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# **A PILOT STUDY ON THE EFFECT OF MUSIC-HEART BEAT FEEDBACK SYSTEM ON HUMAN HEART ACTIVITY**

We developed a music-heart beat feedback system to test the efficacy of the entrainment between music and human heart beat. As a result of regulating the music tempo as 10% faster (namely FAST condition) or slower (SLOW) than heart beat in a real time series, the subjects' heart rate was successfully modulated as significantly higher in the FAST condition and lower in the SLOW condition. The timeliness regulation of this feedback system may play a key role to bring forth the music-heart beat entrainment.

## **1. INTRODUCTION**

Music affects human mind and body. Many studies have demonstrated that a sedative music makes one feel calm and relax, and it is accompanying with alleviation of the sympathetic nervous activity, resulting in the reduction of heart rate, respiration rate, blood pressure, skin temperature [1] and so on. It was reported that music affects even immune system [2]. On top of such an explicitly observed physiological effect, there are studies which demonstrated a mechanical or direct impact of the auditory stimulation on the body; as such monotonous auditory stimuli entrain the heart rate, which means the auditory stimuli having faster tempo than one's heart beat makes it faster, and vice versa [3], [4]. These intriguing phenomena are compared with the "entrainment" of the coupled non-linear oscillators' system. Theoretically, when two or more non-linear self-regulating (limit-cycle) oscillators, such as the Van der Pol oscillator, interacts each other, they entrains each other and their frequency are shifted to be equal [5]. So it is considered that some sort of entrainment (or coupling) occurs among the neurons in the central nervous system which are responsible for processing auditory stimuli and heart beat control [3].

However, it was quite some time since these phenomena have been reported for the first time, and there is still few number of studies which demonstrates this auditory stimuli-heart beat entrainment. Moreover it is not clearly shown if such an entrainment would take place even between "music" and heart beat. This might attribute to a rather weak connection between the musical tempo and heart beat. So, in this study, we developed a music-heart beat feedback system to test the efficacy of the entrainment between the music and heart beat. Since this system achieves musical tempo control in a real time series in accordance with the heart beat, we expected that the entrainment between music and heart rate can be observed more explicitly if so there is.

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## 2. METHOD

### 2.1. MUSIC-HEART BEAT FEEDBACK SYSTEM

The objective of this study is to test the efficacy of the entrainment of the heart activity with the specially designed music of which the tempo of music is modulated in a real time series in accordance with the heart rate of the subjects. For this purpose, we developed a music-heart beat feedback system as shown in Fig. 1. This real time feedback system consists of three units: they are (1) the sensor unit by which the subject's electrocardiogram (ECG) is monitored at 200 Hz sampling rate and 12 bit resolution, (2) the data processing unit in which the instant heart beat interval (or instant R-R interval) is successively calculated from the digitalized ECG signal detected by the sensor unit, and (3) the music control unit in which the tempo of music is successively changed in a real time series in accordance with the instant heart beat interval of a subject which is found by the data processing unit. Fig. 2 shows the flowchart of the tempo regulation algorithm of this system.

The ECG monitoring at the sensor unit is carried out by multi-purpose bio-signal amplifier system (MP150, BIOPAC Systems Inc., USA). The analogue to digital conversion of ECG signal is also done by this system. Followed by the determination of the instant heart beat interval, the tempo information of the music at the same instance, which is determined by the heart beat interval, is send to the music control unit via an application programming interface (BIOPAC Hardware API interface, ver.1.1, BIOPAC Systems Inc., USA). The music control unit regulates the tempo of the music which is played by the MIDI system (SD-50, Roland Co., Japan) in a real time series. The conversion rate between the tempo of music and the heart beat can be defined by the experimenter's choice, such as (musical tempo : heart beat) = 1 : 1, 1 : 1.5, 1 : 0.5, and so on.

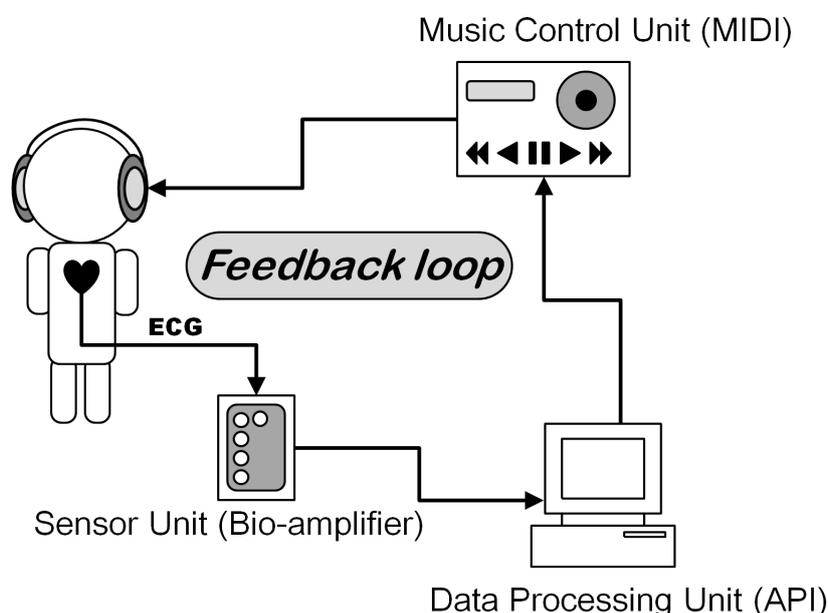


Fig. 1. The architecture of music-heart beat feedback system.

## 2.2. EXPERIMENT

### 2.2.1. SUBJECTS

Subjects are six healthy male undergraduate students aged from 21 to 23 years old. They didn't have any medication at the day of the experiment. They did not have any experience of musical training of any musical instruments nor did any education specialize for music.

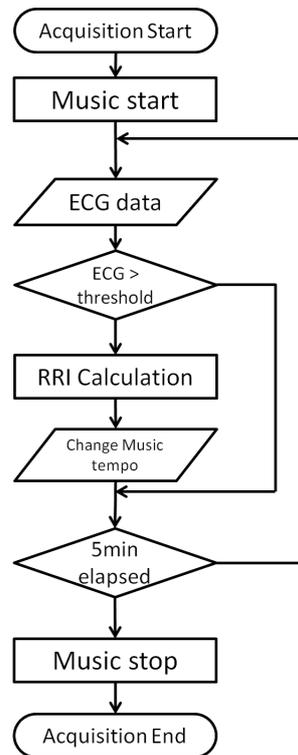


Fig. 2. The flowchart of the tempo regulation algorithm.

### 2.2.2. MUSICAL PIECE AND TEMPO REGULATION

The musical piece used in this experiment is instrumental, easy-listening, and uplifting big-band style jazz music: They are "Kitchen (M03, Tr.03)" and "Bubble (M03, Tr.02)" included in Real World Computing Music Database (The RWC Music Database Sub-Working Group, Japan) [6]. These musical pieces have not been released in the public but specially made for the purpose of music study, so none of the subjects had ever listened to them in advance.

The original tempo of these two musical pieces is around 180 to 220 (in the MIDI format), whereas the average heart rate of the human sitting on the chair is around 60 to 70. So we defined the "BASIC" music-heart beat ratio as 3 : 1, which means that the musical tempo is successively adjusted so that it is always as three times faster as the heart rate. The schematic image of this music tempo regulation is depicted in Fig. 3. It should be noted that the definition of the tempo of the MIDI system is not matched with that of the ordinary paper-written music score, but normally it is much faster. So the BASIC condition of these musical pieces which has around 200 of the tempo is not like a super-fast or bizarre music, but rather smooth and easy-listening background jazz music with natural tempo.

### 2.2.3. EXPERIMENTAL CONDITION

For the purpose of investigating the entrainment phenomena, we prepared two tempo regulating conditions as depicted in Fig. 3: they are the FAST condition in which the music is always playing as 10% faster as the BASIC condition (thus, musical tempo : heart beat = 3.3 : 1 ) and the SLOW condition in which the music is always playing as 10% slower as the BASIC condition (so, musical tempo : heart beat = 2.7 : 1 ).

Fig. 4 shows the schedule of the experiment. Followed by a five minute of initializing period, subjects were exposed to each one of a musical piece with either FAST or SLOW condition. Then it repeated four times with changing the music piece and the tempo regulation. All subjects went through both FAST and SLOW condition and two musical pieces in a counter-balanced order (within-subject design). Subjects are sitting on a reclining chair all through the experiment. The noise-cancelling headphone (MDR-NC600D, Sony Co., Japan) is used for listening to the music.

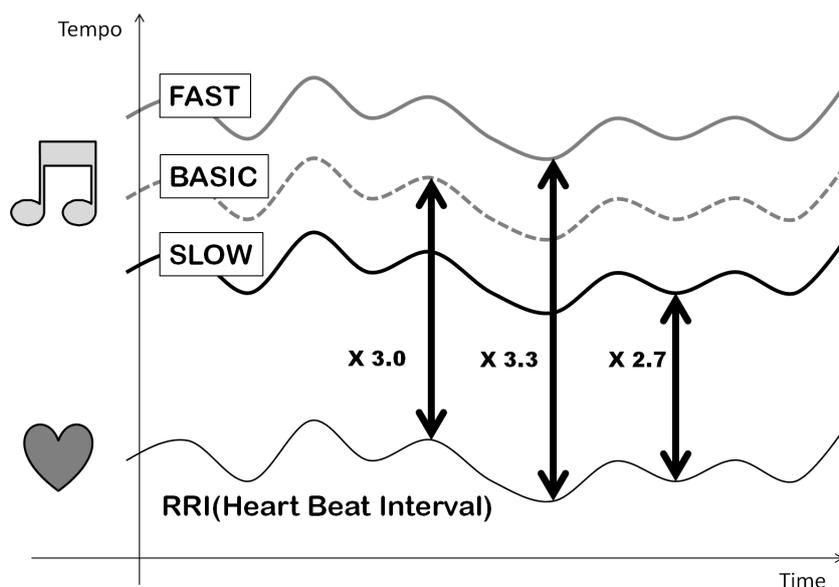


Fig. 3. The schema of musical tempo regulation of the music-heart beat feedback system: in the BASIC condition, the musical tempo is always as three times faster as the heart beat, where, in the FAST and SLOW condition, it is 10% faster and slower than the BASIC condition.

The experimental condition, which are the FAST and the SLOW, and even the regulation of the tempo of music by the music-heart beat feedback system were not informed to the subjects before the experiment. After the experiment, the regulation and purpose of the experiment were explained and a simple questionnaire was given to the subjects.

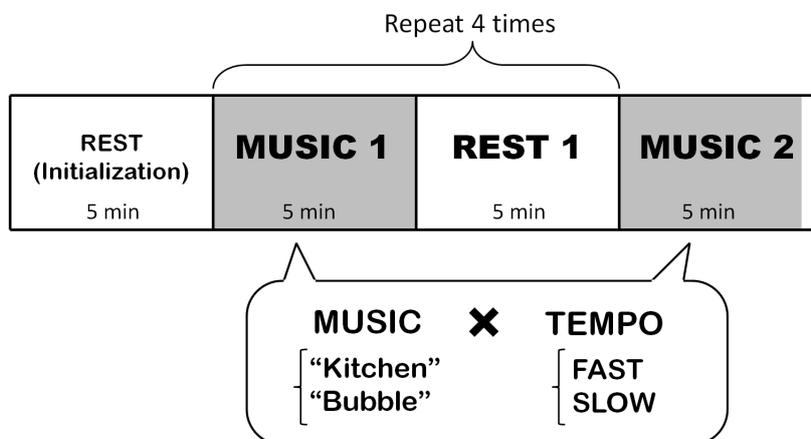


Fig. 4. The schedule of the experiment.

### 3. RESULT & DISCUSSION

Analysis has done separately with regard to each musical piece to investigate a native influence of the tempo regulation. As for a musical piece, "Kitchen (M03, Tr.03)," Fig. 5 shows the average of the change in the heart rate in the FAST and SLOW condition (Fig. 5(a)) and the overall average of the heart rate during the experiment period (Fig. 5(b)). Fig. 6 shows the result in the same manner with Fig. 5 under the other musical piece, "Bubble (M03, Tr.02)." As these figure shows, the average heart rate was significantly higher in the FAST condition and lower in the SLOW condition regardless of the music pieces. So, as for one thing, our music-heart beat feedback system successfully modulated

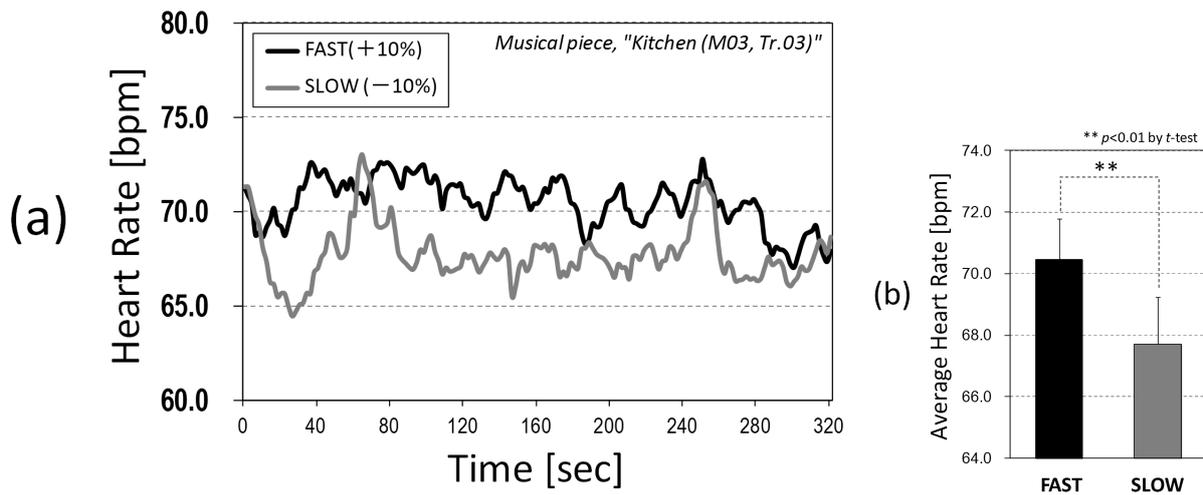


Fig. 5. The result of the experiment with a music piece "Kitchen (M03, Tr.03)": (a) the averaged change in the heart rate in the FAST and SLOW condition and (b) the overall average of the heart rate during the experiment period.

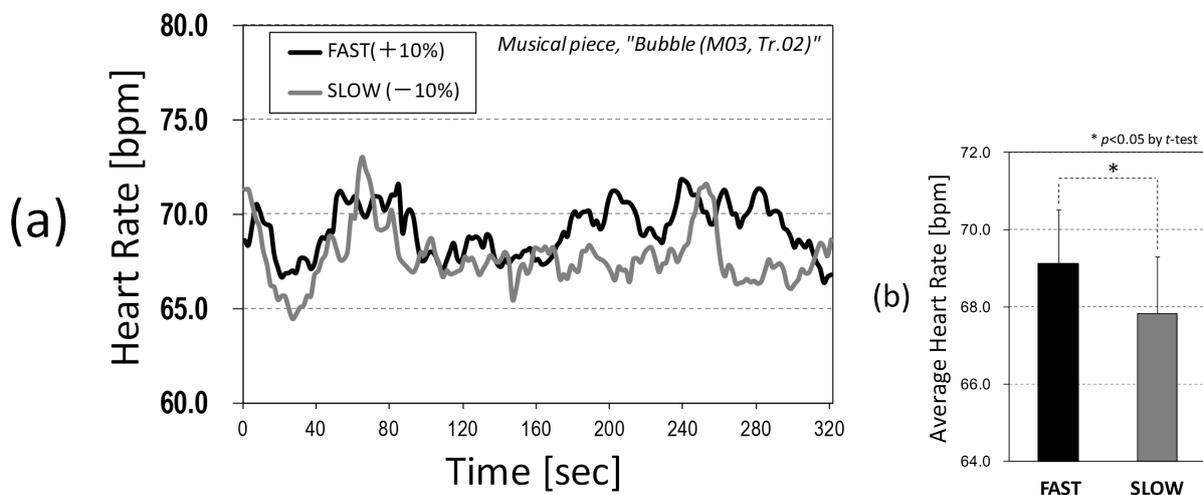


Fig. 6. The result of the experiment with a music piece, "Bubble (M03, Tr.02)": both figure (a) and (b) shows the result in the same manner with Fig. 5.

subjects' heart beat along with musical tempo as expected in advance.

The average rate of the heart beat in the normal population varies largely. In fact, it was varied from 57.4 to 86.4 in the average of the subjects of this experiment; nevertheless, the modulation of the heart beat was observed regardless of the average heart rate of each subject. Therefore, the heart rate modulation found in this experiment might not merely result from the exposure of "relatively fast or slow" music, but rather derived by coupling, or entrainment, between musical tempo and heart beat, which may be involved in a higher cognitive brain functioning.

There were no subjects who claimed that the musical pieces were odd or unnatural. Moreover, none of them even noticed that the tempo of the music had changed as 25.2% (in the MIDI format) in average within a 5 minutes musical piece. So it implies that the entrainment observed in this experiment was not derived by the subjective intervention, but rather primitive or unconscious level cognitive processing.

It is well understood empirically and scientifically that music has a power to affect human mind and body: a sedative music makes one relax with alleviating sympathetic nervous system activation. As already described, monotonous auditory stimuli possibly entrain the heart rate. However, as far as we know, the entrainment between "music" and heart rate has not been reported. The result of our experiment can be unique in this sense, though it is very preliminary one. The physiological mechanism of this result is still black box and it would still be difficult to analyze even by the current brain study tool box: it should require real time monitoring of relevant brain regions, e.g. brain stem which is

responsible for autonomic control.

One possible reason of that our system successfully demonstrated the entrainment between music and heart rate may attribute to a technological merit of the system. Recent development of hardware, which are memory, CPU, PCI bus, A/D board, and bio-signal amplifier, enable us to implement this system which achieves the music tempo regulation with heart rate feedback at 200Hz sampling rate and 12bit resolution. This specification is sufficient enough to achieve the real time feedback of the instant heart beat to musical tempo at that moment. This timeliness regulation, of which it would have been quite difficult to achieve even a decade ago, may play a key role to bring forth entrainment. However, integrating more number of experimental and brain study is needed for further discussion.

#### BIBLIOGRAPHY

- [1] MCFARLAND R. A., Relationship of skin temperature changes to the emotions accompanying music, *Biofeedback Self Regul.*, 1985, Vol. 10, No. 3, pp. 255-267.
- [2] KNIGHT W. E., RICKARD PhD N. S., Relaxing music prevents stress-induced increases in subjective anxiety, systolic blood pressure, and heart rate in healthy males and females, *J Music Ther.*, 2001, Vol. 38, No. 4, pp. 254-272.
- [3] BASON P. T., CELLER B. G., Control of the Heart Rate by External Stimuli, *Nature*, 1972, Vol. 238, pp. 279-280.
- [4] KUSUNOKI Y., FUKUMOTO M., NAGASHIMA T., A Statistical Method of Detecting Synchronization for Cardio-Music Synchrogram, *IEICE transactions, Nonlinear Theory and its Applications*, Vol. E86-A, 2003, No. 9, pp. 2241-2247.
- [5] Y. KURAMOTO., *Chemical Oscillations, Waves, and Turbulence*, Dover Publications, New York, 2003.
- [6] MASATAKA G., Development of the RWC Music Database, *Proceedings of the 18th International Congress on Acoustics (ICA 2004)*, April 2004, pp. I-553-556.