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Twin-Peak Effect in Both Cardiac Response and Tempo of Popular Music

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Abstract— **How the musical tempo affects the performance of heart rate variability (HRV) was studied in this work. By understanding the relationship between the HRV response and the music tempo with decreasing tempo from 140 to 70 beats per minute (bpm) periodically in six successive weeks. There were two groups in the experiment, one was listening drum loop music 3 minutes in the middle of experiment and the other was just rest for 20 minutes. After the processed the information from the objects, the distribution of difference of HRV response between before and after listening various tempo drum loop was similar to the distribution of modern popular music in tempo. Both distributions have the twin peaks about 70-85 and 110-125 bpm.**

I. Introduction

Music, even just tempo, can affect people in different fields or situations. Previous researches have shown that music can raise the level of arousal [1] and affect physiologic phenomena such as cardiovascular, cerebrovascular and respiratory [1], [2]. Even behavior of shoppers [3] or students in queues [4], the performance of cyclists [5], temperament [6] and memory of human [7] are also influenced by music.

A study about shopping experiences indicated that most consumers liked slow music if the density of the crowd was high. Otherwise, fast music was preferred [3]. A similar finding showed that if the subjects were in a registration queue, slow tempo can produce more flattering responses. However, this effect only existed in a lower crowd density [4]. In the opposite way, faster tempo was preferred if participants were engaged in vigorous exercise, such as a speedy cycled test. The performance was also better in this condition [8].

Tempo has been usually investigated with other musical features, such as loudness [6] and timbre [7]. Perseveration and endurance were found to correlate with the perceived tempo in a psychological experiment. Meanwhile, endurance and emotional reactivity were found to correlate with the perceive loudness [6]. In the other practical study, implicit tune recognition was reduced following tempo change. For the meantime, both tempo and timbre change were established that they could impair explicit memory [7]. Beyond mood and memory, decision making was also influenced by tempo. Faster tempo music can improve the accuracy of harder decision-making, not that of easier one [5].

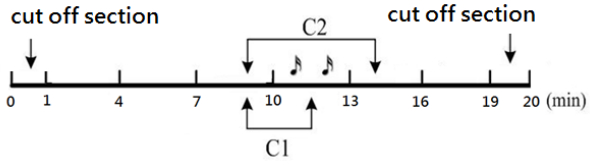

Fig. 1. The overall experimental flow of one trial.

Although physiological response could be adapted to musical tempo, the relations between the tempo and the physiological response are unclear. To assess physiological response, heart rate variability (HRV), which can be obtained noninvasively and simply, is an adequate measurement [9]. Recent researches have involved in the relation of tempo and HRV [1], [2], [10]. First, music with the fast tempo and simple rhythmic structures induced an arousal effect [2]. Second, slow music and pause caused objects relaxing [1]. Based on these facts, we considered that the physiological response and tempo have some connections. Our experiments were to explore the relations between tempo and physiological response (i.e. HRV).

II. Method

A. HRV Signal Processing

The ECG signals were captured by a 3-channel portable device (MSI E3-80, FDA 510(k) K071085) at 500 Hz sampling rate. The QRS complex is the most notable waveform within the electrocardiograph (ECG).

The RR intervals data were recorded in the flash memory card. The MATLAB program calculated all the commonly used time-domain and frequency-domain measures of HRV. HRV is the standard deviation of time sequence (RR-intervals) and also called SDNN, stand deviation of normal to normal RR-intervals. The time domain analysis of HRV reports the activity of circulation system. Through the

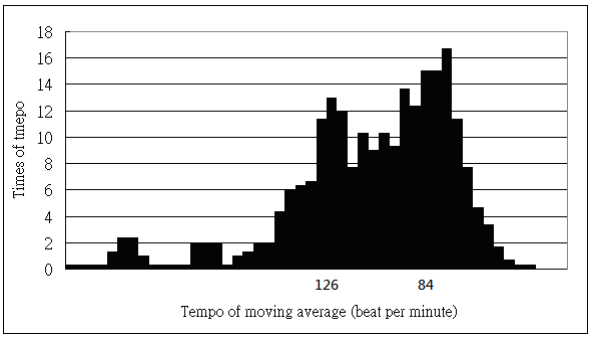

Fig. 2. Tempo distribution after moving window average in a popular music corpus, derived from [12].

Fourier transform, the Low Frequency (LF) and the High Frequency (HF) indicate lower component and higher component of power spectrum. The frequency domain analysis of HRV reflects the sympatho-vagal balance of autonomic nervous system (ANS) [9]. The related algorithms were listed in [11].

The HRV measures of time and frequency domain analysis are listed in Table I and Table II. They are recommended for theshort-term HRV analysis by The European Society of Cardiology and The North American Society of Pacing and Electrophysiology [9].

B. Experiment Design

First, there were 27 male and 1 female subjects whose ages were from 19 to 34 years, and the average age was 23.2 years engaged in the group of tempo. Second, there were 34 male and 1 female subjects whose ages were from 19 to 23 years, and the average age was 20.7 years engaged in the group of rest. All of them were undergraduate and graduate students in National Chiao Tung University.

Each subject sat in the chair first in a quiet room. After a subject rested about 5 minutes and the machine was held in place on the body, ECG signals were continuously recorded with the subject's eye closed for the subsequent twenty minutes. The experiment was executed in the afternoon. Each participant had to been recorded six times in six successive weeks. The group of tempo required to obey the following steps but the group of rest.

The music clip was a three-minute drum loop pattern, named as L3 which had the most influence in our previous study [2]. L3 was a simple bass drum dominated rhythm about 140 bpm (beats per minute). For between 0-10 minutes, there was no sound emitted from the headphones and the recorded data were used as the control. In the next 10-13 minutes interval, the drum loop pattern was played still 3 minutes and the headphones returned to silence in 13-20 minutes. The tempo of L3 was decreased 10% each week in these six trials. The overall experimental flow of one trial is shown in Fig. 1.

After processing the data, the first minute and the last minute were cast aside to lower the interference of corrupt data and some noise. Two comparisons, C1 and C2, were the

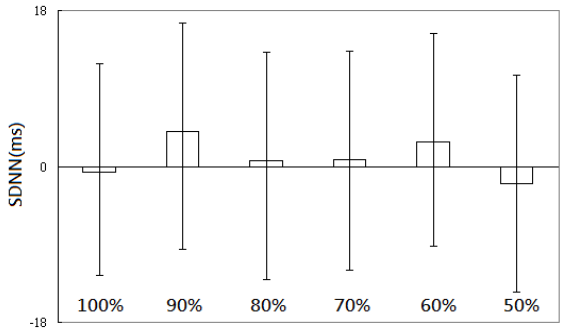

Fig. 3. SDNN of comparison C1 for tempo speed 100%-50%.

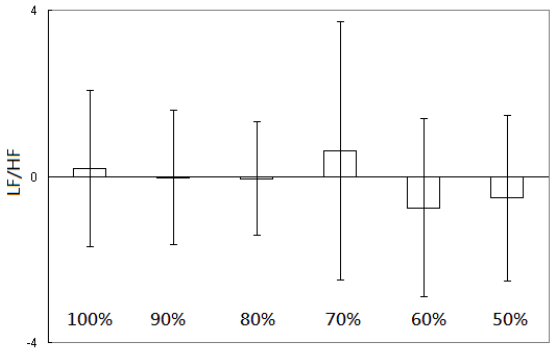

Fig. 4. LF/HF of comparison C1 for tempo speed 100%-50%.

key important indexes in this study. C1 presented the differences of the HRV measures between the baseline (7-10 minutes) and the listening part (10-13 minutes) for indicating the influence of listening to the drum loop. And C2 presented the differences of the HRV measures between baseline (7-10 minutes) and the influence after music (13-16 minutes).

C. Frequency Domain Analysis

By calculating the power of series RR value in the frequency domain, the Low Frequency (LF) was in 0.04-0.15Hz and the High Frequency (HF) was in the 0.15-0.4 Hz. Both of them were the significant index for indicating the sympathetic nerve and parasympathetic nerve, and together with the LF/HF ratio.

D. Time domain analysis

For the analysis of short-term HRV, the SDNN expressed the standard deviation (SD) of each series RR value. While processing the analysis, the information from experiments was divided into six 3-minute parts and calculated the SDNN respectively.

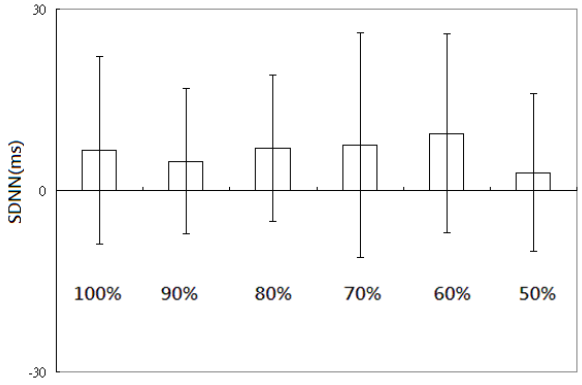

Fig .5. SDNN of comparison C2 for tempo speed 100%-50%.

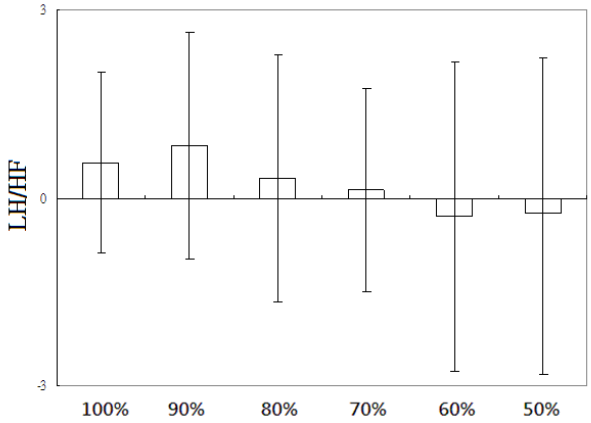

Fig. 6. LF/HF of comparison C2 for tempo speed 100%-50%.

III. Results

The comparisons C1 and C2 for LF/HF and SDNN are presented from Fig. 3 to Fig. 6 and the resting situation as comparing to tempo group is showed at Fig. 7. The measures results are listed in Table I and Table II.

IV. Discussion

A. Two peaks in music tempo and the SDNN of C1

The tempo preference of modern popular music does not only present people's favorite but our experiments also showed why people like it. According to Fig. 3, there are two peaks above the tempo 90% and 60% (about 126 and 84 bpm) while the drum loop was playing. [12] indicated 353 pieces of modern popular music converted to single channel signal by averaging the left and right channels and draw the point of 353 musical tempo on the histogram. The smooth histogram can be revealed by averaging previous, next and original tempo numbers shown in the Fig. 2. Obviously, two peaks occurred at the 60-85 bpm and 110–125 bpm, which almost matched the two peaks of SDNN of C1. [13] indicated the comparison of time domain traces revealed that there was greater heart rate variability in positive emotion than that in negative emotion.

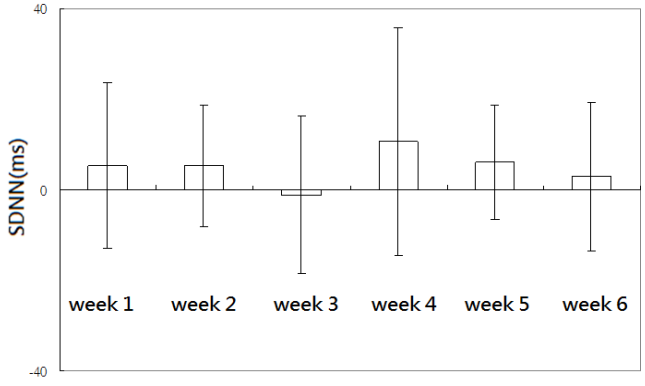

Fig .7. SDNN of comparison C2 for rest in continuous 6 week

From the Fig. 2, people preferred the two peaks tempo location. It leads composers choosing the tempo for their works. Based on above results, the music tempo above two peaks was not only preferred by people but also similar to the tempos, in which SDNN becomes larger than that in the other tempos.

B. Music Aspect

Tension and attention are two ways to reach the sympathetic activity. [2] showed that music induces an arousal effect, predominantly related to the simpler rhythmic structures compared with the baseline. So the drum loop the lowest complexity is chosen for the experiments. Slow music and pause caused objects relaxing [1] .

Comparing the influence of drum loop between Fig. 5 and Fig. 7, the SDNN of the subjects in the group of tempo is much more than that in the group of rest. It meant listening to the music can prompt the people positive emotion.

C. Speed Aspect

First, as shown in the Fig. 4 and Fig. 6, the average of LF/HF between the 50% (70bpm) and 60% (84 bpm) tempo drum loop is obviously decreasing and that is close to the mean heart rate (about 75-85 Hz). Second, we obtained a downward trend for LF/HF in the Fig. 6 and a upward trend for SDNN in the Fig. 5 when the tempo speed differed from 90% to 60% (about 126-84 bpm). Both of them are in the comparison C2 which stand for the tempo of music can enhance the SDNN to the subjects by reducing the tempo speed.

V. Conclusion

Table I. Averages and standard deviations on C1, C2 in different tempo

Tempo			Week1 100%	Week1 90%	Week1 80%	Week1 70%	Week1 60%	Week1 50%
C1	LF/HF	Average	0.195	-0.030	-0.052	0.604	-0.758	-0.523
		Standard Deviation	1.876	1.616	1.369	3.110	2.146	1.997
	SDNN	Average	-0.710	4.000	0.624	0.810	2.881	-1.959
		Standard Deviation	11.847	13.542	13.655	12.767	12.139	12.512
C2	LF/HF	Average	0.566	0.826	0.305	0.124	-0.3027	-0.287
		Standard Deviation	1.443	1.816	1.969	1.615	2.468	2.470
	SDNN	Average	6.651	4.800	6.956	7.494	9.451	2.959
		Standard Deviation	15.571	12.033	12.118	18.555	1.434	12.985

Table II. Averages and standard deviations on C1, C2 in resting state

Tempo			Week1	Week1	Week1	Week1	Week1	Week1
C1	LF/HF	Average	0.863	0.728	-0.184	0.596	-0.523	-0.469
		Standard Deviation	2.897	3.566	3.708	2.974	2.835	1.865
	SDNN	Average	3.800	4.230	-1.870	7.580	3.040	1.480
		Standard Deviation	18.87	17.65	15.720	23.450	12.280	14.06
C2	LF/HF	Average	0.358	0.724	-0.872	0.150	-0.177	-0.303
		Standard Deviation	2.805	3.202	3.369	3.528	2.616	2.989
	SDNN	Average	5.320	5.223	-1.153	10.668	6.164	2.975
		Standard Deviation	18.339	13.442	17.393	25.058	12.653	16.301

In this study, the goal was to find the relations between the musical tempo and the physiological response. Choosing the simpler drum loop is more appropriate to exclude the effect of other music features. In the comparison C1, listening to the music regardless of the two peaks tempo was observed to increase the SDNN significantly. There are two results from the discussion. First, the tempo locations of the two bigger peaks showed at Fig. 2 state the tempo preference of modern popular music. Compared to SDNN analysis showed at Fig. 3, the bigger two SDNN response also occurred at the same tempo location. And one of the two peaks was close to 70-85 bpm which was the average range of mean heart rate (MHR) in our study. Second, music can increase the subjects' SDNN by reducing the tempo in 130-80 bpm. Based on these investigations the ideal tempo for people to get the maximal increasing SDNN response might be close to 70-84 bpm which is located above on one peak in Fig. 2. In conclusion, music can make people having positive emotion and raise SDNN obviously in two tempo peaks.

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