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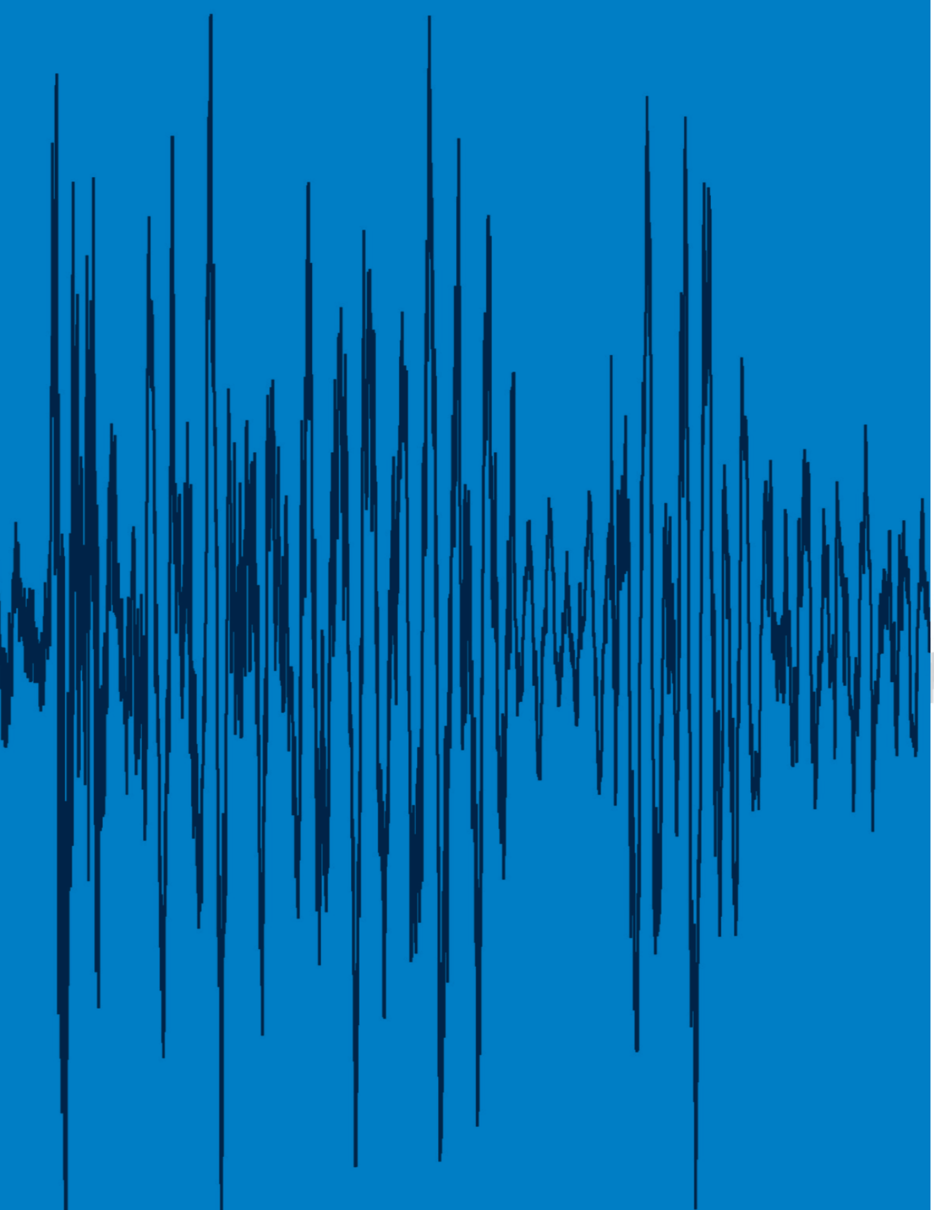

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Effects of different "relaxing" music styles on the autonomic nervous system

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Abstract

The objective of this study was to assess the effects on heart rate variability (HRV) of exposure to different styles of "relaxing" music. Autonomic responses to musical stimuli were correlated with subjective preferences regarding the relaxing properties of each music style. Linear and nonlinear HRV analysis was conducted in 25 healthy subjects exposed to silence or to classical, new age or romantic melodies in a random fashion. At the end of the study, subjects were asked to choose the melody that they would use to relax. The low-to-high-frequency ratio was significantly higher when subjects were exposed to "new age" music when compared with silence (3.4 ± 0.3 vs. 2.6 ± 0.3, respectively, $P < 0.02$), while no differences were found with "classical" or "romantic" melodies (2.1 ± 0.4 and 2.2 ± 0.3). These results were related to a reduction in the high frequency component with "new age" compared to silence (17.4 ± 1.9 vs. 23.1 ± 1.1, respectively $P < 0.004$). Significant differences across melodies were also found for nonlinear HRV indexes. Subjects' preferences did not correlate with autonomic responses to melodies. The results suggest that "new age" music induced a shift in HRV from higher to lower frequencies, independently on the music preference of the listener.

Keywords: *Autonomic nervous system, cognition, emotion, heart rate variability, music, music therapy*

Introduction

Music has been used with therapeutic purposes since ancient ages.[1-3] For example, one of the first reports of the therapeutic effect of music is found in the Bible: David played the harp to relieve King Saul's depressive state.[3] Furthermore, Romans and ancient Greeks played music in healing in spas.[1]

Music powerfully modulates socioemotional processes, cognitive status, and mood, thus contributing to the healing.[4] It has even been proposed that music may make people smarter![5] The term "Mozart effect" has been coined to reflect the proposed pleiotropic effect of music, which have not been entirely demonstrated.

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Music therapy employs specific musical elements such as sound, rhythm, melody, harmony, dynamic, and tempo to encourage or facilitate movement, positive interactions, and/or improved emotional or cognitive states.[1] A recent meta-analysis revealed that anxiety appears to be reduced by playing music in women undergoing colposcopy.[6] Similar results have been shown in patients undergoing different kind of surgical procedures,[7,8] in ventilated patients[9] and in cancer patients.[10] Positive effects of music on the motor parameters in patients affected by Parkinson's disease, Alzheimer's disease, multiple sclerosis, ataxia or spasticity, have also been observed.[2] Beneficial effects of music in mild asthma were suggested by an open-label comparative study.[11]

The biological effects of music leading to its therapeutic efficacy are not entirely known. In this study, we aimed at further studying some biological correlates of listening to music. The autonomic nervous system may serve as one path by which music exerts its therapeutic effect,[12] which can be explored by the assessment of heart rate variability (HRV).[13] Therefore, the objective of this study was to assess the effects on HRV of exposure to different styles of "relaxing" music in a sample of healthy subjects. Secondarily, we correlated autonomic responses to musical stimuli with subjective preferences regarding the relaxing properties of each music style.

Methods

Sample

Twenty-eight healthy subjects coming from a middle/high socioeconomic background were recruited for this study. Health was checked at the selection by a brief questionnaire. None of the subjects referred amusia, auditory disorders, or cardiovascular pathology. Institutional Review Board approval was obtained at the Brain Decision Braidot Center, and all subjects gave informed consent for participating in the study.

Procedures

Subjects were exposed sequentially to a silence period or to three melodies in a random fashion. Each session lasted 3½ min, with 1 min intervals in-between. Subjects remained comfortably seated during the whole examination. A standard CD player set up at a nondisturbing volume (50-60 dB) was used in all cases. An electrocardiogram (ECG) signal sampled at 225 Hz was recorded during the whole examination period using a digital Holter device (Holter HCAA 348, Servicios Computados S.A., Buenos Aires, Argentina).

Three styles of "relaxing" music were studied:

1. "Classical" music: An der schönen blauen Donau, Op. 314 (*The Blue Danube)*, Johann Strauss II (1866);
2. "New age" music: Only Time, Enya (2000);
3. "Romantic" music: El día que me quieras (*The day you will love me*), Carlos Gardel and Antonio Le Pera by Luis Miguel (1994).

They were considered as relaxing mainly because of the predominance of their slow to medium tempo (80-85 bpm), the predictability of their rhythm and clear musical form, according to a previous musicological analysis.[14] This analysis was performed by one of the co-authors, a music expert (JD). Its results will be mentioned in the results section.

At the end of the study, subjects were questioned about their preferences regarding the music pieces heard. They were asked to select which one of them they would choose to expend some relaxed time.

Heart rate variability analysis

Autonomic nervous system activity was assessed through HRV analysis. The analysis was performed on the ECG recording during exposure to "silence" or "classical," "new age" or "romantic" musical pieces. ECG signals were visually inspected to detect the presence of arrhythmias. The time elapsed between R waves (RR intervals) was computed and premature, and lost beats were replaced by RR intervals resulting from linear interpolation.[15]

Time domain HRV analysis included RRm (mean duration of RR intervals in millisecond), which quantifies the mean heart rate and standard deviation of RR intervals in millisecond, which represents a coarse quantification of overall variability.[15,16]

Frequency domain (spectral) measurement of HRV was obtained by Fast Fourier Transform, and included total spectral power (0-0.4 Hz, ms^2), very low frequency power ([VLF], below 0.04 Hz, ms^2), low frequency power ([LF], 0.04-0.15 Hz, ms^2), high frequency power ([HF], 0.15-0.4 Hz, ms^2) and their percentage values.[15] HF is related to respiratory sinus arrhythmia and mediated solely by parasympathetic activity, whereas LF is related to baroreflex control and depends upon sympathetic and parasympathetic mechanisms.[13] In the short term recordings, VLF rhythm is related with changes in mean heart rate,[15] and depends primarily on the presence of parasympathetic outflow.[17]

Nonlinear analyses of the RR interval time series included the scaling exponent $\alpha 1$ and approximate entropy (sample entropy [SampEn]).[18] The scaling exponent $\alpha 1$, based on the "detrended fluctuation analysis," quantifies the short-term (<11 beats) fractal correlation properties of the interbeat time data.[19] Fluctuations in any interbeat interval time series can be analyzed by comparing their behavior to various types of "noise" seen in dynamic systems.[18] The noisy signals produced by these systems have different statistical correlations that reveal important properties of their dynamics.[20] Values of $\alpha 1$ close to 0.5 are associated with white noise (no correlation between values), whereas values close to 1.5 are associated with Brownian noise (strong correlation between values). Values near one are characteristic of fractal-like processes associated with the dynamic behavior of time series generated by complex systems, such as the autonomic regulation of the sinus rhythm of a healthy subject.[20]

Sample entropy measures the regularity and complexity of the RR interval time series by taking the logarithm of the probability that patterns that are close to each other will remain close to each other in subsequent comparisons.[21] Regular sequences will result in lower SampEn values, whereas random behavior is associated with larger SampEn values.[18]

Statistical analysis

A power analysis revealed that 25 subjects would be enough to detect a 10% difference in HRV parameter between the groups with 80% power and 1% alpha error. A within-subject approach was used, assuming a standard deviation of 15% and a within-subject correlation of 0.6. In order to compensate for drop-outs we recruited 28 subjects.

Variables are described as means ± standard error of the mean (SE). A mixed-model analysis of variance (ANOVA) was used for statistical comparisons, using subject as a random within-subject factor and exposure to silence, classic, new age of romantic music as a fixed between-subjects factor. In this study, LF, HF, and LF/HF ratios were considered as co-primary outcomes. A Holms step-down procedure was employed to avoid alpha-error inflation that is, to maintain experiment-wise alpha error at 5%.[22]

All analyzes were performed with IBM SPSS 20.0 (New York, USA).

Results

Three subjects had to be excluded from the analysis as their ECG signals presented excessive noise, which prevented HRV analysis. Final sample was thus composed of 25 subjects of whom 40% were women. Mean ± SE of age, weight, height, and body mass index in the sample were 39.7 ± 2.0-year-old, 70.1 ± 3.3 kg, 1.72 ± 0.02 m, and 23.5 ± 0.8 kg/m^2, respectively.

Significant differences were found in the autonomic indexes derived from HRV analysis. As shown in Figure 1, the percentage of the high frequency component was significantly lower when subjects were listening to new age music, whereas no differences were found in the other indexes. Similarly, the LF/HF ratio was higher when subjects were listening to new age music [Figure 2]. Compared to silence, listening to new age music was associated with a 31% increase in the LF/HF ratio, whereas it was reduced by 19% or 14% when subjects were listening to classical or romantic music, respectively. Mean RR intervals and secondary linear HRV parameters were similar across groups [Table 1].

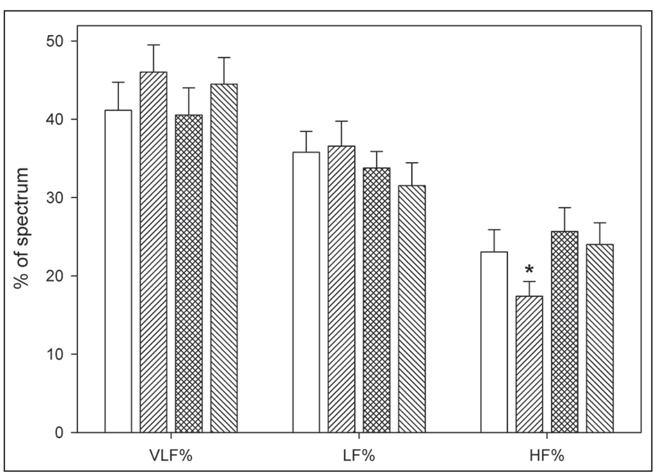

Figure 1: Linear heart rate variability co-primary outcomes when subjects were exposed to silence (), new age (), classical () or romantic () music. A mixed-effects analysis of variance model disclosed a significant between-group difference in the percentage of HF signal (P < 0.004), whereas no differences were detected in LF or VLF. Means and SE are shown. VLF = Percentage very low frequency power, LF = Percentage low frequency power, HF = Percentage high frequency power

When nonlinear HRV parameters were explored, α1 was found to be higher when subjects were listening to new age music, whereas SampEn was significantly lower in this group. In order to exclude a possible relationship between this indexes and the sympathetic activation, analyses were repeated, but using the LF/HF ratio as covariate. Results were no longer significant for α1 and border significant for SampEn [Figure 3].

When interrogated, 60% of subjects reported preferring new age music for relaxing, while 12% preferred classical music, 12% romantic music, 12% silence and 4% (one subject) was unable to make any choice. We then analyzed the HRV response to musical stimuli taking into consideration the preference of the subject. This was done by adding an extra fixed factor to the mixed-effects ANOVA model, representing subjects' choices. As shown in Table 2, no differences were detected in HF%, LF/HF ratio, α1 or SampEn when accounting for subjects' personal preferences.

Musicological analysis

All the music stiles herein employed have a musical structure that could be considered complex. They presented either constant harmony (Only time, The Blue Danube), a soft timbre (only time), a steady rhythm (The Blue Danube), or melodies with long notes and natural pauses (only time, The day you love me). Despite the tempo of the waltz is slow (85 bpm), it has rhythmic variations of a short note

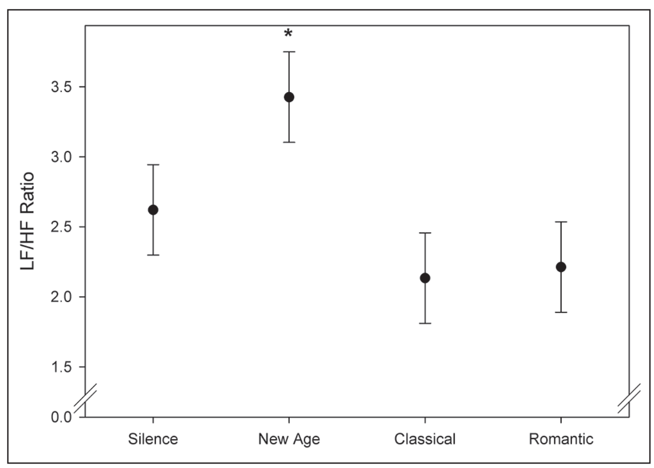

Figure 2: Means and SE of LF/HF signals ratio when subjects exposed to silence or different kind of "relaxing" musical themes. A mixed-effects analysis of variance model disclosed a significant between-group difference (P < 0.02). LF/HF, ratio between low frequency absolute power and high frequency absolute power3: Nonlinear heart rate variability outcomes when subjects were exposed to silence (), new age (), classical () or romantic () music, controlling for the LF/HF ratio. A mixed-effects analysis of variance model found no differences for α1 (P = 0.09) and a border significant difference in SampEn (P < 0.05). Means and SE are shown. LF/HF = Ratio between low frequency absolute power and high frequency absolute power, α1 = Scaling exponent α1, SampEn = Sample entropy

Table 1: Secondary linear heart rate variability parameters

Parameter	Silence		New age		Classical		Romantic		ANOVA
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	*P*-value
Mean RR	841.77	23.36	838.83	24.01	840.28	25.64	843.93	24.91	NS
SDNN	56.74	4.46	58.31	4.54	52.58	4.42	55.36	4.94	NS
TA ms^2	7.67	0.19	7.67	0.17	7.50	0.18	7.58	0.19	NS
VLF ms^2	6.66	0.20	6.82	0.15	6.47	0.19	6.69	0.20	NS
LF ms^2	6.57	0.22	6.56	0.22	6.36	0.19	6.32	0.22	NS
HF ms^2	5.98	0.25	5.74	0.22	5.94	0.24	5.96	0.23	NS

A mixed-effects ANOVA model was used to identify differences, but none were found. Mean RR = Mean of RR interval duration, SDNN = Standard deviation of RR intervals, TA = Total area power, VLF = Absolute very low frequency power, LF = Absolute low frequency power, HF = Absolute high frequency power, SEM = Standard error of the mean, RR = interval between two R waves at the ECG, ANOVA = Analysis of variance

Table 2: Selected linear and nonlinear heart rate variability parameters when accounting for subjects' personal preferences

Parameter	Exposure to the most relaxing music selected by each subject		*P* value
	No	Yes	
HF %	22.17±0.98	23.75±2.02	0.51
LF/HF ratio	2.69±0.02	2.27±0.40	0.37
α1	1.12±0.02	1.12±0.04	0.95
SampEn	1.64±0.02	1.55±0.05	0.15

Data were analyzed by adding subjective preference to the mixed-effects ANOVA model used for the principal analysis. HF % = Percentage high frequency power, LF/HF = Ratio between low frequency absolute power and high frequency absolute power, α1 = Scaling exponent α1, SampEn = Sample entropy, ANOVA = Analysis of variance

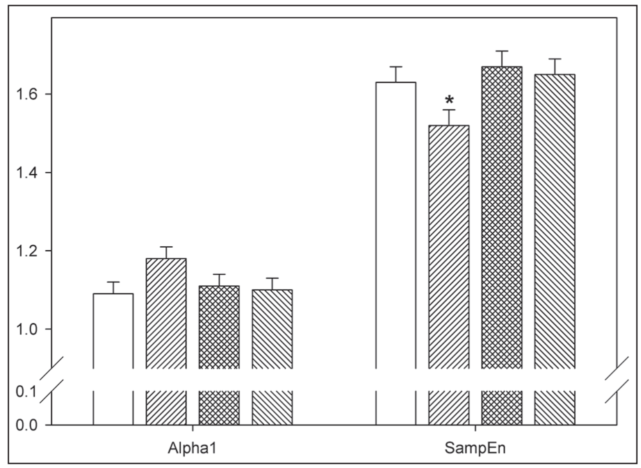

Figure 3: Nonlinear heart rate variability outcomes when subjects were exposed to silence (▬), new age (), classical (▬) or romantic (▬) music, controlling for the LF/HF ratio. A mixed-effects analysis of variance model found no differences for α1 (*P* = 0.09) and a border significant difference in SampEn (*P* < 0.05). Means and SE are shown. LF/HF = Ratio between low frequency absolute power and high frequency absolute power, α1 = Scaling exponent α1, SampEn = Sample entropy

and syncopation that make it looks lighter, almost with an invitation to dance. Furthermore, the waltz has a triple meter, whether duple or quadruple meter is usually associated with greater relaxation. Concerning the registration, in Luis Miguel's version of "El día que me quieras" the body is simple at the beginning; then the bolero seems to open, like releasing layers, expanding sonority. Even though, it has a slightly lower tempo than the others (80 bpm), is quite expansive, and has clear contrasts and accumulation, which inevitably creates tension. The battery only enters in the chorus (that is, it adds a new element) and from then on, it stays. Enya's case is clear: Slow pulse, square, and full of voices that make long notes, as accompanying a moderate andante. It never gets to explode, because there is insufficient accumulation. Interestingly, structure is defined and predictable; there is an accent (almost percussive) followed by a de-emphasized note that resembles a heartbeat, thus making explicit the tempo of 82 bpm.

Discussion

In this study, listening to "relaxing" music evoked significant autonomic responses as measured by HRV analysis. Notwithstanding, subjects did not react similarly to all musical styles. Indeed, when subjects listened to a "new age" style song a strong and statistically significant reduction of the HF spectral component and increased LF/HF ratio were noted. On the contrary, nonsignificant 15-20% reductions in LF/HF ratio were noticed when subjects listened to "classical" or "romantic" musical pieces. Similar results were found in nonlinear indexes of HRV. Interestingly, personal feelings and preferences regarding musical styles had no effects on autonomic responses.

Before considering the physiological and therapeutic meanings of our results, it should be noted that our study might have been underpowered for some outcomes. Indeed, 15-20% reductions in the LF/HF ratio with classical or romantic music were not statistically significant, but can be considered of physiological importance. Therefore, our work must be considered as preliminary, and further studies with larger samples are warranted. Furthermore, the selected compositions should be regarded only as examples for the addressed music styles, rather than representative of them. Therefore, caution is advised when extrapolating these results to other pieces from similar music styles.

The effects of music on HRV have been studied in the past. For example in one study, the LF increased during exposure to either "sedative" or "stimulating" music, whereas the HF component increased only with sedative music.[23] In another study, rock music and noise increased Mayer Waves (i.e., the LF component) which seems to be related to sympathetic activation.[24] Finally, mechanical sounds inhibited the parasympathetic nervous system and promoted feelings of unpleasantness and alertness.[25] Another study in healthy women showed that acute exposure to heavy metal music reduced sympathetic activity by 50%.[26] Our results confirm that listening to music may exerts part of their effects in the human body by influencing autonomic activity.

We also compared, for the first time, the effects of melodies with similar tempos, and thus considered a priori as equally "relaxing." A preliminary musicological analysis revealed significant differences between them other than their tempo. Tempo, accentuation, and rhythmic articulation are recognized as major determinants of physiological responses to music.[27] Notwithstanding, responses to "happy" and "sad" music as measured by blood pressure, electrodermal activity and zygomatic activity, require tonal variations and thus cannot be described solely by entrainment to tempo and rhythm.[28] Interestingly, subjects showed different patterns of autonomic activation to these melodies. Results are not easy to explain from a physiological perspective, but some hypotheses can be entertained. At first sight, increased LF/HF ratio observed after "new age" music can be regarded as a marker of sympathetic predominance as seen when passing from the supine to a standing position.[13] Nonetheless, the absence of changes in heart rate suggests that this is not a likely explanation. LF-over-HF predominance has also been observed during relaxation response to meditation derived from Chinese Chi, Yoga, and Zen traditions as well as from rosary prayer.[29-33] In subjects during meditation, when slow breathing patterns are achieved, a shift of power to the LF band appears to correlate with changes in respiratory sinus arrhythmia frequency, a physiologic parameter conventionally associated with vagal modulation.[30,34,35] In this context, increased LF/HF ratio observed during Enya's Only time might reflect changes in the breathing pattern causing parallel modulation of respiratory sinus arrhythmia (i.e., cardiorespiratory coupling) and not with increased sympathetic activity.

Interestingly, autonomic responses were stereotyped and not related to subjects' preferences, which rules out potential effects of emotional processing. Although this result contradicts a recent report demonstrating substantial coherence between emotional states and autonomic variables during music emotion-inducing music,[36] it goes in line with the notion that autonomic nervous system responses are stimulus-specific rather than individual-specific.[37]

In summary, different profiles of autonomic activity were observed in this study in connection with the type of music to which subjects were exposed. On one hand, these results indicate that music exerts some of its biological effect by influencing the autonomic system. On the other hand, different styles of music showed particular profiles of autonomic responses, pointing out the need to explore the effects of different music styles on the brain and body before they can be proposed as an effective music therapy.

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