Music Therapy on Heart Rate Variability

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Abstract—**Music has good effects on easing pressure and treating depression. However, at present, the evaluation of the effect of music therapy mainly depends on a number of subjective criteria, yet there is no appropriate objective evaluation standard. Some studies have suggested that: Heart rate variability can be used to assess the activity of sympathetic nervous system and parasympathetic nervous system. Since music can affect the activity of autonomic nervous system, some parameters of heart rate variability thus can be used as indicators to measure the effect of music therapy.**

Our study focused on the influence of music therapy on heart rate variability. Experiments were performed upon 16 undergraduates and 4 middle-aged women. As the music treatment goes on, subjectives show significant relaxation. Heart rate variability in very low frequency component (VLF), low frequency component (LF), high frequency component (HF) increase significantly after music treatment, while the LF / HF ratio has no significant change. Approximate entropy after music therapy is also lower than before. These studies suggest that relaxing music can increase the activity of parasympathetic nervous system.

Keywords-Music therapy; Heart rate variability; Somatosensory music; Approximate entropy

I. INTRODUCTION

Music treatment, also known as music therapy, or so called music medicine, is a newly developed interdisciplinary treatment including music, medicine and psychology [1-2]. Somatosensory music therapy refers to the treatment using hearing and touching to sense music in order to achieve physical and psychological treatment effects. Somatosensory music therapy uses songs that are the harmony of non-single frequencies that are rich in low frequency and mainly sine waves [3].

Music is multi-level signal, and the mechanism it stimulates the body is physical in nature. Hearing organs pass music signal to the nerve center, then affect the cerebral cortex and hypothalamus, causing autonomic nervous system's responses, which in turn affects the self-discipline of sinus and the rhythm of heart rate. In addition, as a kind of acoustic wave, when its frequency, rhythm and strength are equal to the physiological rhythms and frequency inside the human body, music can have resonance with human body, and produces an effect similar to cell massage. Music plays an important role in sedation, abirritation and blood-pressure reduction.

Heart rate variability (HRV) describes the variations between consecutive heartbeats. The regulation mechanisms of HRV originate from the sympathetic and parasympathetic nervous systems and, thus, HRV can be used as a quantitative marker of the autonomic nervous system [4-8].

There are three methods for heart rate variability analysis: time-domain analysis, frequency-domain analysis and nonlinear analysis. The indicators of time-domain analysis are the mean, the standard deviation and so on. Time-domain analysis is too simple, and loses time order information that the data contains. Frequency-domain analysis takes HRV signal as a random signal, and analyzes power spectral characteristics of HRV signal. The power spectrum analysis (PSD) of normal people may get 2 to 3 major peaks. A peak frequency of less than 0.05 Hz, which was called very low frequency (VLF), was considered to relate to body temperature. A frequency band around 0.1 Hz (0.05–0.15 Hz) indicated what was called the low-frequency (LF) component. This frequency band was related to the regulation of blood pressure and reflected the combined activity of the sympathetic and parasympathetic nervous systems. The band ranging from 0.15 to 0.4 Hz was called the high-frequency (HF) component, which is caused by respiration and reflects the activity of the parasympathetic nervous system. Power spectrum analysis focuses on the regulation of cardiac autonomic nervous [9].

In recent years, with the development of nonlinear dynamics, HRV signal is generally considered to be chaotic or a chaotic component, so the nonlinear analysis method is pulled in to analyze the complexity of the cardiovascular system. The indicators of nonlinear analysis are complexity, approximate entropy (ApEn), scatter plot and so on. Approximate entropy is an indicator of the Complexity Science Theory, and its value reflects the level of a system's complexity. The larger the ApEn is, the closer the system is to random state, the more abundant frequency components it contains, the stronger adaptability the system has. The smaller the ApEn is, the more periodic the signal tends to be; the less abundant frequency components it contains, the lower adaptability the system has.

Our current study focused on the influence of music therapy on heart rate variability. The music the subject listened to was soft and relaxing.

II. METHOD

A. *Subjects*

Twenty people participated in our study, including 16 undergraduates and 4 middle-aged women, with 9 of them are males, and 11 are females.

B. *Experimental environment*

Experiments were performed at music treatment center of Tianjin Nursing Home. We use the somatosensory music therapy for the treatment, and soft and relaxing music were selected. The main aim of our treatment is to produce a relaxed mood for subjects and to alleviate their fatigue.

C. Procedure

The 20 subjects are divided into five groups, having music therapy at different days. Each of the treatment time was about 40 minutes. The time before music therapy is 10 minutes, in order to let subjects calm down and maintain the same respiration rate during the following music treatment. The time of music treatment is about 20 minutes, and after music treatment is 10 minutes.

D. Equipment

We use multi-sensor music therapy device to conduct music therapy, and 12-lead synchronous digital ECG workstation to obtain ECG signal, with sampling frequency of 512Hz. Both the equipments are supplied by Orking company.Fig.1 shows both of them.

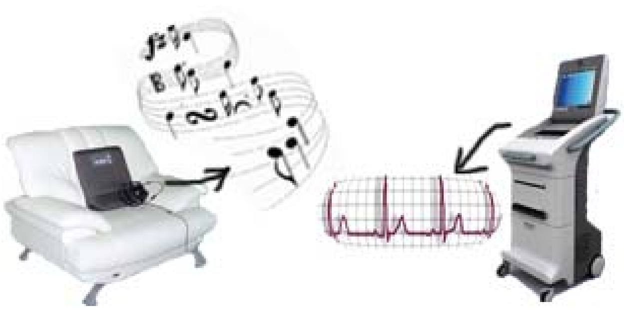


Figure 1. Multi-sensor music therapy device and 12-lead synchronous digital ECG workstation.

E. Analysis

First, pre-process the 40-minute ECG data to remove the interferential signal, and separate the data according to before, during and after music therapy. Then, conduct Poincare, power spectral analysis and approximate entropy analysis of HRV.

1) Poincare: Use the previous RR-interval RR(i) for axis X, and the next RR-interval RR(i+1) for axis Y, then we can get one point. Put all the points together, we get the Poincare.

2) Power spectral density: Methods for the calculation of PSD may be generally classified as non-parametric[e.g. fast Fourier transform (FFT) base]) and parametric [e.g. based on autoregressive (AR) models] methods. In most instances, both methods provide comparable results. In our study, AR-model was used to conduct PSD.

*3) Approximate entropy:*Definition of ApEn[10] is as follows:

a) In evaluating RR-interval series {X(1), X(2), … , X(N)} of length N, first, reconstruct an associated series of vectors {Y(i)}of length m, define

Y(i)=[X(i), X(i+1), …, X(i+m-1)]. (1)

Form a sequence of vectors {Y(l), Y(2), … , Y(N-m+l)} as in equation (1).

b) Given a distance "r", for $1 \le i \le N-m+1$, define

$$C_i^m(r) = (\text{number of j such that } d[Y(i), Y(j)] \le r)/(N-m+1) \quad (2)$$

We define d[Y(i),Y(j)] for vectors Y(i) and Y(j) as

$$d[Y(i), Y(j)] = \max_{k=1,2,\ldots,m}(|X(i+k-1) - X(j+k-1)|) \quad (3)$$

c) From the $C_i^m(r)$, construct

$$\phi^m(r) = 1/(N-m+1) \times \sum_{i=1}^{N-m+1} \ln(C_i^m(r)) \quad (4)$$

d) Reconstruct the m+1-dimensional phase space for original data, repeat step *a)~d)*, we can get $C_i^{m+1}(r)$ and $\phi^{m+1}(r)$.

e) Calculate

$$ApEn(m, r) = \lim_{N\to\infty}[\phi^m(r) - \phi^{m+1}(r)]$$
(5)

f) Given N data points, we implement equation (5) by defining

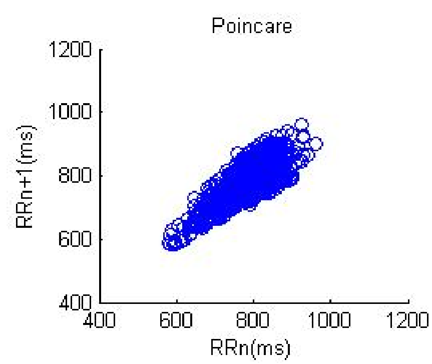
$$ApEn(m, r, N) = \phi^m(r) - \phi^{m+1}(r) \quad (6)$$

Generally we considered when m=2, r=0.2 SD, ApEn is the most appropriate.

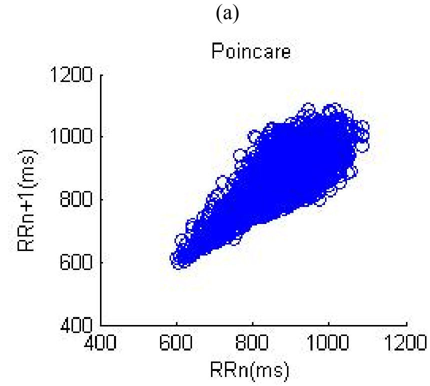
III. RESULTS

A. Poincare

Fig.2 is the Poincare before, during and after music therapy.



(a)



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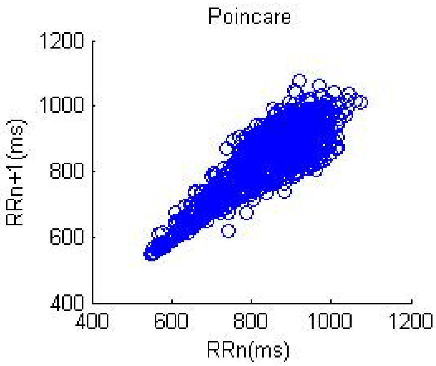


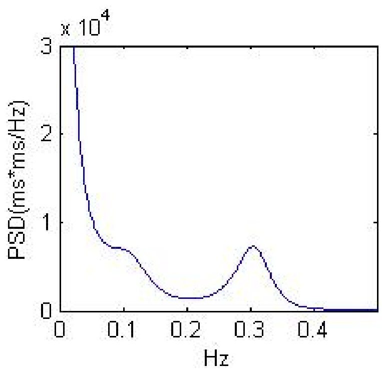
(c)

Figure 2. Poincare of music therapy of 1 subject
(a)before music therapy (b)during music therapy (c)after music therapy

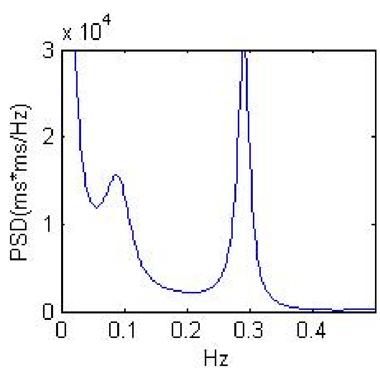
We can intuitively see from Fig.2 that after music therapy, the range of RR interval is wider and heart rate is significantly slower. That is to say beautiful and soft music help people calm down, and have a relaxed mood.

B. Power spectral density

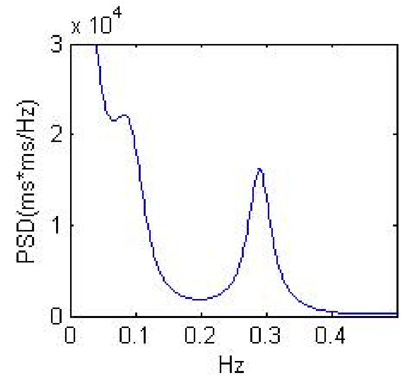
Fig.3 is the power spectral density before, during and after music therapy. TABLE I is Parameters of PSD before, during and after music therapy.



(a)



(b)



(c)

Figure 3. Power spectral density of music therapy of 1 subject
(a)before music therapy (b)during music therapy (c)after music therapy

TABLE I. PARAMETERS OF PSD BEFORE, DURING AND AFTER MUSIC THERAPY

Stage	*VLF*	*LF*	*HF*	*LH*
Before	1722	765	702	1.0897
During	3685	1747	1272	0.9025
After	6395	1778	1114	1.5950

We can see from Fig.3 and TABLE I that after music therapy, each component of HRV is higher than before.

C. Approximate entropy

TABLE II. APPROXIMATE ENTROPY BEFORE AND AFTER MUSIC THERAPY

Number	*Sex*	*Before*	*After*	*Change*
1	Female	1.36	1.18	↓
2	Male	1.35	1.29	↓
3	Female	1.35	1.29	↓
4	Male	1.44	1.37	↓

We can see from TABLE II that ApEn decreased significantly after music therapy.

IV. DISCUSSION

1) Subjects of our study are most college students. For other people or patients, may be different type of music should be chosen. And the results may be quite different.

2) Because the respiration rate affects the HF component of HRV, to assess this component it is necessary to control respiration cycles. However, as the respiration cycle is influenced by musical tempo, it is difficult to maintain the same respiration rate during music that is maintained without music. So it is necessary to develop an effective method of controlling respiration.

3) The treatment time for somatosensory music therapy shouldn't be too long, less than 30 minutes is all right, or there may not be so good for some people.

V. CONCLUSION

Ruling out individual differences and some special factors, after music therapy Music therapy, heart rate variability in very low frequency, low frequency and high frequency components are all increased, while the ApEn decreased. Results are given in TABLE III.

TABLE III. CHANGES OF HRV BEFORE AND AFTER MUSIC THERAPY

Group	*Sex*	*VLF*	*LF*	*HF*	*LF/HF*	*ApEn*
The first group	Male	↑	↑	↓	↑	↑
	Female	↓	↓	↓	↓	↓
	Female	↑	↑	↑	↑	↓
	Male	↑	↑	↑	↓	↓
The second group	Female	↑	↑	↑	↑	↓
	Male	↓	↓	↓	↑	↓
	Female	↑	↑	↓	↓	↓
	Female	↑	↑	↑	↑	↓
The third group	Female	↑	↑	↑	↑	↓
	Female	↑	↑	↓	↑	↓
	Female	↑	↓	↓	↑	↓
	Female	↑	↑	↑	↓	↓
The fourth group	Male	↑	↑	↑	↓	↓
	Male	↓	↓	↑	↑	↓
	Male	↑	↑	↑	↑	↑
	Male	↑	↑	↓	↑	↑
The fifth group	Female	↑	↓	↑	↓	↓
	Male	↑	↓	↑	↓	↓
	Female	↑	↑	↑	↓	↓
	Male	↑	↑	↑	↓	↓

The VLF component is thought to reflect the activity of the sympathetic nervous system. In our study, the VLF component generally increased. We might think that this type of music increased the activity of the sympathetic nervous system.

The HF component is thought to reflect the activity of the parasympathetic nervous system. In our study, the HF component generally increased. We might conclude that this type of music increased the activity of the parasympathetic nervous system. So that heart rate slowed down, and HRV increased. That means after music therapy, people become very relaxed.

The LF component is considered to reflect the activity of the whole autonomic nervous system. In our study, the LF component generally increased, indicating that this type of music increased the activity of the whole autonomic nervous system.

The LF / HF ratio is a reflection of the coordination of the sympathetic nervous system and parasympathetic nervous system. The overall variation was not obvious.

The ApEn is an indicator of system's complexity. In our study, ApEn decreased after music therapy, which indicates that the system becomes less complexity, with less frequency components.

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