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Original article

Effects of auditory stimulation with music of different intensities on heart period

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ABSTRACT

Various studies have indicated that music therapy with relaxant music improves cardiac function of patients treated with cardiotoxic medication and heavy-metal music acutely reduces heart rate variability (HRV). There is also evidence that white noise auditory stimulation above 50 dB causes cardiac autonomic responses. In this study, we aimed to evaluate the acute effects of musical auditory stimulation with different intensities on cardiac autonomic regulation. This study was performed on 24 healthy women between 18 and 25 years of age. We analyzed HRV in the time [standard deviation of normal-to-normal RR intervals (SDNN), percentage of adjacent RR intervals with a difference of duration >50 ms (pNN50), and root-mean square of differences between adjacent normal RR intervals in a time interval (RMSSD)] and frequency [low frequency (LF), high frequency (HF), and LF/HF ratio] domains. HRV was recorded at rest for 10 minutes. Subsequently, the volunteers were exposed to baroque or heavy-metal music for 5 minutes through an earphone. The volunteers were exposed to three equivalent sound levels (60–70, 70–80, and 80–90 dB). After the first baroque or heavy-metal music, they remained at rest for 5 minutes and then they were exposed to the other music. The sequence of songs was randomized for each individual. Heavy-metal musical auditory stimulation at 80–90 dB reduced the SDNN index compared with control (44.39 ± 14.40 ms vs. 34.88 ± 8.69 ms), and stimulation at 60–70 dB decreased the LF (ms^2) index compared with control (668.83 ± 648.74 ms^2 vs. 392.5 ± 179.94 ms^2). Baroque music at 60–70 dB reduced the LF (ms^2) index (587.75 ± 318.44 ms^2 vs. 376.21 ± 178.85 ms^2). In conclusion, heavy-metal and baroque musical auditory stimulation at lower intensities acutely reduced global modulation of the heart and only heavy-metal music reduced HRV at higher intensities.
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1. Introduction

Auditory stimulation with music as a therapy has received attention for treatment and prevention of disorders.[1] Studies on music therapy were performed on patients under pharmacological treatment, immediately after surgery or awaiting surgical procedures.[2] Musical auditory stimulation produces an extensive variety of psychological and hemodynamic effects by influencing the cardiac autonomic modulation.[3,4]

In this regard, heart rate variability (HRV) is a method that analyzes the oscillations of the intervals between consecutive heartbeats (RR intervals). HRV is well accepted in the literature to investigate cardiac autonomic regulation, which is influenced by the sinus node.[5] Reduction in HRV is an indicator of poor cardiovascular function, such as in the case of chronic heart failure, whereas the increase in HRV corresponds to an improvement of cardiovascular function.[6]

Patients with cancer treated with anthracycline, a cardiotoxic medication, had improvements in HRV after music therapy intervention for 10 weeks. However, after the treatment cessation, their HRV levels returned to control values reported before the music therapy intervention, indicating the positive effects of music

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therapy on HRV in that population.[3] Another study suggested that music therapy increased parasympathetic activity and reduced the probability of congestive heart failure development in elderly patients with dementia and cerebrovascular disease.[7]

Although it was already evidenced that acoustic stimulation with white noise above 50 dB caused cardiac sympathetic changes,[8] it is not well understood whether the effects of musical auditory stimulation on HRV are dependent on equivalent sound level. Moreover, knowledge on cardiac autonomic responses elicited by music exposure is important for developing future therapies that might contribute to the prevention of cardiovascular disorders. Therefore, in this study, we evaluated the acute effects of baroque and heavy-metal musical auditory stimulation at different intensities on cardiac autonomic regulation.

2. Methods

2.1. Study population

Volunteers were 28 healthy female college students (all nonsmokers; age, 18–25 years). All volunteers were informed about the procedures and objectives of the study and gave written informed consent. All study procedures were approved by the Ethics Committee in Research of the Faculty of Sciences of the Universidade Estadual Paulista, Campus de Marilia (No. Protocol: 2011-385), and were in accordance with Resolution 196/96 National Health 10/10/1996.

2.2. Noninclusion criteria

Volunteers were excluded if they had cardiopulmonary, auditory, psychological, and neurological disorders, and other impairments that would prevent them from performing the study procedures. We also excluded those undergoing treatment with drugs that influence cardiac autonomic regulation.

2.3. Initial evaluation

Baseline criteria for initial evaluation were age, sex, weight, height, and body mass index (BMI). Weight was determined using a digital scale (W 200/5; Welmy Ind Com Ltda, São Paulo, Brazil) with a precision of 0.1 kg. Height was determined using a stadiometer (ES 2020; Sanny, São Paulo, Brazil) with a precision of 0.1 cm and extension of 2.20 m. BMI was calculated as weight/height,[2] with weight in kilograms and height in meters.

2.4. Measurement of the auditory stimulation

Measurements of the equivalent sound levels were conducted in a soundproof room using an SV 102 audio dosimeter (Svantek, Warsaw, Poland). This device was programmed to take measurements in the "A" weighting circuit with a slow response.

Measurements were taken when participants relaxed for 10 minutes by listening to classical baroque music. An insert-type microphone (microphone in real ear) was placed inside the auditory canal of the volunteer, just below the speaker, which was connected to a personal stereo.

Before each measurement, the microphone was calibrated with an acoustic CR:514 model calibrator (Cirrus Research).

For the analysis, we used Leq (A), which is defined as the equivalent sound pressure level and which corresponds to the constant sound level in the same time interval. It contains the same total energy as the sound. We also analyzed the frequency spectrum of the sound stimulation (octave band).[9]

2.5. HRV analysis

The RR intervals recorded by the portable RS800CX HR monitor (sampling rate, 1000 Hz) were downloaded to the Polar Precision Performance program (version 3.0; Polar Electro, Kempele, Finland). This software enabled the visualization of HR and the extraction of a cardiac period (RR interval) file in ".txt" format. Following digital filtering complemented with manual filtering for the elimination of premature ectopic beats and artifacts, at least 256 RR intervals were used for the data analysis. Only those series with more than 95% sinus rhythm were included in the study.[5] For calculation of the linear indices, we used the HRV analysis software (Kubios HRV version 1.1 for Windows; Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Kuopio, Finland).

2.6. Linear indices of HRV

To analyze HRV in the frequency domain, the low frequency (LF = 0.04–0.15 Hz) and high frequency (HF = 0.15–0.40 Hz) spectral components were measured in m/s and normalized units, representing a value relative to each spectral component in relation to the total power minus the very-low-frequency components, and the ratio between these components (LF/HF). The spectral analysis was performed using the fast Fourier transform algorithm.[10]

The time domain analysis was performed in terms of standard deviation of normal-to-normal RR intervals (SDNN), percentage of adjacent RR intervals with a difference of duration > 50 ms (pNN50), and root-mean square of differences between adjacent normal RR intervals in a time interval (RMSSD).

We used Kubios HRV version 2.0 software to analyze these indices.[11]

2.7. Protocol

Data collection was carried out in the same soundproof room for all volunteers with the temperature between 21°C and 25°C and relative humidity between 50% and 60%. All volunteers were instructed not to drink alcohol and caffeine for 24 hours before evaluation. Data were collected on an individual basis, between 8 and 12 AM to standardize the protocol. All procedures necessary for data collection were explained to every volunteer individually. The volunteers were instructed to remain at rest and avoid talking during the data collection.

After the initial evaluation, the heart monitor belt was placed over the thorax, aligned with the distal third of the sternum, and the Polar RS800CX HR receiver (Polar Electro) was placed on the wrist. The volunteers (eyes opened) wore headphones and avoided tapping with a finger or a foot (to avoid art factual entrainment), which was confirmed by continuous visual monitoring.

The women variables were compared between the following: (1) rest control; (2) music at 60–70 dB; (3) music at 70–80 dB; and (4) music at 80–90 dB. The musical auditory stimulation was performed using an excitatory heavy metal (Gamma Ray: "Heavy Metal Universe") and a relaxant baroque (Pachelbel: "Canon" in D Major; an example of the first nine measures in shown in Fig. 1). The sequence of intensity of songs was randomized for each individual.

2.8. Statistical analysis

Standard statistical methods were used to calculate the means and standard deviations. The normal Gaussian distribution of the data was verified by the Shapiro–Wilk goodness-of-fit test ($z > 1.0$). For parametric distributions, we applied analysis of variance for repeated measures followed by the Bonferroni post-test. For

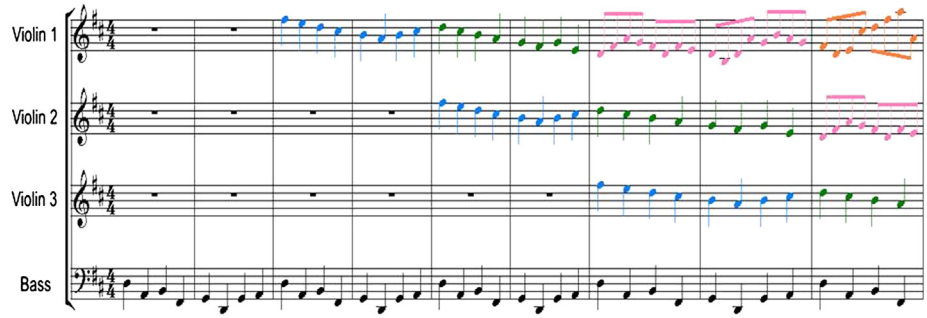


Fig. 1. The first nine measures of the Canon in D. Colors highlight the individual canonic entries. *Note*. Edited from "Johann Pachelbel: Organist, Teacher, Composer, A Critical Reexamination of His Life, Works, and Historical Significance [dissertation]," by K.J. Welter, 1998. Cambridge, MA: Harvard University; 1998.

nonparametric distributions, we used the Friedman test followed by Dunn post-test. Differences were considered significant when the probability of a Type I error was less than 5% ($p < 0.05$). We used BioStat 2009 Professional 5.8.4 software for statistical analysis.

3. Results

Data on baseline systolic arterial pressure, diastolic arterial pressure, HR, mean RR interval, age, height, body weight, and BMI are presented in Table 1.

In relation to the time domain indices of HRV, we noted that the SDNN index reduced during exposure to auditory stimulation with heavy-metal music at 80–90 dB compared with the control condition, whereas the RMSSD and pNN50 indices were not significantly changed during exposure to heavy-metal musical auditory stimulation at three equivalent sound levels (Table 2).

In Table 2, it can be seen that the LF domain index in absolute units was decreased during heavy-metal musical auditory stimulation at 60–70 dB compared with the control condition, whereas no significant change was noted for the LF index in normalized units, HF index in normalized and absolute units, and LF/HF ratio.

With regard to baroque musical auditory stimulation, the SDNN, RMSSD, and pNN50 time domain indices of HRV were not significantly changed during exposure to this music style at the three equivalent sound levels (Table 3).

From Table 3, it can be seen that auditory stimulation with baroque music style at 60–70 dB reduced the LF index in absolute units. By contrast, the LF index in normalized units, HF index in absolute and normalized units, and LF/HF ratio were not significantly changed during exposure to this music style at the three equivalent sound levels.

Fig. 2 shows an example of the visual evaluation of the power spectrum density analysis observed in one volunteer before exposure to baroque musical auditory stimulation, during music exposure between 60 and 70 dB, during music exposure between 70 and 80 dB, and during music exposure between 80 and 90 dB.

Fig. 3 presents an example of power spectrum density analysis in one volunteer before exposure to heavy-metal musical auditory stimulation, during music exposure between 60 and 70 dB, during music exposure between 70 and 80 dB, and during music exposure between 80 and 90 dB (Fig. 3).

Table 1
Baseline DAP, SAP, HR, mean RR, weight, height, and BMI of the volunteers.

Variable	Value
Age (y)	20.9 ± 2.2
Height (m)	1.6 ± 0.1
Weight (kg)	56.7 ± 7.3
BMI (kg/m^2)	21.3 ± 2.7
HR (bpm)	82.55 ± 12.57
Mean RR (ms)	749.12 ± 140.05
SAP (mmHg)	110.4 ± 6.2
DAP (mmHg)	75 ± 8

BMI = body mass index; DAP = diastolic arterial pressure; HR = heart rate; mean RR = mean RR interval; SAP = systolic arterial pressure.

4. Discussion

The investigation of the intensity of musical auditory stimulation is important to improve musical therapy for alternative treatments.[12] A recent study reported that white noise stimulation above 50 dB heightened the sympathetic component of HR regulation and also demonstrated significant association between the LF/HF ratio and the equivalent sound level—the higher the sound intensity the higher the sympathetic tone on the heart and the lower the HRV.[8] In this context, our investigation was undertaken to evaluate the acute effects of auditory stimulation with distinct music styles of different intensities on cardiac autonomic regulation. Interestingly, we noted that low-intensity (60–70 dB) heavy-metal and baroque styles acutely reduced the frequency domain LF index in absolute units, and the SDNN index in the time domain was decreased during exposure to high-intensity (80–90 dB) heavy-metal musical style.

We had previously reported that auditory stimulation with Pachelbel's music between 60 and 70 dB decreased global modulation of HR by reducing the LF index in absolute units. This index corresponds to sympathetic and parasympathetic components of the autonomic regulation of HR.[13] A recent study showed that the same music acutely reduced the same index in healthy women,[14] but Canon in D music from Pachelbel had no significant effects on cardiac autonomic regulation in previous studies.[9,15] This contradictory data may be explained by the difference between the study methods. Roque et al[14,15] also conducted studies on women who were exposed to baroque music and subsequently to heavy-metal music. It is possible that the sequence of music exposure influenced the cardiac autonomic responses. In our study, however, we did not select women in the luteal and follicular phases of the menstrual cycle, whereas in the aforementioned studies this was not a noninclusion criterion.

The baroque music chosen in our study was Canon in D from Johann Pachelbel, a German composer of Protestant church music. Canon in D from Pachelbel associates the techniques of canon and ground bass. Canon is a polyphonic device in which several voices play the same music, entering in sequence.[16] Previous studies on animals reported significant effects of different music on autonomic nervous system. Rats under urethane anesthesia were

Table 2
Time and frequency domain indices before and after exposure to auditory stimulation with excitatory heavy-metal musical style.

Index	Control	60–70 dB	70–80 dB	80–90 dB	*p*
RMSSD	31.71 ± 14.2	30.31 ± 14.27	31.17 ± 12.64	30.1 ± 11.83	0.97
pNN50	13.37 ± 14.36	12.81 ± 15.7	13.11 ± 13.13	11.83 ± 12.07	0.98
SDNN	44.39 ± 14.4	35.09 ± 9.42	37.49 ± 10.09	34.88 ± 8.69[a]	0.01
HF (ms^2)	516.33 ± 550.48	296.5 ± 245.61	350.88 ± 255.7	311.71 ± 215.97	0.11
LF (ms^2)	668.83 ± 648.74	392.5 ± 179.94[a]	406.75 ± 241.37	411.58 ± 241.14	0.04
HF (nu)	42.44 ± 19.11	38.01 ± 17.91	42.53 ± 18.22	41.11 ± 18.82	0.82
LF (nu)	57.4 ± 19.11	61.52 ± 17.96	56.94 ± 18.34	58.38 ± 18.98	0.83
LF/HF	2.2 ± 2.93	2.43 ± 2.19	1.86 ± 1.57	2.28 ± 2.37	0.86

Data are presented as mean ± standard deviation.
HF = high frequency; LF = low frequency; LF/HF = low frequency/high frequency ratio; pNN50 = percentage of adjacent RR intervals with a difference of duration >50 ms; RMSSD = root-mean square of differences between adjacent normal RR intervals in a time interval; SDNN = standard deviation of normal-to-normal RR intervals.
[a] Different from control.

Table 3
Time and frequency domain indices before and after exposure to auditory stimulation with baroque musical style.

Index	Control	60–70 dB	70–80 dB	80–90 dB	*p*
RMSSD	34.45 ± 16.46	29.29 ± 12.9	30.85 ± 13.72	31.2 ± 14.08	0.65
pNN50	15.21 ± 15.06	12.26 ± 13.51	12.78 ± 12.74	13.55 ± 14.72	0.89
SDNN	41.74 ± 10.23	35.9 ± 10.5	38.77 ± 13.23	37.96 ± 10.56	0.34
HF (ms^2)	466.04 ± 405.06	356.33 ± 368.47	389.46 ± 336.15	361.46 ± 394.76	0.73
LF (ms^2)	587.75 ± 318.44	376.21 ± 178.85[a]	462.17 ± 304.83	406.21 ± 216.02	0.03
HF (nu)	40.3 ± 21.5	41.3 ± 20.52	40.96 ± 19.1	40.39 ± 21.07	1.00
LF (nu)	58.65 ± 21.44	58.36 ± 20.62	58.88 ± 19.13	56.92 ± 20.94	0.99
LF/HF	2.46 ± 2.29	2.36 ± 2.83	2.10 ± 1.67	2.40 ± 2.24	0.95

Data are presented as mean ± standard deviation.
HF = high frequency; LF = low frequency; LF/HF = low frequency/high frequency ratio; pNN50 = percentage of adjacent RR intervals with a difference of duration >50 ms; RMSSD = root-mean square of differences between adjacent normal RR intervals in a time interval; SDNN = standard deviation of normal-to-normal RR intervals.
[a] Different from control.

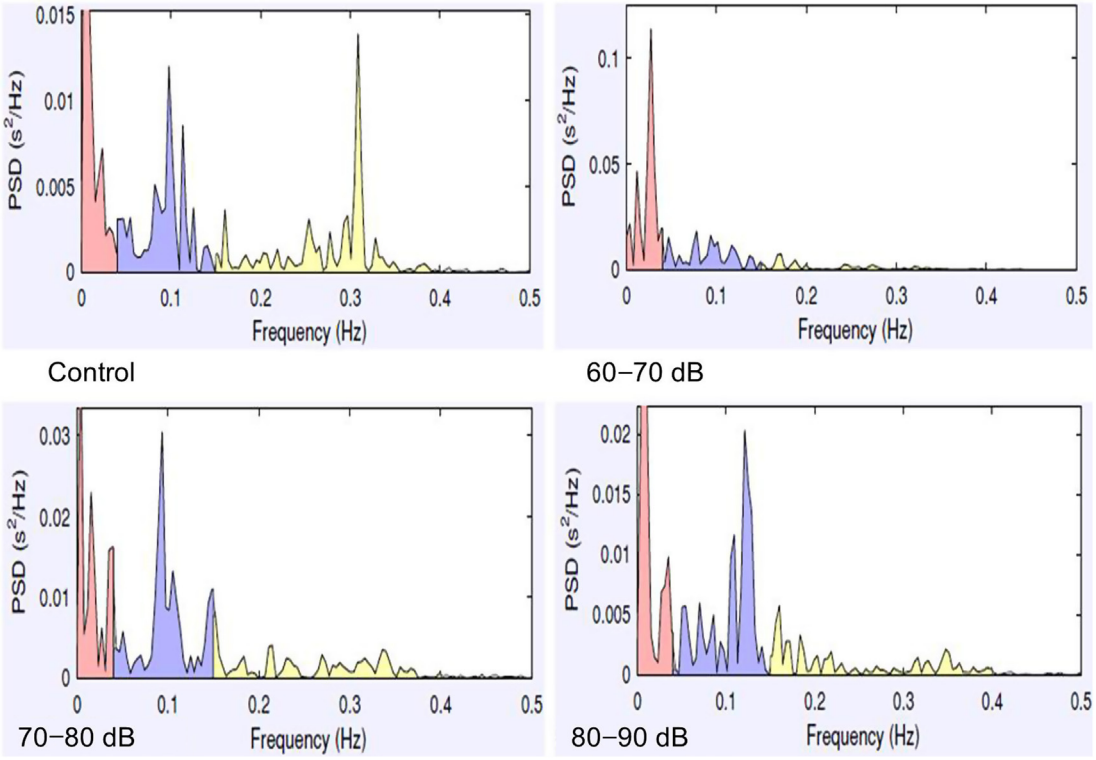


Fig. 2. Power spectrum density (PSD) analysis observed in one volunteer before exposure to baroque musical auditory stimulation, during music exposure between 60 and 70 dB, during music exposure between 70 and 80 dB, and during music exposure between 80 and 90 dB.

exposed to a relaxant music ("Träumerei" from Kinderszenen Op.15-7, R. Schumann) and an increase in gastric vagal nerve activity was observed.[17] Another study by the same group found that the same music reduced sympathetic nerve activity and arterial blood pressure in anesthetized rats and elucidated that some but not all music can induce the same responses. This mechanism was further investigated and the authors observed that this effect depends on the intact auditory cortex and cochleae.[18] The Pachelbel

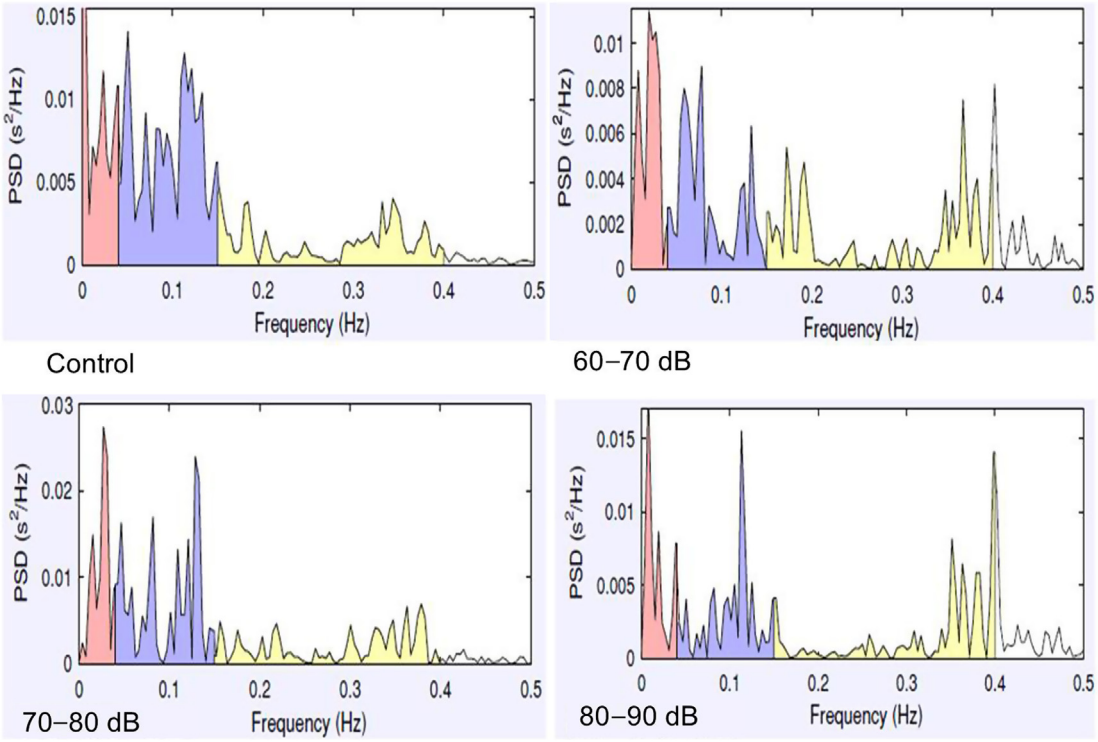


Fig. 3. Power spectrum density (PSD) analysis observed in one volunteer before exposure to heavy-metal musical auditory stimulation, during music exposure between 60 and 70 dB, during music exposure between 70 and 80 dB, and during music exposure between 80 and 90 dB.

Canon in D music is not considered sedative. In this sense, we suggest that we reported acute reduction of HRV in individuals exposed to music with absence of relaxant rhythm.

According to our findings, heavy-metal musical auditory stimulation reduced global modulation of HR at the highest intensity (80–90 dB). The music used in our investigation was also reported to reduce HRV in healthy women.[14] Another previous study similarly showed that healthy women had increased psychological responses to auditory stimulation with another heavy-metal music.[19] The cardiac autonomic responses observed in our study are suggested to be due to the excitatory feature of the heavy-metal music style. We believe that the excitatory profile of heavy-metal music associated with the high-equivalent sound level was responsible for acutely decreasing HRV. Cardiac autonomic responses were instantaneously elicited by low-intensity (50 dBA) white noise.

Lee et al[8] observed a significant interaction between the cardiac sympathetic modulation and white noise intensity—the higher the white noise intensity the higher the LF/HF ratio and the lower the HRV. The association between noise intensity and activity of autonomic nervous system is based on the acoustic startle reflex. This reflex is a sudden response of arterial blood pressure and HR induced by an unexpected loud auditory stimulation.[20] This reflex can cause an immediate inhibition of muscle sympathetic nerve activity, and the magnitude of the arterial blood pressure reaction is inversely associated with the intensity of early muscle sympathetic nerve activity inhibition.[21] Taken together, we may surmise that the reduced HRV elicited by high-intensity heavy-metal music was elicited by an autonomic response involved in the acoustic startle reflex.

Our results showed that musical auditory stimulation with baroque and heavy-metal styles between 60 and 70 dB decreased global modulation of HR in healthy women. This data is supported by the study results of Lee et al,[8] who observed that cardiac autonomic responses induced by binaural exposure to white noise above 50 dB continuously for 5 minutes decreased HRV. In another study, healthy women were exposed to white noise at 90 dB and they were reported to have reduced parasympathetic regulation of HR and no significant changes in the sympathovagal balance through analysis of the LF/HF ratio.[14] It is worth mentioning the difference between baroque or excitatory heavy-metal musical stimulation and white noise. Music has a high range of intensity, whereas white noise is characterized by a small range in its equivalent sound level.[22] Furthermore, white noise has no significant effect on the cognitive system, whereas musical auditory stimulation affects emotions and memory,[23,24] which in turn is related to cardiac autonomic regulation.[25] In this circumstance, we suggest that the cardiac parasympathetic and sympathetic responses depend on the style of acoustic stimulation.

Based on our data, there was a relationship between the music intensity and the overall variability of HR, because we found reduced HRV during acute exposure to baroque and heavy-metal musical auditory stimulation between 60 and 70 dB, and in addition, heavy metal decreased HRV between 80 and 90 dB, whereas no significant responses were noted when both music styles were played between 70 and 80 dB. To avoid the effect of music intensity sequence on HRV responses, the order of music intensity was randomized to each volunteer. In this context, we discarded the influence of this mechanism on cardiac autonomic responses induced by musical auditory stimulation. However, it does not rule out the influence of habituation. Indeed, Iwanaga et al[26] evaluated HRV during exposure to repetitive musical auditory stimulation with excitatory and sedative music. The authors observed that in the second session of music exposure, the LF index in normalized units and the LF/HF ratio increased, whereas no significant change in the HF index was observed, indicating that HRV reduced after repetitive exposure to music. In this regard, we believe that the habituation of cardiac autonomic responses may have influenced our findings.

The cardiac autonomic responses found in our investigation are supported by previous studies that showed physiological

mechanisms to explain it. The brain and brain stem process auditory[27] and cardiovascular information.[28,29] Histaminergic H3 receptors in the suprachiasmatic nucleus of the hypothalamus were also reported to be involved in sympathetic and parasympathetic responses induced by relaxant music.[18] Musicians were exposed to self-selected piece of music that induced intense pleasant emotional responses and increases in regional cerebral blood flow in the left ventral striatum and dorsomedial midbrain and reductions in the right amygdala and left hippocampus/amygdala, suggesting that music recruits neural mechanisms of recompense.[24,30] In addition, a recent study reported that dopamine release in the right caudate and the right nucleus accumbens, brain areas related to reward mechanisms,[31] increased during exposure to self-selected pleasurable music.[32] In this circumstance, an important question to be raised is the style of music used by the authors because each study used different music. Thus, we must be careful when interpreting data.

To avoid sex-dependent effects on cardiac autonomic responses elicited by music, we investigated only women in this study. The literature reported contradictory data regarding cardiovascular and physiological responses between men and women. Cardiac autonomic responses induced by auditory stimulation were suggested to be dependent on sex regarding experience and emotional expression.[33] Women were observed to have more intense stressful responses induced by auditory stimulation compared with men. It was also indicated that sex-based differences in psychophysiological responses to auditory stimulation are strongly influenced by hormonal status.[19] Nonetheless, there is a lack of this information in the literature studies that investigated differences between women and men concerning the cardiac autonomic responses to musical auditory stimulation. Furthermore, the menstrual cycle was also indicated to affect baseline nonlinear properties of HRV.[34] To exclude the interference of the follicular and luteal phases of the menstrual cycle on cardiac autonomic regulation, we did not evaluate volunteers on 10–15 days and 20–25 days after the 1st day of the menstrual cycle.

5. Conclusion

Auditory stimulation with baroque and heavy-metal music styles at lower intensities acutely decreased global modulation of HR, whereas only heavy metal reduced HRV at higher intensities. We suggest that the equivalent sound level range in the music selected in our study presents significant effect on cardiac autonomic regulation.

Conflicts of interest

All contributing authors declare no conflicts of interest.

References

1. Phipps MA, Carroll DL, Tsiantoulas A. Music as a therapeutic intervention on an inpatient neuroscience unit. *Complement Ther Clin Pract*. 2010;16:138–142.
2. Lin LC, Lee MW, Wei RC, Mok HK, Yang RC. Mozart K.448 listening decreased seizure recurrence and epileptiform discharges in children with first unprovoked seizures: a randomized controlled study. *BMC Complement Altern Med*. 2014;14:17.
3. Chuang CY, Han WR, Li PC, Young ST. Effects of music therapy on subjective sensations and heart rate variability in treated cancer survivors: a pilot study. *Complement Ther Med*. 2010;18:224–226.
4. Valenti VE, Guida HL, Frizzo AC, Cardoso AC, Vanderlei LC, Abreu LC. Auditory stimulation and cardiac autonomic regulation. *Clinics (Sao Paulo)*. 2012;67:955–958.
5. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation*. 1996;93:1043–1065.
6. Vanderlei LC, Pastre CM, Hoshi RA, Carvalho TD, Godoy MF. Basic notions of heart rate variability and its clinical applicability. *Rev Bras Cir Cardiovasc*. 2009;24:205–217.
7. Okada K, Kurita A, Takase B, et al. Effects of music therapy on autonomic nervous system activity, incidence of heart failure events, and plasma cytokine and catecholamine levels in elderly patients with cerebrovascular disease and dementia. *Int Heart J*. 2009;50:95–110.
8. Lee GS, Chen ML, Wang GY. Evoked response of heart rate variability using short-duration white noise. *Auton Neurosci*. 2010;155:94–97.
9. de Castro BC, Guida HL, Roque AL, et al. Previous exposure to musical auditory stimulation immediately influences the cardiac autonomic responses to the postural change maneuver in women. *Int Arch Med*. 2013;6:32.
10. Corrêa PR, Catai AM, Takakura IT, Machado MN, Godoy MF. Heart rate variability and pulmonary infections after myocardial revascularization. *Arq Bras Cardiol*. 2010;95:448–456 [Article in Multiple languages].
11. Tarvainen MP, Niskanen J-P, Lipponen JA, Ranta-aho PO, Karjalainen PA. Kubios HRV – A software for advanced heart rate variability analysis. In: van der Sloten J, Verdonck P, Nyssen M, Haueisen J, eds. *4th European Conference of the International Federation for Medical and Biological Engineering*. Berlin, Germany: Springer; 2008:1022–1025.
12. Valenti VE, Guida HL, Monteiro CBM, et al. Relationship between cardiac autonomic regulation and auditory mechanisms: importance for growth and development. *J Hum Growth Dev*. 2013;23:94–98.
13. Abreu LC. Heart rate variability as a functional marker of development. *J Hum Growth Dev*. 2012;22:279–281.
14. Roque AL, Valenti VE, Guida HL, et al. The effects of different styles of musical auditory stimulation on cardiac autonomic regulation in healthy women. *Noise Health*. 2013;15:281–287.
15. Roque AL, Valenti VE, Guida HL, et al. The effects of auditory stimulation with music on heart rate variability in healthy women. *Clinics (Sao Paulo)*. 2013;68:960–967.
16. Welter KJ. *Johann Pachelbel: Organist, Teacher, Composer, A Critical Reexamination of His Life, Works, and Historical Significance* [dissertation]. Cambridge, MA: Harvard University; 1998.
17. Nakamura T, Tanida M, Niijima A, Nagai K. Effect of auditory stimulation on parasympathetic nerve activity in urethane-anesthetized rats. *In Vivo*. 2009;23:415–419.
18. Nakamura T, Tanida M, Niijima A, Hibino H, Shen J, Nagai K. Auditory stimulation affects renal sympathetic nerve activity and blood pressure in rats. *Neurosci Lett*. 2007;416:107–112.
19. Nater UM, Abbruzzese E, Krebs M, Ehlert U. Sex differences in emotional and psychophysiological responses to musical stimuli. *Int J Psychophysiol*. 2006;62:300–308.
20. Turpin G, Siddle DA. Cardiac and forearm plethysmographic responses to high intensity auditory stimulation. *Biol Psychol*. 1978;6:267–281.
21. Eder DN, Elam M, Wallin BG. Sympathetic nerve and cardiovascular responses to auditory startle and prepulse inhibition. *Int J Psychophysiol*. 2009;71:149–155.
22. Daee S, Wilding JM. Effects of high intensity white noise on short-term memory for position in a list and sequence. *Br J Psychol*. 1977;68:335–349.
23. Burns JL, Labbé E, Arke B, et al. The effects of different types of music on perceived and physiological measures of stress. *J Music Ther*. 2002;39:101–116.
24. Blood AJ, Zatorre RJ. Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proc Natl Acad Sci USA*. 2001;98:11818–11823.
25. Zeki Al Hazzouri A, Haan MN, Deng Y, Neuhaus J, Yaffe K. Reduced heart rate variability is associated with worse cognitive performance in elderly Mexican Americans. *Hypertension*. 2014;63:181–187.
26. Iwanaga M, Kobayashi A, Kawasaki C. Heart rate variability with repetitive exposure to music. *Biol Psychol*. 2005;70:61–66.
27. Schecklmann M, Landgrebe M, Kleinjung T, et al. State- and trait-related alterations of motor cortex excitability in tinnitus patients. *PLoS One*. 2014;9:e85015.
28. Valenti VE, Abreu LC, Sato MA, Ferreira CATZ. (3-amino-1,2,4-triazole) injected into the fourth cerebral ventricle influences the Bezold-Jarisch reflex in conscious rats. *Clinics (Sao Paulo)*. 2010;65:1339–1343.
29. Valenti VE, De Abreu LC, Sato MA, Fonseca FL, Riera AR, Ferreira C. Catalase inhibition into the fourth cerebral ventricle affects bradycardic parasympathetic response to increase in arterial pressure without changing the baroreflex. *J Integr Neurosci*. 2011;10:1–14.
30. Salimpoor VN, van den Bosch I, Kovacevic N, McIntosh AR, Dagher A, Zatorre RJ. Interactions between the nucleus accumbens and auditory cortices predict music reward value. *Science*. 2013;340:216–219.
31. Leite-Morris KA, Kobrin KL, Guy MD, Young AJ, Heinrichs SC, Kaplan GB. Extinction of opiate reward reduces dendritic arborization and c-Fos expression in the nucleus accumbens core. *Behav Brain Res*. 2014;263:51–59.
32. Salimpoor VN, Benovoy M, Larcher K, Dagher A, Zatorre RJ. Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nat Neurosci*. 2011;14:257–262.
33. Kring AM, Gordon AH. Sex differences in emotion: expression, experience, and physiology. *J Pers Soc Psychol*. 1998;74:686–703.
34. Bai X, Li J, Zhou L, Li X. Influence of the menstrual cycle on nonlinear properties of heart rate variability in young women. *Am J Physiol Heart Circ Physiol*. 2009;297:H765–H774.