.792	3.580	4.600	4.215	4.989	2.817	3.110	2.861	4.385	4.787	5.404	3.248	2.528	2.360	3.230	3.102	3.283
Player_2	4.947	3.659	3.383	4.191	4.066	3.927	2.533	2.817	2.531	4.943	4.566	4.044	3.047	2.422	2.549	4.525	3.070	2.846
Player_3	4.043	3.678	3.626	4.872	3.987	3.853	2.705	2.726	2.667	5.052	4.224	4.422	2.605	2.418	2.575	4.746	2.986	3.015
Player_4	4.970	2.934	4.717	3.862	4.116	4.131	2.696	2.892	2.755	4.497	3.753	4.268	3.259	2.575	2.481	4.505	3.136	3.263
Mean	4.609	3.489	3.771	4.349	4.098	4.198	2.686	2.885	2.702	4.697	4.312	4.502	3.015	2.486	2.484	4.150	3.074	3.097
S.D.	0.9078	0.8330	0.9665	1.192	0.6570	0.8185	0.4831	0.3915	0.3924	0.5210	0.7032	0.8465	0.5211	0.3954	0.3563	1.277	0.5774	0.5802
t-Test		**			**			**			**			**			**	
			**			0.0911			0.604			**			**			**

Table 2
Relative value of mean respiration period of listeners

(a) Face to Face

Face to Face	Player_1	Player_2	Player_3	Player_4
Listener_A	1.0868	1.0488	1.0541	0.84099
Listener_B	1.0285	0.99209	0.97292	1.0043
Listener_C	1.0779	0.97636	0.94476	1.0023
Listener_D	1.1100	1.0587	0.97956	0.87029
Listener_E	1.0167	0.97425	0.97247	1.0355
Listener_F	1.0092	0.99869	0.97121	1.0201
Mean	1.0549	1.0081	0.98250	0.96225
ANOVA	*			

(b) Partition

Face to Face	Player_1	Player_2	Player_3	Player_4
Listener_A	1.0084	0.95311	1.0215	1.0533
Listener_B	1.1884	0.93542	0.91776	0.98401
Listener_C	1.0589	0.93683	0.98691	1.0195
Listener_D	1.2003	0.89834	0.98216	0.94794
Listener_E	0.95010	1.0260	1.0365	0.99886
Listener_F	1.0599	0.91874	0.97341	1.0536
Mean	1.0777	0.94474	0.98637	1.0095
ANOVA	*			

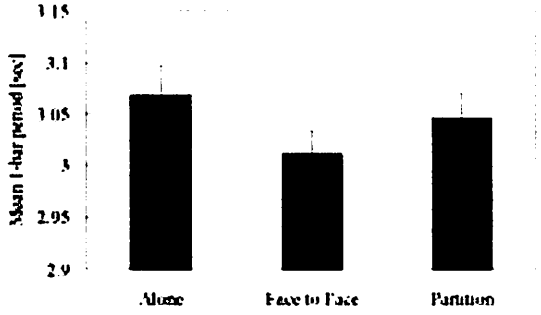


Fig.6. Mean 1-bar period of a player

Listener_F and Player_3, Fig.7(b) shows Listener_A and Player_2. Both figures are in "Face to Face" condition. In this figure, y-axis shows period, x-axis shows time. Two time courses are overlapping without around 125sec of Fig.7(a) and 0 to 120sec of Fig.7(b). In 3.1 and 3.2, it is indicated that listener's respiration period is changed by music of each player, and player's 1-bar period is changed by each listener's existence. In this subsection, we verify that there is an interaction between respiration period and 1-bar period.

1) Effect from 1-bar period to respiration period

To verify whether 1-bar period of player affect respiration period of listener is equal to verify whether change of respiration period shown Table 2 depends on 1-bar period of a player. Fig.8(a) shows a relation between the value of Table 2(a) and corresponding values of "Face to Face" in Table 3. Fig.8(b) shows a relation between the value of Table 2(b) and corresponding value of "Partition" in Table 3. Correlation value of Fig.8(a) is 0.445, and that of Fig.8(b)is 0.477. It suggests that 1-bar period of player affect respiration period of listener, and this result support Haas's report.

2) Effect from respiration period to 1-bar period

To verify whether respiration period of listener affect 1-bar period of player is equal to verify whether change of 1-bar period shown Table 4 depends on respiration period of listener. Fig.9(a) shows a relation between the value of Table 4(a) and corresponding values of "Face to Face" in Table 1, Fig.9(b) shows a relation between the value of Table 4(b) and corresponding value of "Partition" in Table 1. Correlation value of Fig.9(a) without the upper left point is 0.335 (if include the point, its value is 0.163. Regression line reflects this value.), and that of Fig.9(b)is 0.0780. It suggests that respiration period of listener affect 1-bar period of player.

IV. DISCUSSION

In 3.3, it is suggested that there is interaction between respiration period and 1-bar period, and also suggested that the longer 1-bar becomes, the longer respiration becomes, and the longer respiration becomes, the longer 1-bar becomes. It means that mutual entrainment occurred between both periods. However, comparing the values of Table 1 to corresponding values of Table

Table 3
1-bar period of players

	Player_1			Player_2			Player_3			Player_4		
	Alone	Face to Face	partion	Alone	Face to Face	partion	Alone	Face to Face	partion	Alone	Face to Face	partion
Listener_A	3.318	3.234	3.206	2.900	2.939	3.042	2.705	2.842	2.856	3.019	2.984	3.020
Listener_B	3.278	3.197	3.219	2.955	3.004	2.973	2.728	2.834	2.839	3.053	3.014	3.041
Listener_C	3.313	3.233	3.244	2.952	3.074	2.971	2.791	2.844	2.842	3.093	3.007	3.037
Listener_D	3.267	3.255	3.299	2.959	3.030	3.009	2.778	2.847	2.781	3.062	3.031	3.075
Listener_E	3.211	3.227	3.273	2.958	2.981	2.948	2.759	2.797	2.812	3.093	3.024	3.050
Listener_F	3.197	3.250	3.311	3.026	2.975	2.977	2.773	2.821	2.795	3.091	3.008	3.053
Mean	3.264	3.233	3.259	2.958	3.001	2.987	2.756	2.831	2.821	3.069	3.011	3.046
S.D.	0.3717	0.3328	0.3923	0.3436	0.3213	0.3222	0.4848	0.4604	0.4680	0.6383	0.5322	0.5515
t-Test		0.148			*			*			0.111	
			0.817			0.162			*			0.536

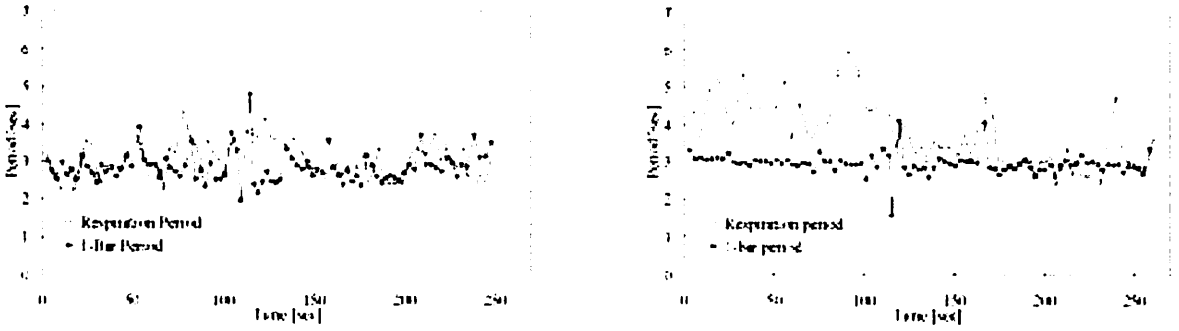
Table 4
Relative value of mean 1-bar period of players

(a) Face to Face

Face to Face	Listener_A	Listener_B	Listener_C	Listener_D	Listener_E	Listener_F
Player_1	1.0005	0.98899	1.0000	1.0070	0.99813	1.0054
Player_2	0.97951	1.0011	1.0246	1.0097	0.99365	0.99150
Player_3	1.0041	1.0012	1.0045	1.0056	0.98805	0.99661
Player_4	0.99113	1.0008	0.99855	1.0065	1.0042	0.99881
Mean	0.99380	0.99801	1.00691	1.0072	0.99601	0.99808
ANOVA	0.126					

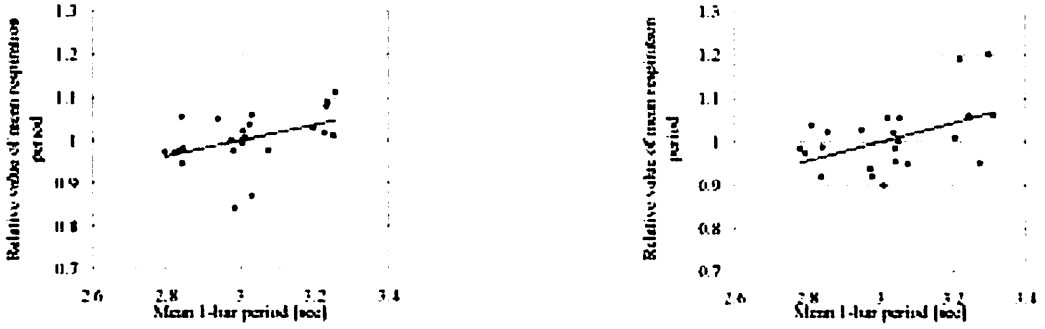
(b) Partition

Partition	Listener_A	Listener_B	Listener_C	Listener_D	Listener_E	Listener_F
Player_1	0.98400	0.98772	0.99562	1.0124	1.0043	1.0160
Player_2	1.0184	0.99535	0.99472	1.0077	0.98698	0.99687
Player_3	1.0125	1.0065	1.0072	0.98606	0.99680	0.99089
Player_4	0.99146	0.99830	0.99706	1.0094	1.0014	1.0024
Mean	1.0016	0.99696	0.99867	1.0039	0.99738	1.0015
ANOVA	0.925					



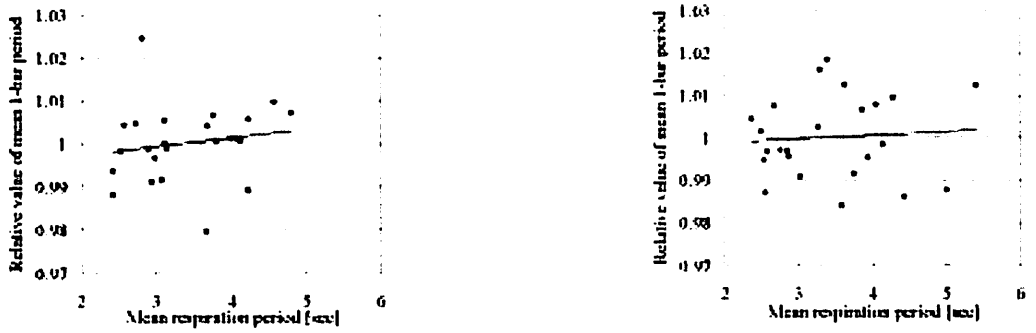
(a) Face to Face (b) Partition

Fig.7. Time course of respiration period and 1-bar period



(a) Face to Face (b) Partition

Fig.8. Relation between mean 1-bar period and relative value of mean respiration period



(a) Face to Face (b) Partition

Fig.9. Relation between mean respiration period and relative value of mean 1-bar period

3. entrainment occurred not only with ratio of 1:1 but also other ratio. To investigate details of entrainment, it is necessary to consider not only 1-bar period but also other musical tone unit. Comparing the results of 3.1 to those of 3.2, and the results of 3.3.1 to those of 3.3.2, change of 1-bar period is smaller than that of respiration period. It suggests that there is an interaction between them, however, the effect from player to listener is stronger than the effect from listener to player.

A player is affected by listener's respiration, but there is little possibility that player perceives listener's respiration directory. As shown in 3.3.2, correlation value becomes small at "Partition" condition, and it means that a player is affected by visual information such as body motion that correlate to respiration [11].

V. CONCLUSION

In this paper, we focused interaction between a player and a listener as a reason why we feel better music of a live concert than that of CD, and analyzed it. Firstly, it is showed that listener's respiration period was affected by music of each player, and secondly it is indicated that player's 1-bar period was affected by listener. Thirdly, it was suggested that there was interaction between 1-bar period and respiration period.

In future works, we intend to construct the system that realizes

to play music of CD as a live concert from these results.

Reference

[1] T.Yamamoto and Y.Miyake, "Generation of sympathetic space in embodied music communication," Proc. of 1999 IEEE International Conference on Systems, Man, and Cybernetics, pp. V-1045-V-1048, 1999.

[2] 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, pp.763-768, 2000.

[3] R.A.Rasch, "Synchronization in Performed Ensenmble Music," ACUSTICA, Vol.43, pp.121-131, 1979.

[4] K.Ohgushi, "How Are the Player's Ideas Conveyed to the Audience?" Music Perception, Vol.4, No.4, pp.311-324, 1987.

[5] T.Nakamura, "The communication of dynamics between musicians and listeners through musical performance," Perception & Psychophysics, Vol.41, No.6, pp.525-533, 1987.

[6] R.A.Kendall and E.C.Carterette, "The Communication of Musical Expression," Music Perception, Vol.8, No.2, pp.129-164, 1990.

[7] C.M.Diserens, "Reaction to music stimuli," Psychol. Bull. 20, pp.173-199, 1920.

[8] D.S.Ellis and G.Brighouse, "Effects of music on respiration-and heart-rate ," American Journal of Psychology, Vol.65, pp.39-47, 1952.

[9] F.Haas,S.Distenfeld and K.Axen, "Effects of perceived musical rhythm on respiratory pattern," J. APPL. PHYSIOL., Vol.61, NO.3, pp.1185-1191, 1986.

[10] E .Grossman, A.Grossman, MH .Schein, R .Zimlichman and B .Gavish," Breathing-control lowers blood pressure," J.Human Hypertension Vol.15, No.4, pp.263-269, 2001.

[11] R.R.Bechbache and J.Duffin, "THE ENTRAINMENT OF BREATHING FREQUENCY BY EXERCISE RHYTHM," J.Physiol, 272, pp.553-561, 1977.

[12] W.S.Condon and L.W. Sander, "Neonate Movement is Synchronized with Adult Speech," Science,Vol.183, pp.99-101, 1974.

[13] N.Kobayasi,T.Ishii and T.Watanabe : Quantitative Evaluation of Infant Behavior and Mother-Infant Interaction,• h Early Development and Parenting, Vol.1, No.1, pp.23-31, 1992.

[14] T.Watanabe and M.Okubo, "Evaluation of the Entrainment Between a Speaker 's Burst-Pause of Speech and Respiration and a Listener's Respiration in Face-to-Face Communication," Proc. of 6th IEEE International Workshop on Robot and Human Communication, pp.392-397, 1997.

[15] J.Borchers and M.Muhlhauser,"Design Patterns for Interactive Musical Systems," IEEE Multimedia, Vol.5, No.3, pp.36-46, 1998.