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Effects of Music on Cardiac Functioning in Young Women and Men

Ateke GOSHVARPOUR [1], Ataollah ABBASI [2,*], Atefeh GOSHVARPOUR [3], Neda KARAMLOO[4], Fatemeh GHORBANI[4]

[1] Ph.D. Student, Computational Neuroscience Laboratory, Department of Biomedical Engineering, Faculty of Electrical Engineering, Sahand University of Technology, Tabriz, Iran.
[2] Assistant professor, Computational Neuroscience Laboratory, Department of Biomedical Engineering, Faculty of Electrical Engineering, Sahand University of Technology, Tabriz, Iran.
[3] Ph.D. Student, Computational Neuroscience Laboratory, Department of Biomedical Engineering, Faculty of Electrical Engineering, Sahand University of Technology, Tabriz, Iran.
[4] B.Sc. Student, Computational Neuroscience Laboratory, Department of Biomedical Engineering, Faculty of Electrical Engineering, Sahand University of Technology, Tabriz, Iran.
E-mails: ak_goshvarpour@sut.ac.ir; ata.abbasi@sut.ac.ir; af_goshvarpour@sut.ac.ir; karamloo.neda@yahoo.com; fatemeh.ghorbani_s@yahoo.com

*Author to whom correspondence should be addressed; Tel.: +98 4113459363, Fax: +98 4113444322 CNLab: http://ee.sut.ac.ir/Labs/CNLab/index.htm

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Abstract

Purpose: Music not only improve quality of life but may also effect changes in heart rate. This study examined the effects of "Persian traditional music" on cardiac variability. For this purpose, heart rate signals of 62 college students (22 women and 40 men) attending Sahand university of technology were collected. ***Basic Methods***: Time, frequency and nonlinear features (Mean, power spectrum and Lyapunov exponents) of heart rate signals were calculated during rest and music in two groups of healthy young college students: women and men. ***Main Results***: The results show that mean heart rate signals in men group increased during music; however, it decreased in the same protocol in women group. Frequency analysis reveals that maximum power spectrum of heart rate signals is higher in the women's group than that of the men's group. In addition, mean Lyapunov exponents fluctuations are higher in the women's group than that of men's group in both conditions (during rest and music). ***Principal Conclusions***: The current study of heart rate (HR) time series using linear and nonlinear techniques has shown significant differences between before and during the music, and thus could give additional insight into the underlying dynamics of HR and in the investigation of cardiac autonomic function during music in two genders. In addition, it is concluded that music period evoke different reflections of heart rate signals in women and men.

Keywords: Heart Rate Signal; Lyapunov Exponent; Music Effect; Power Spectrum.

Introduction

The electrocardiogram (ECG) is the record of bioelectric potential changes with respect to time as the heart beats of human. Electrocardiography is an important tool in diagnosis of the condition of the heart. It provides valuable information about the functional aspects and autonomic neural regulation of the heart and cardiovascular system. The autonomic nervous system (ANS) regulates the activity of the heart through its sympathetic and parasympathetic parts. The sympathetic as well as the parasympathetic systems of the ANS are both able to innervate the cardiac sinoartial node, which controls the normal rhythm of the heart. The parasympathetic system inhibits the heart rate while the sympathetic system accelerates the heart rate [1].

The analysis of heart rate variability (HRV), the variation of period between consecutive heart beats, provides valuable information to assess the autonomous nervous system. Furthermore, the HRV can be significantly affected by physiological state changes and many disease states. Hence, HRV analysis is becoming a major experimental and diagnostic tool. Its low cost, noninvasive nature and effectiveness encourages the development of new HRV analysis methods to broaden and improve its applications. There are many factors which have a direct and indirect effect on heart rate fluctuations such as age, respiration, cardiovascular and neurological diseases, medication, as well as physical and mental stress and states [2].

It is well established that music can evoke emotional responses that improve quality of life, although they can induce stress and aggressiveness [3]. Music may enhance positive or calming emotions and has played an important role in the 'making of health' throughout human history through its use in rituals and religious services. Although music improves concentration, it has different neurophysiological aspects, the effectiveness of which is governed by individual preferences [4].

The ability of music to improve quality of life, increase physical work activity, concentrate attention, improve sport activity during games, and improve exercise training has been documented for many years ago. In addition, it has shown that music may affect changes in heart rate and heart rate variability (HRV). Therefore, music therapy is also progressively more used in special disciplines, from patients with neurological disease to intensive care and palliative medicine and for motor function in neurologically impaired patients with stroke or parkinsonism [5-14].

Autonomic regulation of the heart and the cardiovascular system has been investigated widely. However, there are a few investigations on the effect of music on heart rate signals. In addition, the influences of music on HRV in non-medical studies are only rarely reported. For this purpose, research done in the laboratory aims at using the information contained in the fluctuation response of ECG heart rate in Persian traditional musical state in two groups of healthy young college students: women and men. To achieve this goal, it is important to study the mechanisms underlying the sympathetic/ parasympathetic activity. Specifically, this study focused on quantifying the difference between women and men ECG heart beats during the music.

The spectral parameters are used to gain insight into the autonomic nervous system (ANS) response induced by music. Frequency domain methods estimate the power spectral densities by using parametric and nonparametric methods. The nonparametric method of analysis is done by applying Fast Fourier Transforms (FFT) or periodograms. These methods can show the cause producing the effect in terms of the frequency components and power spectral density [15].

The frequency spectrum of heart rate signals not only provide a valuable information about the balance of the autonomic neural activity, but it also has the ability to expose different sources of fluctuations.

In other studies by Yoshie et al. [16] and Nakahara et al. [17], it has been shown that music will have beneficial effects on heart rate, heart rate variability and anxiety levels not only in skilled pianists but also in non-musicians during both performances of and listening to music. The findings of these studies suggest that musical performance has a greater effect on emotion-related modulation in cardiac autonomic nerve activity than musical perception [18-19]. In contrast, heavy metal or techno music can lead to stress and restlessness, sleep disturbances, fatigue, exhaustion, impairment of the immune system, hardness of hearing and/or loss of hearing [20]. Ellis [21] compared changes in mean HR and HRV while subjects listened to 2.5-minute excerpts of music at three different tempos (60, 90, 120 bpm).

This paper is organized as follows. In section II, the sets of data, which are collected for this study, are briefly described. Then, the extracted features based on frequency and nonlinear domains is developed. Section III presents the results and comparisons between women and men heart rate during the music. Finally, a discussion and conclusions are described in section IV.

Material and Method

Data collection

To understand the control of Sympathetic/ parasympathetic events elicited by music, heart rate in 62 college students attending Sahand university of technology, 22 females (age range: 20-24 years; mean age: 21.64 years) and 40 males (age range: 19-26 years; mean age: 21.43 years) is studied. All of the participants are Iranian students.

The experimental procedure was divided into two different stages: Subjects were first instructed to lay in supine position quietly for 5 minutes and kept their eyes closed. After five minutes of rest, fourteen minutes of electrocardiogram signals were recorded during the music. Five minutes were used as the baseline to compare with music. Fourteen minutes of music period consist of 3 different traditional Persian music with 30 seconds of the calm period at the beginning and the end of each track. In this study, the second track (traditional Persian music) which is about 3 minutes and 43 seconds is examined.

All tests were performed by participants in the supine position in comfortable temperature, humidity, and light. Musical pieces were presented via headphone at a comfortable volume using KMPlayer software. Participants were asked to listen carefully to the music and to keep their eyes closed during the whole experiment, making the measurements more comfortable. All participants reported normal hearing and no history of neurological disease. The subjects were asked not to eat salty or fat foods before data recording. Mean temperature of the room is about 27.6oC. All the musics are performed with the same instrumentation by Persian musician Dr. Keyvan Saket.

The electrocardiogram signals (ECG) - lead I- of all subjects were recorded in Computational Neuroscience Laboratory using 16-channel PowerLab (manufactured by ADInstruments). Heart rate signals were extracted online using Chart5 for Windows software (based on heart rate = 60/RR interval in seconds). A digital notch filter is applied to the data at 50 Hz to remove any artifacts caused by alternating current line noise. The sampling rate was 400 Hz.

Feature extraction

Frequency power

Two measures in time domain including the mean heart rate and standard deviation is considered. The spectral HRV measures were calculated by using Fast Fourier transform.

According to the Task Force [22], the power spectrum of short time series can be classified into 3 ranges as follows:

- Power in the very low frequency range (VLF), 0.003–0.04 Hz,
- Power in the low frequency range (LF), 0.04–0.15 Hz,
- Power in the high frequency range (HF), 0.15–0.4 Hz.

However, the physiological explanation of the VLF component is not well established. There is some evidence that it is related to thermoregulation [23-24], and humoral regulatory. Thus, cardiac variability reflects a variety of homeostatic functions that are specific for the particular frequency ranges. Greater amplitude and complexity suggest a greater variety of more active homeostatic reflexes and thus may be indexes of adaptive capacity.

Low frequency (LF) spectral power reflects sympathetic and vagal influences on cardiac control via baroreceptor-mediated regulation of blood pressure [25].

The high frequency (HF) power is a function of respiratory modulation of vagal activity [26]. In other words, the HF power is primarily modulated by the parasympathetic system [22].

Periodogram can be defined as finding the discrete fourier transform (DFT) of datasets, taking the magnitude squared of the results and estimating the PSD [27]. This definition is presented mathematically as:

$$\hat{P}_{xx}(f) = \frac{|X_L(f)|^2}{f_s L} \tag{1}$$

where

$$X_L(f) = \sum_{n=0}^{L-1} X_L[n] e^{-j2\pi f_n / f_s} \quad (2)$$

where L is length of $x_L[n]$ signal and f_s is sampling frequency. In practically, periodograms perform the N-point PSD estimate and is defined as:

$$\hat{P}_{xx}(f_k) = \frac{|X_L(f_k)|^2}{f_s L}, \quad f_k = \frac{kf_s}{N}, \quad k = 0, 1, 2, \ldots, N-1 \quad (3)$$

where

$$X_L(f) = \sum_{n=0}^{N-1} X_L[n] e^{-j2\pi kn/N} \quad (4)$$

Lyapunov exponents

Consider two (usually the nearest) neighboring points in phase space at time 0 and at a time t, distances of the points in the ith direction being $||\delta x_i(0)||$ and $||\delta x_i(t)||$, respectively. The Lyapunov exponent is then defined by the average growth rate λ_i of the initial distance

$$\frac{\|\delta x_i(t)\|}{\|\delta x_i(0)\|} = 2^{\lambda_i t} \quad (t \to \infty) \quad (5)$$

$$\lambda_i = \lim_{t \to \infty} \frac{1}{t} \log_2 \frac{\|\delta x_i(t)\|}{\|\delta x_i(0)\|}$$

An exponential divergence of initially nearby trajectories in phase space coupled with folding of trajectories, ensures that the solutions will remain finite, and is the general mechanism for generating deterministic randomness and unpredictability. Therefore, the existence of a positive λ for almost all initial conditions in a bounded dynamical system is widely used.

To discriminate between chaotic dynamics and periodic signals Lyapunov exponent (λ) is often used. It is a measure of the rate at which the trajectories separate one from other. In chaotic signals the trajectories follow typical patterns in phase space. The trajectories which are closely spaced, relative to each other, converge and diverge exponentially.

For dynamical systems, sensitivity to initial conditions is quantified by the Lyapunov exponent (λ). They characterize the average rate of divergence of these neighboring trajectories.

- A negative exponent implies that the orbits approach a common fixed point. These systems are non conservative (dissipative). The absolute value of the exponent indicates the degree of stability.
- A zero exponent means the orbits maintain their relative positions on a stable attractor. Such systems are conservative and in a steady state mode.
- Finally, a positive exponent implies the orbits are on a chaotic attractor [28-29]. The magnitude of the Lyapunov exponent is a measure of the sensitivity to initial conditions, the primary characteristic of a chaotic system.

Statistical analysis

In this study, the t-test of the null hypothesis that data in the vector x are a random sample from a normal distribution with mean 0 and unknown variance, against the alternative that the mean is not 0 is performed. The result of the test is returned in p-value. P-value→0 indicates a rejection of the null hypothesis at the 5% significance level ($p<0.05$). P-value→1 indicates a failure to reject the null hypothesis at the 5% significance level.

Results

In this study mean, spectral amplitude and frequency, and Lyapunov exponents of HR signals were calculated. Then the extracted features are compared in two conditions: normal and music, in two groups of youth college students (men and women).

Figure 1 shows heart rate signals during rest and music in one subject.

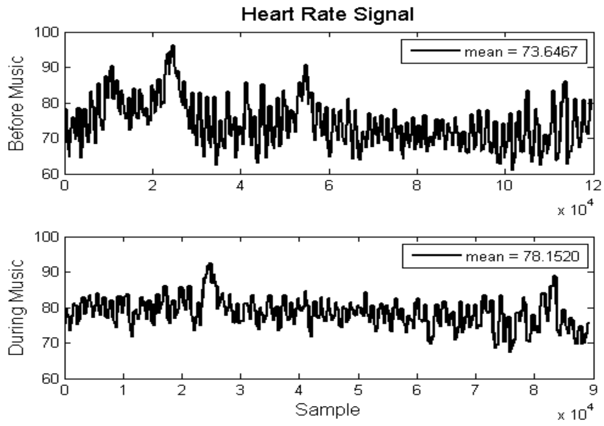

Figure 1. Heart rate signals

top: before music. bottom: during music (record 37).

Mean heart rate signals for all subjects is calculated. Figure 2 depicts the observed fluctuations in two groups: women and men, during rest (left panel) and listening to music (right panel).

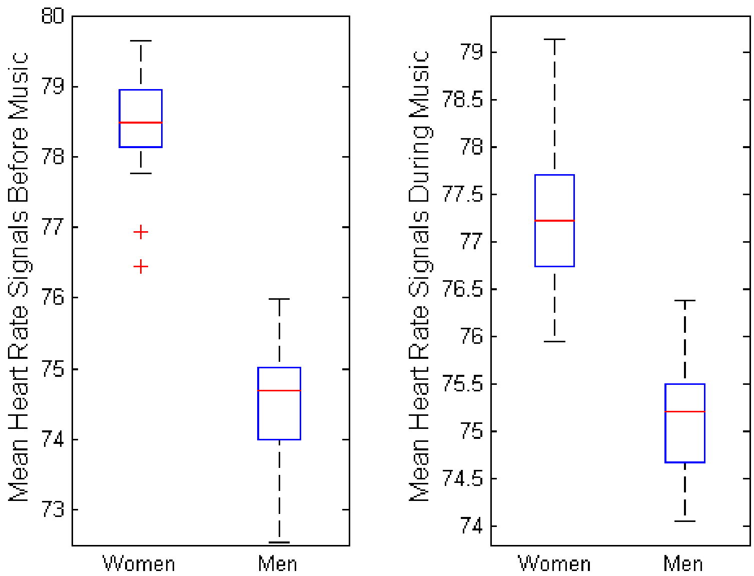

Figure 2. The box plot of the mean heart rate signals in women and men. left: before music. right: during music.

According to results, mean heart rate signals before listening to music is about 78.53 and 74.49 for women and men, respectively; whereas, these values are about 77.28 for women's group and 75.14 for men group during the music. In other words, Mean heart rate signals are higher in the women's group than that of the men's group. Therefore, the results indicate that there is a discrepancy between heart rate signals of two genders in both conditions (before and during the music). Mean heart rate signals in men group increased during music; however, it decreased in the same protocol in women group. Although fluctuations in HR occurred among women and men subjects, these changes were small and not statistically significant.

In order to study the autonomic regulation of the heart during music, the power spectrum of heart rate time series is calculated. Figure 3 represents the power spectrum of heart rate signal of one men subject (record 39).

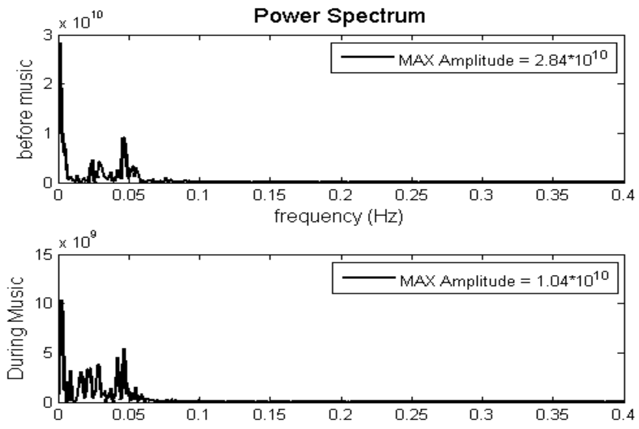

Figure 3. The power spectrum of heart rate signal for one subject in men group. top: before music, bottom: during music.

The results presented in Figure 3 suggest that although in both conditions (before and during the music) the dominate peaks occurred at the very low frequency range, the amplitudes of the power spectrum are significantly different ($p<0.05$). Figure 4 shows the box plot of maximum PSD amplitudes before and during music for all subjects in two groups: women and men.

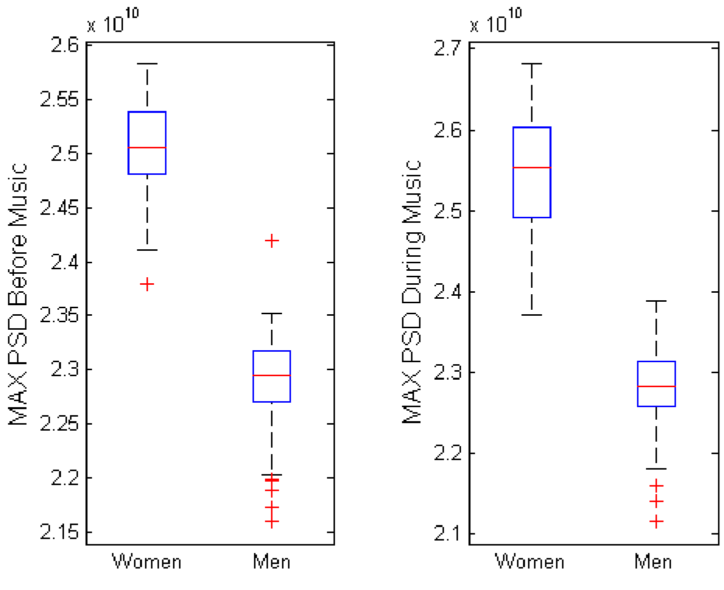

Figure 4. The box plot of the power spectrum of heart rate signal for all subjects: women and men. left: before music, right: during music.

As shown in Figure 4, in both conditions (before and during the music), maximum power spectrum of heart rate signals is higher in the women's group than that of the men's group. Furthermore, the mean of maximum power spectrum increased in women group during music; whereas, it decreased in the men group (Figure 4). In sum, music periods evoke different reactions on heart rate signals than silent periods in two groups. In addition, although changes in PSD occurred among women and men, these changes were just significant in women's groups and small and not significant in the men's group.

Finally the Lyapunov exponents of heart rate signals are calculated during rest and music. Figure

5 depicts the box plot of Lyapunov exponents in women and men's groups.

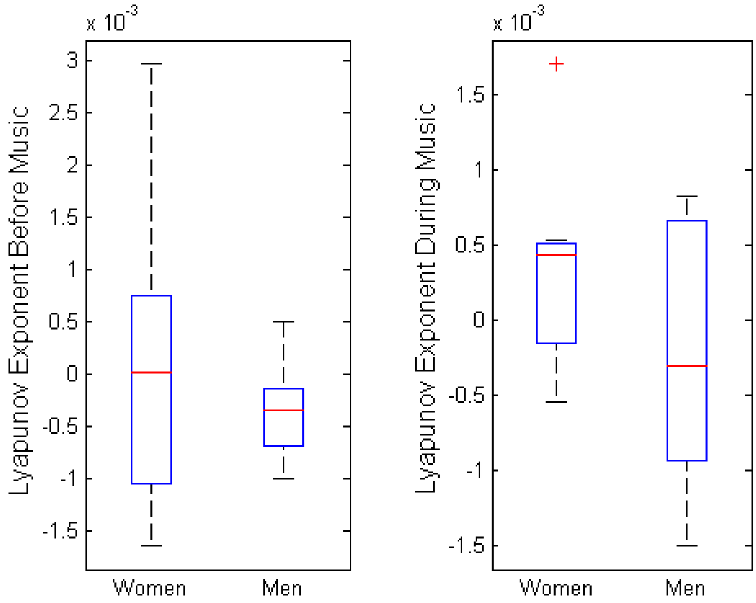

Figure 5. The box plot of Lyapunov exponent of HR signals in two groups: women and men. left: before music, right: during music.

As shown in Figure 5, mean Lyapunov exponents fluctuations are higher in the women's group than that of men's group in both conditions (during rest and music). It reveals that music may alter HR signals differently in different genders.

Discussion

Listening to music is a complex phenomenon, which consist of neurological, psychological, emotional, and cardiovascular fluctuations, with behavioral modifications of breathing [30-31].

It is important to investigate the physiological effect of listening to music in order to achieve an increased understanding of autonomous control of cardiovascular functions. In this paper, heart rate variability (HRV) time series is characterized during music using linear and nonlinear dynamical parameters.

Ellis [21], show that HRV decreased as the tempo increased, indicating that the "challenge" of arousing music prompted a withdrawal of PNS activity. No significant change was observed in mean heart rate, however, despite there is a significant correlations between mean HR and measures of HRV at baseline ($p<0.001$).

The results of the current study reveal that in both conditions (before and during music), there is a discrepancy between heart rate signals in women and men groups. According to Figure 2, mean heart rate signals are higher in the women's group than that of the men's group. Ramaekers et al [32] conclude that a lower mean basal heart rate in men is unexplained, however may derive from different neurohumoral and central autonomic mechanisms in men and women rather than solely from differences in autonomic outflow. The higher basal heart rate in women can also be related to a lower stroke volume.

In addition, mean heart rate signals increased during music in men group; however, it decreased in the same protocol in women group. Although fluctuations in HR occurred during the music, these changes were small and not significant. These results are in the line with Argstatter et al [33] who found there were no significant differences in heart rate between three randomized groups: group I represented patients with 'music only' during catheterization procedures; group II patients had both musics during catheterization and extended information prior to the procedure; and group III patients served as controls. In addition, other researchers did not observe any significant differences regarding heart rate signals in music and control groups [11-34]. Similar effects have been reported by Antonietti [12] in patients who underwent rehabilitation after surgery.

According to the results of frequency domain analysis, although in both conditions (before and during the music) the dominant peaks in the power spectrum occurred at the very low frequency range, the amplitude of the power spectrum is significantly different in the women's group (at the 5% level) and this difference in men subjects is not statistically significant. In addition, the mean of the maximum power spectrum decreased in the men's group during music; while, it increased in the women's group (Figure 4). Therefore, one can conclude that music periods evoke different reactions on heart rate signals than silent periods in two genders: women and men.

In another study, van der Zwaag et al [1] conclude that men significantly differ in their ECG frequency domain measures than women. They claim that men compared to women show a higher ratio between the low and high frequency components, which implies that the difference between the amount of sympathetic activity and the amount of the parasympathetic activity is larger in men [1].

The predictability of the system is quantified by Lyapunov exponent, which also gives the presence of chaos. The Lyapunov exponent describes the rate of exponential divergence of trajectories and sensitive dependence on the initial condition. It is demonstrated that, in both conditions (during rest and music) mean Lyapunov exponents are higher in women group than that of men group. It reveals that music may alter HR signals differently in men and women.

The current study of HR time series using linear and nonlinear techniques has shown significant differences between before and during the music, and thus could give additional insight into the underlying dynamics of HR and in the investigation of cardiac autonomic function during music in two genders.

Trappe [4] concludes that music is effective under different conditions and can be utilized as an effective intervention in patients with pain, cardiovascular disturbances, psychiatric diseases, depressive syndromes and in intensive care medicine. Therefore, music plays an important role in people's lives and, by extension, an important role in medicine.

Conclusions

It has shown that in both conditions (before and during the music), there is a significant discrepancy between extracted features from heart rate signals in women and men's groups, which confirms that music may alter HR signals differently in men and women. Specifically, the results show that maximum power spectrum and mean Lyapunov exponents fluctuations of heart rate signals are higher in the women's group than that of the men's group. Therefore, it could give additional insight into the underlying dynamics of HR and in the investigation of cardiac autonomic function during music in two genders. In addition, it is concluded that music period evoke different reflections of heart rate signals in women and men.

Further investigations need to concentrate on other techniques that can characterize the nonlinear behavior of heart rate signals during the music. Although, heart rate signals have valuable information about physiological changes during music, more studies can be carried out on other signals such as electroencephalograms and respiration rates. Finally, the results of the current study demonstrate that in women subjects, very low frequency wave amplitudes particularly increased, which may be related to thermoregulation. As we did not specifically examine thermoregulation, vascular tone, blood pressure, or any index of sympathetic activity, additional data are required on vascular and body temperature changes during music and their possible relationship with HR very low frequency wave activity.

Conflict of Interest

The authors declare that they have no conflict of interest.

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References

1. van der Zwaag MD, van der Broek EL, Westerink JHDM. Directing affect through music, Radboud University, Nijmegen [Msc Thesis] 2007
2. Tikkanen P. Characterization and application of analysis methods for ECG and time interval variability data [Dissertation]. 1999; 1-103
3. Grandjean D, Sander D, Scherer KP. Conscious emotional experience emerges as a function of multilevel, appraisal-driven response synchronization. Conscious Cogn 2008;17:484-495.
4. Trappe Hj. The effects of music on the cardiovascular system and cardiovascular health. Heart 2010;96:1868-1871.
5. Bernardi L, Porta C, Sleight P: Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence. Heart 2006;92:445-452.
6. Szmedra L, Bacharach DW. Effect of music on perceived exertion, plasma lactate, norepinephrine and cardiovascular hemodynamics during treadmill running. Int J Sports. 1998;19(1):32-7.
7. Szabo A, Small A, Leigh M. The effects of slow- and fast-rhythm classical music on progressive cycling to voluntary physical exhaustion. J Sports Med Phys Fitness 1999;39:220-225.
8. Krout RE. Music therapy with imminently dying hospice patients and their families: facilitating release near the time of death. Am J Hosp Palliat Care 2003;20:129-134.
9. Mramor KM. Music therapy with persons who are indigent and terminally ill. J Palliative Care 2001;17:182-187.
10. Norton A, Zipse L, Marchina S, Schluag G. Melodic intonation therapy: shared insights on how it is done and why it might help. Ann NY Acad Sci 2009;1169:431-436.
11. Nilsson U. Soothing music can increase oxytocin levels during bed rest after openheart surgery: a randomized control trial. J Clin Nurs 2009;18:2153-2161.
12. Antonietti A. Why is music effective in rehabilitation? Stud Health Technol Inform 2009;145:179-194.
13. Schauer M, Mauritz KH. Musical motor feedback (MMF) in walking hemiparetic stroke patients: randomized trials of gait improvement. Clin Rehabil 2003;17:713-722.
14. Pacchetti C, Aglieri R, Mancini F, Martignoni E, Nappi G. Active music therapy and Parkinson's disease: methods, Funct. Neurol 1998;13:57-67.
15. RenuMadhavi CH, Ananth AG. Estimation of Approximate Entropy of Heart Rate Variability of healthy subjects and investigation of the effect of meditation on it. International Conference on Signal Acquisition and Processing IEEE 2010;304-307.
16. Yoshie M, Kudo K, Murakoshi T, Ohtsuki, T. Music performance anxiety in skilled pianists: effects of social-evalutive performance situation on subjective, autonomic, and electromyographic reactions. Exp Brain Res 2009;199:117-126.
17. Nakahara H, Furuya S, Obata S, Masuko T, Kinoshita H. Emotion-related changes in heart rate and its variability during performance and perception of music, Ann NY Acad Sci 2009;1169:359-362.
18. Chan MF, Chan EA, Mok E, Kwan Tse FY. Effect of music on depression levels and physiological responses in community-based older adults. Int J Health Nurse 2009;18:285-294.
19. Koelsch S. A neuroscientific perspective on music therapy. Ann NY Acad Sci 2009;1169:374-384.

20. Storm F. Die Heilkraft bestimmter Musikstile In: Storm Fed Heilen mit Tonen Stuttgart: Luchow-edition 2006;17-47.
21. Ellis RJ. The effect of musical tempo on subjective and physiological indices of affective response Unpublished doctoral dissertation, The Ohio State University 2009.
22. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology Heart rate variability: standards of measurement, physiological interpretation, and clinical use. Eur Heart J 1996;17(3):354-381.
23. Taylor JA, Carr DL, Myers CW, Eckberg DL. Mechanisms underlying very-low-frequency RR-interval oscillations in humans. Circulation 1998;98:547-555.
24. Kitney RI. An analysis and simulation of the human thermoregulatory control system. Med Biol Eng 1974;12:56-64.
25. Pagani M, Rimoldi O, Malliani A. Low-frequency components of cardiovascular variabilities as markers of sympathetic modulation. Trends Pharmocol Sci 1992;13:50-54.
26. Saul JP. Beat-to-beat variations of heart rate reflect modulation of cardiac autonomic outflow. News in Psychological Sci 1990;5:32-37.
27. Signal Processing Toolbox for use with MATLAB, version 6, MathWorks, Inc.
28. Haykin S, Li XB. Detection of signals in chaos. Proc IEEE 1995;83(1):95-122.
29. Abarbanel HDI, Brown R, Kennel MB. Lyapunov exponents in chaotic systems: their importance and their evaluation using observed data. Int J Mod Phys B 1991;5(9):1347-1375.
30. Orem J, Trotter RH. Behavioral control of breathing. News Physiol Sci 1994;9:228-232.
31. Shea SA. Behavioural and arousal-related influences on breathing in humans. Exp Physiol 1998;81:1-26.
32. Ramaekers D, Ector H, Aubert AE, Rubens A, Van de Werf F. Heart rate variability and heart rate in healthy volunteers Is the female autonomic nervous system cardioprotective? European Heart Journal 1998;19:1334-1341.
33. Argstatter H, Haberbosch W, Bolay HV. Study of the effectiveness of musical stimulation during intracardiac catheterization. Clin Res Cardiol 2006;95:14-22.
34. Nilsson U. The effect of music intervention in stress response to cardiac surgery in a randomized clinical trial. Heart Lung 2009;38:201-207.