Cardiac autonomic responses induced by auditory stimulation with music is influenced by affinity

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INTRODUCTION: We aimed to evaluate the effects of musical auditory stimulation on cardiac autonomic regulation in subjects who enjoy and who do not enjoy the music.

METHOD: The study was performed in young women (18-27 years old) divided in two groups (1) volunteers who enjoyed the music and (2) volunteers who did not enjoy the music. Linear indices of heart rate variability were analyzed in the time domain. The subjects were exposed to a musical piece (Pachelbel: Canon in D Major) during 10 minutes. Heart rate variability was analyzed at rest with no music and during musical auditory stimulation.

RESULTS: In the group that enjoyed the music the standard deviation of normal-to-normal R-R intervals (SDNN) was significantly reduced during exposure to musical auditory stimulation. We found no significant changes for the other linear indices. The group composed of women who did not enjoy the music did not present significant cardiac autonomic responses during exposure to musical auditory stimulation.

CONCLUSION: Women who enjoyed the music presented a significant cardiac autonomic response consisting of a reduction in heart rate variability induced by the musical auditory stimulation. Those who did not enjoy the musical piece presented no such response.

KEYWORDS: Hearing; Autonomic nervous system; Cardiovascular physiology.

■ INTRODUCTION

Auditory stimulation with music evokes particular emotional states. These emotional states are associated with brain and autonomic nervous system activity. However, the relationship between musical and autonomic features is far from being completely understood[1]. Musical auditory stimulation presents an extensive variety of psychological and hemodynamic effects through modulating the cardiac autonomic modulation[2,3].

In this context, heart rate variability (HRV) is a method that analyzes the oscillations of intervals between consecutive heartbeats (R-R intervals), and is a well-accepted procedure to investigate cardiac autonomic regulation. This mechanism is influenced by the sinoatrial node[4]; reductions in HRV are an indicator of poor cardiovascular function, such as in the case of chronic heart failure. In contrast, the increase in HRV corresponds to an improvement of cardiovascular function[5].

Previous studies from our group observed that musical auditory stimulation with a specific baroque musical piece (Pachelbel-Canon in D) acutely reduced HRV[6,7]. Other studies from our group did not report significant effects of the same musical piece[8,9]. However, this was found in subjects who had no affinity for that musical piece. In addition, published reports indicate that some effects of music on physiological responses are dependent on the affinity for the particular music piece to which subjects are exposed[10]. Thus, in order to clarify this issue, we aimed to evaluate the effects of musical auditory stimulation on women with affinity or with no affinity for a specific tune.

■ METHOD

Study Population

Subjects were 22 healthy female students, all nonsmokers, aged between 18 and 27 years old and divided into two groups: 1) Group composed of women who enjoyed the music and 2) Group composed of women who did not enjoy the music. 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 of Marilia
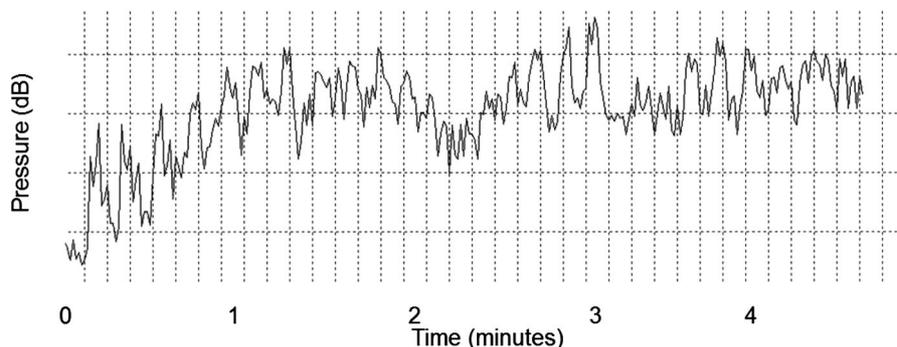
Figure 1 - Equivalent sound level of auditory musical stimulation in the baroque style.

(No. CEP-2011-385), and were in accordance with Resolution 196/96 National Health 10/10/1996.

Non-inclusion criteria

We did not evaluate subjects with the following conditions: cardiopulmonary or auditory disorders, psychological or neurological-related disorders and other impairments that would have prevented the subject from performing the procedures. Subjects undergoing treatment with drugs that influence cardiac autonomic regulation were also excluded.

Initial Evaluation

Prior to the study, baseline criteria included: age, gender, weight, height and body mass index (BMI). Weight was determined using a digital scale (W 200/5, Welmy, Brazil) with a precision of 0.1 kg. Height was determined using a stadiometer (ES 2020, Sanny, Brazil) with a precision of 0.1 cm and 2.20 m of extension. Body mass index (BMI) was calculated as weight (m)/height^2 (kg).

Measurement of the auditory stimulation

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

Measurements were made during the 10-minute sessions of relaxing classical baroque music. An insert-type microphone (MIRE-Microphone In Real Ear) was placed inside the auditory canal of the subject, 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 plc).

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 (Fig. 1). We also analyzed the frequency spectrum of the sound stimulation (octave band), as shown in Fig. 2[11].

HRV analysis

The R-R intervals recorded by the portable RS800CX heart rate (HR) monitor (with a sampling rate of 1000 Hz) were downloaded to the Polar Precision Performance program (v. 3.0, Polar Electro, Finland). The software enabled the visualization of HR and the extraction of a cardiac period (R-R interval) file in "txt" format. Following digital filtering complemented with manual filtering for the elimination of premature ectopic beats and artifacts, at least 256 R–R intervals were used for the data analysis. Only series with more than 95% sinus rhythm were included in the study[4]. For calculation of the linear indices we used the HRV Analysis
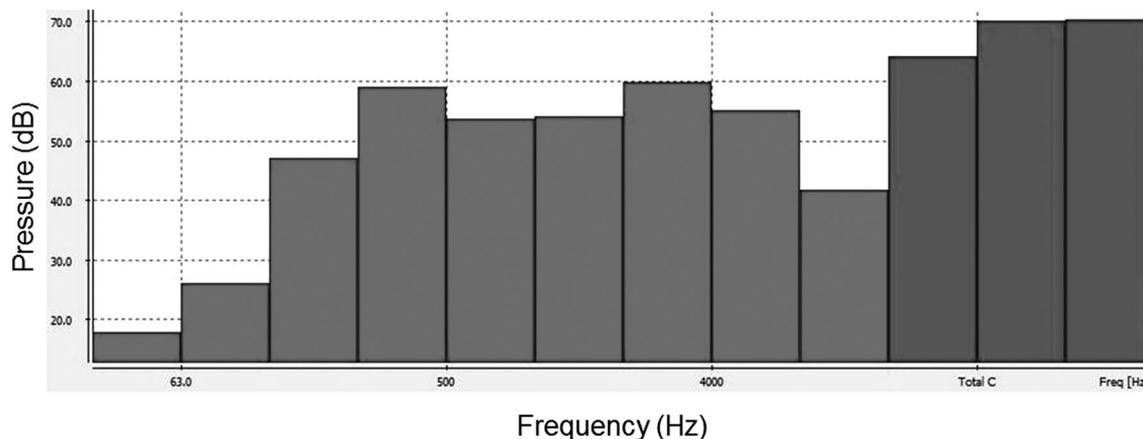

Figure 2 - Spectral sound stimulation analysis.

software (Kubios HRV v.1.1 for Windows, Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland).

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 used in ms^2 and normalized units (nu), representing a value relative to each spectral component in relation to the total power minus the very low frequency (VLF) components, and the ratio between these components (LF/HF). The spectral analysis was calculated using the Fast Fourier Transform algorithm.

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

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

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%. Participants were instructed not to drink alcohol or consume caffeine for 24 hours before evaluation. Data were collected on an individual basis, between 6 PM and 9 PM to standardize the protocol. All procedures necessary for the data collection were explained on an individual basis and the subjects were instructed to remain at rest and avoid talking during the 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 heart rate receiver (Polar Electro®, Finland) was placed on the wrist. The subjects (eyes opened) wore headphones and were instructed to avoid tapping with a finger or a foot, to avoid artifactual entrainment; this was checked by continuous visual monitoring.

The measured variables were compared between the following moments: 1) rest control with the earphones off and; 2) exposure to musical auditory stimulation with selected classical baroque music (Pachelbel: "Canon" in D Major performed by an orchestra).

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 value of >1.0). For parametric distributions we applied paired student t-test and for non-parametric distributions we applied the paired Wilcoxon 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.

■ RESULTS

Data on baseline systolic and diastolic arterial pressure, heart rate and mean R-R interval, age, height, body weight and body mass index are presented in Table 1.

Regarding the time domain indices of HRV, we noted that the SDNN index was reduced during exposure to auditory stimulation in the group that enjoyed the music, whereas no significant change was observed in the RMSSD and pNN50 indices, as shown in Table 2.

On the other hand, in the group that did not enjoy the music we did not find significant responses for any of the HRV indices (SDNN, RMSSD and pNN50) during musical auditory stimulation. These results are displayed in Table 3.

■ DISCUSSION

HRV analysis was proposed as a critical index for the assessment of the effect of music[12]. It has been demonstrated that the physiological response to relaxant and excitatory music was compared in a stationary condition, in the same way as performed in our study. The investigation of musical auditory stimulation as a non-pharmacological therapy has been proposed[2], because some styles of music influence the cardiovascular and autonomic nervous systems[3]. The acute effect of music on cardiac autonomic regulation is important to provide further information regarding the physiological responses induced by this stimulus. In this context, we

Table 1 - Baseline diastolic (DAP) and systolic arterial pressure (SAP), heart rate (HR), mean R-R interval (Mean R-R), weight, height and body mass index (BMI) of the two groups.

Variable	Affinity	No affinity
SAP (mmHg)	103.82 ± 6.69	102.47 ± 6.17
DAP (mmHg)	68.47 ± 6.61	68.42 ± 5.43
Height (m)	1.62 ± 0.06	1.61 ± 0.05
Weight (kg)	56.22 ± 9.58	54.07 ± 8.59
BMI (kg/cm²)	20.66 ± 2.82	19.92 ± 2.59

m: meters, kg: kilograms, bpm: beats per minute, ms: milliseconds, mmHg: millimeters of mercury.

Table 2 - Time domain indices of HRV before and after exposure to auditory stimulation with music in the group who enjoyed the music.

Index	Rest	Music	p
SDNN	54.25 ± 12.29	45.63 ± 10.29	0.04
RMSSD	21.86 ± 12.96	20.94 ± 13.97	0.42
pNN50	40.50 ± 11.15	38.70 ± 12.57	0.35

SDNN: standard deviation of normal-to-normal R-R intervals, pNN50: percentage of adjacent R-R intervals with a difference of duration greater than 50 ms, RMSSD: root-mean square of differences between adjacent normal R-R intervals in a time interval.

Table 3 - Time domain indices of HRV before and after exposure to auditory stimulation with music in the group who did not enjoy the music.

Index	Rest	Music	p
SDNN	47.77 ± 10.19	46.14 ± 11.47	0.37
RMSSD	14.45 ± 15.77	13.65 ± 15.33	0.43
pNN50	34.80 ± 16.43	33.55 ± 14.43	0.40

SDNN: standard deviation of normal-to-normal R-R intervals, pNN50: percentage of adjacent R-R intervals with a difference of duration greater than 50 ms, RMSSD: root-mean square of differences between adjacent normal R-R intervals in a time interval.

aimed to evaluate the acute effect of music on subjects who enjoy and those who do not enjoy a selected musical piece. We report that subjects that enjoyed the presented tune exhibit reduced global modulation of heart rate, while participants who did not enjoy the music did not present significant changes in HRV.

In our study we selected the baroque musical piece Canon in D Major by Johann Pachelbel (1653-1706). Pachelbel was a German composer of Protestant church music. This is music that associates the techniques of canon and ground bass. Canon is a polyphonic device in which several voices play the same theme, entering in sequence[13]. In this sense, previous investigations in animals reported significant effects of different types of music on the autonomic nervous system. Rats under urethane anesthesia were exposed to a relaxant music ("Träumerei" from Kinderszenen Op.15-7, R. Schumann) and an increase in gastric vagal nerve activity was observed[14]. The same group reported that this musical piece decreased sympathetic nerve activity and arterial blood pressure in anesthetized rats and found that some but not all music can induce the same responses. This was further investigated and the authors observed that this effect depends on intact auditory cortex and cochleae[15]. The Pachelbel Canon in D Major is not considered as sedative. In this circumstance, we suggest that the acute reduction of HRV during exposure to that selected music is due to its absence of a relaxant rhythm.

As our main finding, we observed that subjects with affinity for the selected music presented significant cardiac autonomic responses during exposure to the Pachelbel music; in contrast, subjects with no affinity showed no alteration. Higher differences in autonomic responses between pleasant and rest conditions during exposure to musical auditory stimulation were previously noted[10]. The authors proposed that the difference is probably due to the different emotional valence of the two kinds of stimuli (unpleasant vs. pleasant). The same study found that unpleasant music and a sequence of Shepard tones (i.e., sound sequences consisting of a superposition of sine waves separated by octaves) were observed to induce no significant reaction; the volunteers in the mentioned study did not discriminate pleasant vs. unpleasant musical auditory stimulation. Our study did not evaluate pleasant vs. unpleasant stimulus.

There are physiological mechanisms proposed to explain the cardiac autonomic responses observed in women during exposure to pleasant musical auditory stimulation. A recent study reported the first direct evidence that the intense pleasure experienced when listening to music is related to dopamine activity in the mesolimbic reward system, including both the dorsal and ventral striatum[16]. One explanation for this mechanism is that it is associated with the increase of emotions[17]. The emotions elicited by music are evoked by temporal phenomena, such as expectations, delay, tension, resolution, prediction, surprise and anticipation[18]. A temporal dissociation between distinct regions of the Striatum while listening to pleasurable music has been reported[16]. The combined psychophysiological, neurochemical and hemodynamic procedure used revealed that peaks of autonomic nervous system activity, which reflect the experience of the most intense emotional moments, are associated with dopamine release in the nucleus accumbens. In this context, it has been suggested that this area is activated in the euphoric component of psychostimulants,

such as cocaine[19], and is intensely connected with limbic regions that regulate emotional reaction, such as the hippocampus, amygdala, ventromedial prefrontal cortex and cingulate[20]. Conversely, there is support for moderately higher dopamine activity in the caudate immediately before the climax of emotional responses[20,21]. This subregion of the striatum is connected with the motor, associative and sensory regions of the brain and has typically been implicated in the learning of stimulus-response associations[20] and in controlling the reinforcing qualities of rewarding stimulation, such as food[21].

In order to avoid sex-dependent effects on cardiac autonomic responses elicited by music, we investigated only women. Published data contain contradictory information with respect to cardiovascular and physiological responses between men and women. Cardiac autonomic responses induced by auditory stimulation have been suggested to be dependent on gender regarding experience and emotional expression[22]. In contrast, women were reported to present more intense stress responses induced by auditory stimulation compared with men[23]. It has also been indicated that gender-based differences in psychophysiological responses to auditory stimulation are strongly influenced by hormonal status[23]. However, it should be stressed that few studies have investigated differences between women and men concerning the cardiac autonomic responses to musical auditory stimulation.

■ CONCLUSION

Auditory stimulation with music influences cardiac autonomic regulation with higher intensity in women who enjoyed the music, compared to those who did not.

■ RESUMO

INTRODUÇÃ: O objetivo foi avaliar os efeitos da estimulação auditiva musical sobre a regulação autonômica cardíaca em indivíduos que gostam ou que não gostam da peça musical utilizada.

MÉTODO: O estudo foi realizado em mulheres jovens (18-27 anos) divididas em dois grupos (1) voluntárias que gostavam da peça musical e, (2) voluntárias que não gostavam da peça musical. Índices lineares da variabilidade da frequência cardíaca foram analisados no domínio do tempo. Os indivíduos foram expostos a uma peça musical (Pachelbel: Canon in D major) durante 10 minutos. A variabilidade da frequência cardíaca foi analisada em repouso sem música e durante a estimulação auditiva musical.

RESULTADOS: No grupo que gostava da peça musical o desvio-padrão dos intervalos RR normais-a-normal (SDNN) foi significativamente reduzido durante a exposição à estimulação auditiva musical. Não foram encontradas alterações significativas para os outros índices lineares. O grupo composto por mulheres que não gostavam da música não apresentou respostas autonômicas cardíacas significativas durante a exposição à estimulação auditiva musical.

CONCLUSÃO: As mulheres que desfrutaram da música apresentaram resposta autonômica cardíaca significativa constituída por uma redução na variabilidade da frequência cardíaca induzida pela estimulação auditiva musical. Aqueles que não apreciavam a peça musical não apresentaram qualquer resposta autonômica.

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