Puzzling Music

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BIOL 3550_L01 - Human Physiology 2

March 30th, 2022

Abstract

Music has been around for hundreds of years and can be found in most human cultures. Some studies have investigated the influence music has on the autonomic nervous system as well as its therapeutic applications for the treatment of disorders. The intent of this study was to determine the cardiac autonomic effects of different music genres and whether they are altered when stress is added. The study was performed on 10 participants between the ages of 17 and 30 years. In trial 1, volunteers were exposed to a control, classical, heavy rock, rap and pop music for 3 minutes through noise-canceling headphones. In trial 2, the experiment was conducted in the same way with the addition of a puzzle. We analyzed average heart rates for each condition and heart rate variability analysis was performed on the rest, control and rap conditions from trial 2. The major finding that emerged from trial 1 was that the average heart rate for the pop genre (79.11 ± 8.24 BPM) was significantly higher than that of the control (76.56 ± 9.03 BPM). Although heart rate did not significantly vary between the genres, the average heart rate during auditory stimulation did increase in comparison to the control. For trial 2, average heart rate between music genres showed a significant difference between the pop and control conditions. All other genres had a larger average heart rate compared to the control, but none were significant. Finally, HRV analysis indicated changes in heart rate variability between control, rest and rap.

Introduction

Music is an influential part of everyday life for most individuals. We listen to it in the shower, in the car, while exercising and for therapy. It is thought that music stabilizes emotion and decreases stress levels, and, therefore, has physiological influences (Yamashita et al. 2006). There have been many studies conducted to assess the effects that auditory stimulation with music has on various physiological responses. One study noticed changes in both the sympathetic and parasympathetic nervous system activity (Watanabe et al. 2017). The relationship that has been noticed was a decrease in sympathetic activity while parasympathetic activity increased (Watanabe et al. 2017).

Other researchers have found that an increased musical tempo has been linked to increases in heart rate and respiration (Watanabe et al. 2017). Additionally, varying the levels of intensity during different genres of music has shown insight into the effects of musical auditory stimulation on cardiac autonomic regulation (do Amaral et al. 2016). Evidence regarding auditory stimulation via white noise has also proven to induce cardiac autonomic responses (do Amaral et al. 2016).

There has also been a lot of curiosity associated with the impact of music on cognitive ability (Schellenberg 2005). Some results have found correlations between increased cognitive ability and music (Schellenberg 2005). Some experiments have focused on a particular music genre, such as classical music, and have seen similar results (Schellenberg 2005). When testing a classical music genre, one study compared two classical music pieces that had different tempos and found that the piece with the faster tempo had a higher cognitive response (Schellenberg 2005).

As students and young adults, we surround ourselves with music. It is interesting to observe the specific physiological responses we have when subjected to auditory stimulation and when under stress. Physiological responses like stress and anxiety have been known to activate the sympathetic-adrenal medullary system which regulates the body's flight or fight response (Knight and Rickard 2001). The intent of this study is to determine the cardiac autonomic effects of different music genres and whether they are altered when stress is added. Music may be able to provide a simple and effective method for relaxing, studying and reducing stress. For this study, the effects of different music genres were tested to assess whether there were any differences between having music or not. Additionally, the study assessed whether different music genres improved cognitive ability when participants were presented with a stressor in the form of a puzzle.

Methods and Materials

Ten participants between the ages of 17 to 30 years old, male and female, were asked to participate in the study. All participants had no previous history of heart conditions or auditory impairment. Participants were asked to attend two thirty-minute trials during which their heart rate was measured while listening to different music genres. Five music genres were chosen: control, classical, rock, pop, and rap. The control music genre was the absence of music while still wearing the noise-canceling Beat headphones. In both trials, participants were connected to the PowerLab hardware through electrodes placed on both clavicles and the left iliac crest. The positive electrode was placed on the left iliac crest, the negative electrode was connected to the right clavicle and the ground electrode was placed on the left clavicle. All areas connected to electrodes were scrubbed with NuPrep skin prep gel and wiped with an alcohol wipe.

In the first trial, the participants begin with one minute of rest before the first song was randomly played through a pair of noise-canceling Beat headphones and the heart rate was continuously measured through the LabChart Software. Participants sat facing away from the monitors throughout the experiment and the control genre was always played as the 3rd song. One minute of rest without music was recorded between all song genres. Each song genre was played for three minutes total.

The second trial was completed on a different day than the first trial. Participants were connected in the same manner as in the first trial with the same songs for each genre. In addition, a word search puzzle was added to the experiments. The participants were asked to complete five random word search puzzles while listening to the five music genres and their heart rates were continuously recorded through the LabChart Software. One minute of rest was recorded before and between the songs and puzzles. The song genres were played at random except for the

control which was still played as the 3rd song and the puzzle order was also randomized. The participants had three minutes to complete the puzzle while listening to the music genre.

To analyze the results, averages of the participant's heart rates were calculated and two-tailed t-tests were used in order to determine significant differences between music genres and control with a 95% confidence interval. Standard deviations for the average heart rates were also calculated. Heart rate variability was analyzed and the average HF values and LF/HF values were calculated using HRV analysis software to determine the results.

Results

Table 1. Average heart rate for individual participants during different genres of music.

	Average heart rates (beats per minute)					
Participant	Rest	Control	Classical	Rock	Rap	Pop
1	67.63	58.40	64.33	67.15	64.76	67.68
2	77.51	75.84	76.72	75.95	78.44	75.20
3	69.21	69.45	69.25	69.90	71.71	71.33
4	84.26	81.63	75.11	74.04	78.35	79.37
5	63.33	63.29	65.66	65.25	68.37	64.02
6	96.51	89.67	100.57	89.88	93.10	99.89
7	86.58	86.98	85.62	89.04	88.46	87.36
8	80.39	70.64	70.49	73.14	71.81	71.43
9	90.73	91.03	87.80	94.61	92.83	93.95
10	74.88	89.64	82.56	83.23	83.31	83.62
Mean:	79.00	76.56	77.71	78.22	79.11	79.39
Std. deviation:	± 8.69	± 9.03	± 9.14	± 8.77	± 8.24	± 9.46

Table 2. Average heart rate for individual participants during different genres of music when completing puzzles.

	Average heart rates (beats per minute)					
Participant	Rest	Control	Classical	Rock	Rap	Pop
1	68.22	75.00	76.35	76.61	79.82	76.54
2	88.90	81.11	78.86	86.72	79.72	84.68
3	75.06	70.18	72.87	72.79	72.01	77.50
4	63.99	69.58	61.63	66.20	66.11	76.92
5	61.00	68.63	65.36	66.19	72.45	68.01
6	98.97	91.82	98.33	93.45	93.49	103.80
7	72.77	68.26	74.62	69.45	69.50	68.94
8	76.25	70.06	70.84	77.17	71.27	71.65
9	93.89	93.61	100.95	95.62	94.48	95.05
10	64.00	68.66	71.32	72.31	71.01	73.53
Mean:	76.31	75.69	77.11	77.65	76.99	79.66
Std. deviation:	± 12.64	± 9.30	± 12.24	± 10.19	± 9.39	± 11.04

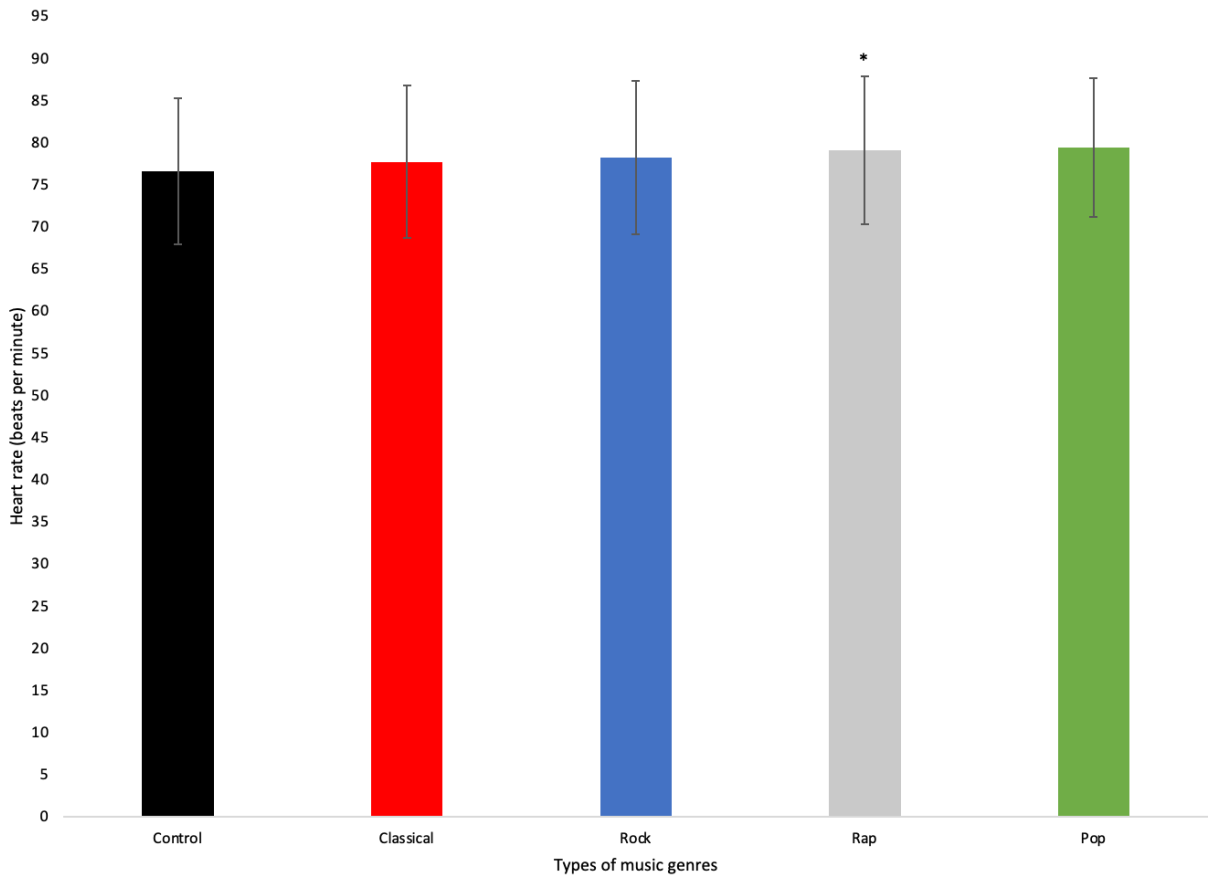

Figure 1. Comparison of average heart rate of individuals while listening to different music genres without a puzzle (n=10). The * indicates a significant ($p<0.05$) difference from the control.

Figure 1 shows that the average heart rate for the rap music genre was significantly higher (79.11 BPM) compared to the control (76.56 BPM). Heart rate increased during each music genre and it can be noted that the control had the lowest average heart rate.

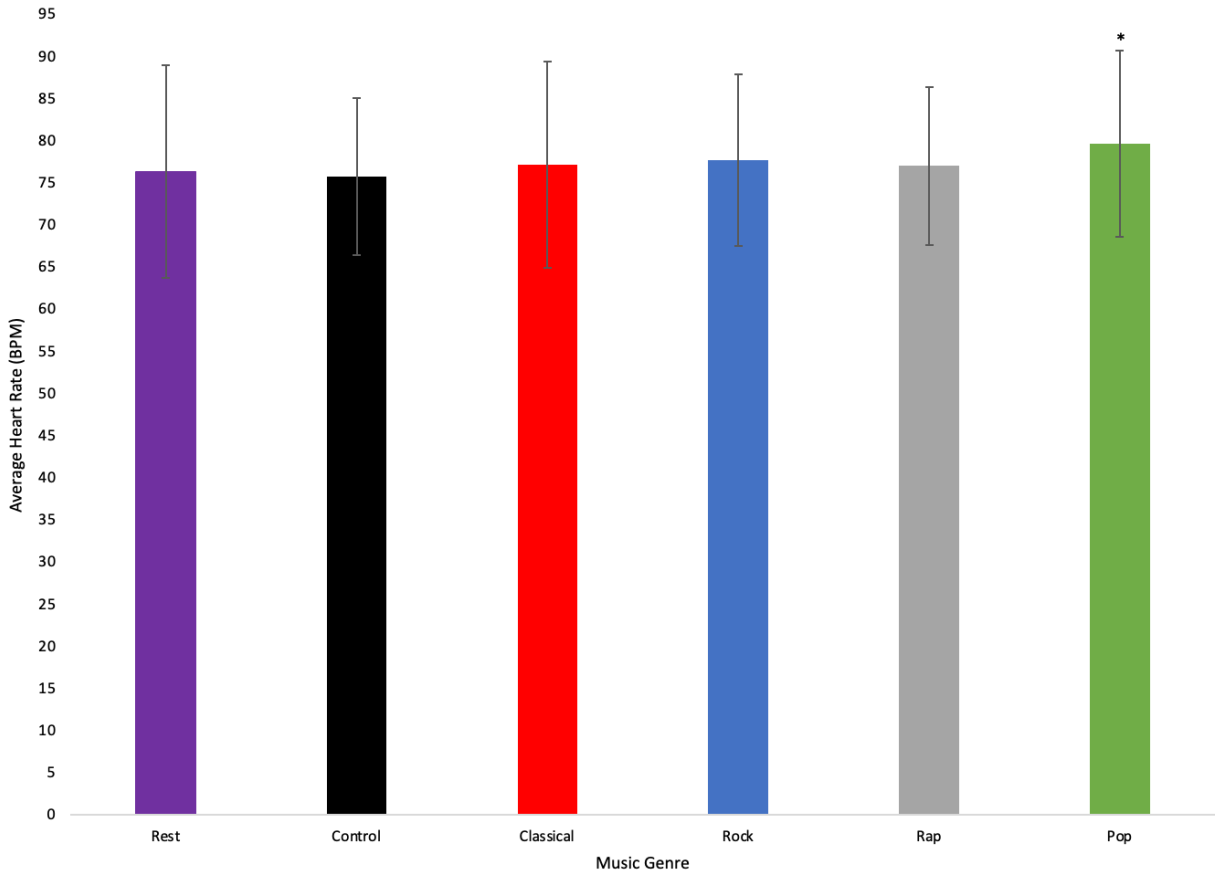

Figure 2. Comparison of average heart rate of individuals while listening to different music genres with a puzzle (n=10). The * indicates a significant ($p<0.05$) difference from the control.

Figure 2 shows that the average heart rate for the pop music genre was significantly higher (79.66 BPM) compared to the control (75.69 BPM). Heart rate stayed fairly constant between each music genre and the addition of the puzzle did not appear to affect heart rate (determined by comparing the rest condition to the control).

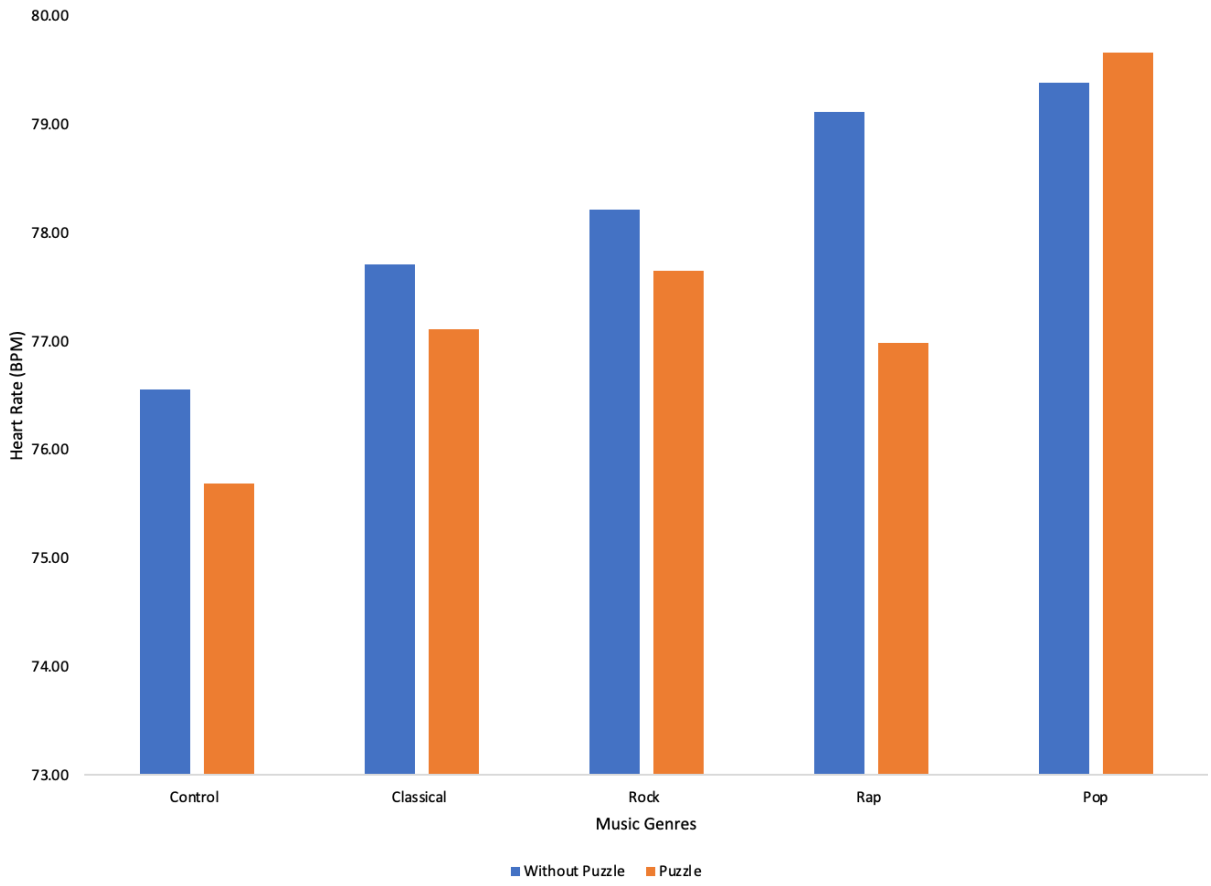

Figure 3. A comparison between the average heart rates of participants listening to different music genres for trials done without puzzles (Blue) and with puzzles (Orange) (n=10).

The average heart rate of the participants when listening to music genres with and without a puzzle was compared. Figure 3 shows that when the participants listened to the music genres without completing a puzzle, their average heart rate was higher than when a puzzle was completed. The only exception to this was seen in the pop genre.

Table 3. The HF and LF/HF values analyzed from heart rate variability analysis for the Control, Rest and Rap genres.

	HRV Analysis Values	
Music genre	Average HF (ms^2)	Average LF/HF
Control	904.3	2.1
Rest	1012.4	2.2
Rap	844.6	1.9

Table 3 demonstrates that the average HF values were highest in the rest condition (1012.4 ms^2) and the same trend was seen for the LF/HF values (2.2). The lowest average HF values of 844.6 ms^2 were seen in the rap genre as well as the lowest LF/HF value of 1.9.

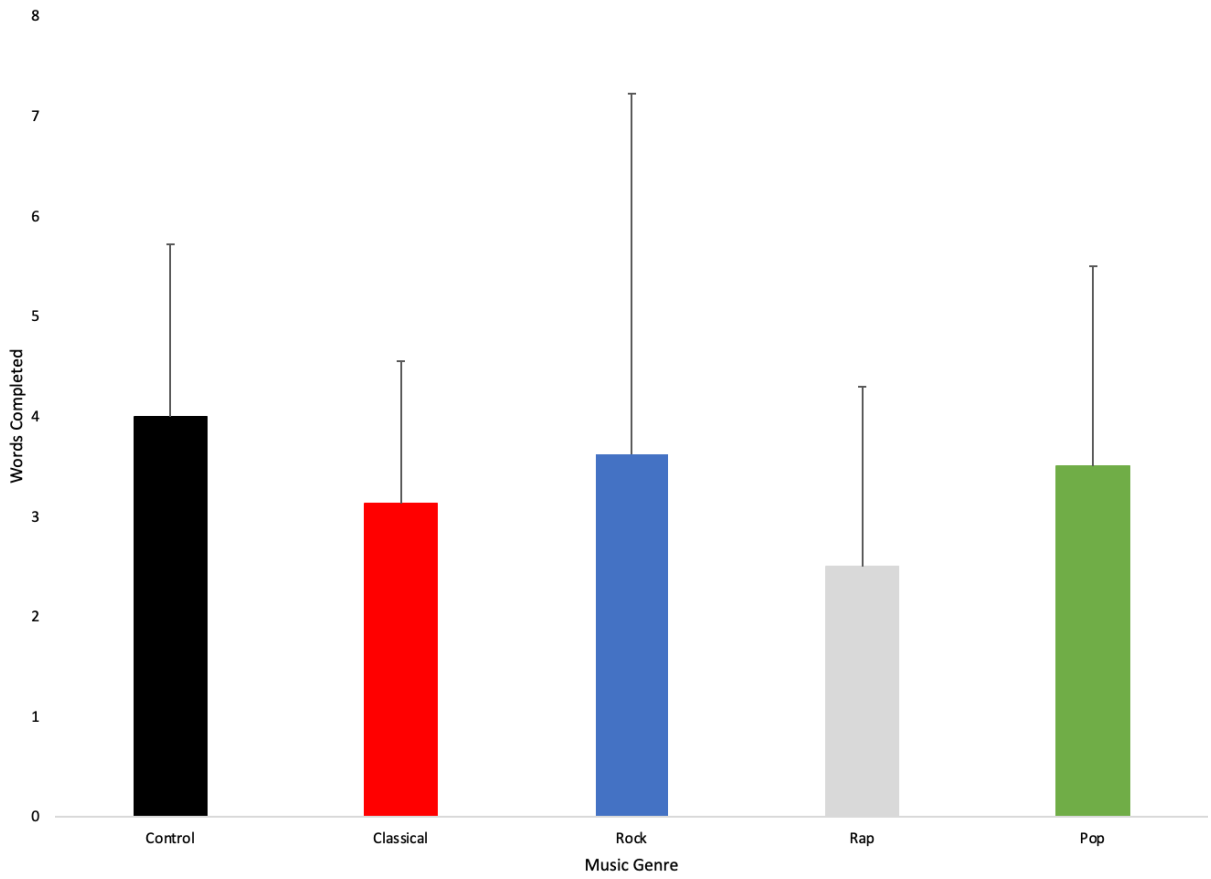

Figure 4. The average number of words completed in the word search puzzle when listening to different music genres (n=5).

Figure 4 shows the average number of words that participants were able to complete when listening to different genres of music. The control genre had the highest number of words completed compared to other genres.

Discussion

This study looked at the effect that music has on human physiology, and whether or not this can impact an individual's performance. During the first trial, the average heart rate between music genres showed a significant difference between the control and the rap genre only, as shown in Figure 1. While the average heart rate for the control was 76.56 ± 9.03 BPM, the average heart rate for the rap genre was significantly higher with a value of 79.11 ± 8.24 BPM (Table 1). All other genres showed no significant difference compared to the control despite the fact that they all had higher average heart rate values compared to the control.

When looking at participants during the second trial, where individuals were asked to complete a word search puzzle, the average heart rate between music genres showed a significant difference between only the pop and control conditions (Figure 2). As shown in Table 2, the average heart rate for the control genre in the second trial was 75.69 ± 9.30 BPM compared to the higher average heart rate of the pop condition which was 79.66 ± 11.04 BPM. All other genres had a larger average heart rate compared to the control, but none of them were significant.

Koelsch and Jancke (2015) found that music with faster tempos typically resulted in higher average heart rates compared to slower, more mellow songs. This was similar to the results that were found in both trials. It is proposed that with a higher heart rate, there would be more blood flow to the brain, resulting in better cognitive abilities (Luque-Casado et al. 2013). However, when comparing the puzzle completeness, where the control genre had the greatest average words completed with 4 words, the lowest average heart rate in all cases was also seen in the control genre (Figure 4). One possible explanation for this result could be that eye movement is reduced when listening to music, which could inhibit a participant's ability to quickly complete the puzzles (Schafer and Fachner 2015).

The heart rate variability was analyzed for the second trial only and looked at conditions under rest, control and rap genres. This analysis looked at the natural variation between heart-beat cycles which allowed the parasympathetic and sympathetic activity to be assessed (Russell et al., 2017). From this analysis, the high frequency (HF) values were used to indicate parasympathetic activity, while LF/HF values were used as an indicator for sympathetic activity (Yamashita, et al. 2006). The reason the LF/HF ratio is assessed for parasympathetic activity instead of just using the LF value is that the LF value is a measure of both parasympathetic and sympathetic activity whereas the HF is only a measure of parasympathetic (Archana and Mukilan, 2016).

From Table 3, the highest HF value of 1012.4 ms^2 and LF/HF value of 2.2 were both seen in the rest condition. This would indicate that both parasympathetic and sympathetic activity were highest in this condition. The lowest average HF values of 844.6 ms^2 and LF/HF values of 1.9 were both seen in the Rap condition (Table 3). This result indicates that the lowest parasympathetic and sympathetic activity was seen in the Rap genre. Archana and Mukilan (2016) suggested that music would increase parasympathetic activity to reduce an increase in heart rate while sympathetic activity would decrease to help regulate heart rate. Although the results did indicate changes in heart rate variability (and therefore autonomic activity) between control, rest and rap, there was no clear indication of how parasympathetic and sympathetic activity differed between one another within the three conditions as they showed the same general trend (Archana and Mukilan, 2016).

Overall, when comparing the average heart rate between the first and second trials, Figure 3 showed that the participants had higher heart rates in the trial without puzzles compared

to trials with puzzles. The exception to this was the pop genre, which showed an increase in heart rate during the puzzle trial.

Although no major issues were observed, possible discrepancies in the data could have occurred due to technological issues (including problems with the ECG electrodes, Power Lab equipment, or the Lab Chart software) during the experimental procedure. The average deviation between heart rates as well as the small sample size could potentially influence the overall results of the study. Noise-canceling headphones were used to mitigate external sounds; however, distractions within the experimental environment could also factor into variation in heart rate. Participant preference for a specific music genre could also affect their heart rate and, thus, heart rate variability.

Future studies should consider which genre of music the participant prefers in comparison to their heart rate and heart rate variability as well as puzzle completion. This could provide insight into how subconscious preference affects the sympathetic and parasympathetic nervous systems. One type of music may affect an individual's heart rate drastically, while another may have little to no effect. Few studies have examined the effects of acoustic characteristics including tempo, harmonic structure, rhythm, or sound pressure level on heart rate (Watanabe et al. 2017). It has been hypothesized that tempo plays an important role in determining whether music is exciting or relaxing for an individual (Watanabe et al. 2017). Further analysis of how frequencies or tempos of similar genres could also highlight how cardiac output is affected by music and how this is altered when a stressor is added. Examining the intensity of auditory stimulation may provide important insight into improving music therapy as an alternative method of treatment for stress management (do Amaral et al. 2016).

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Appendix

Two-tailed T-tests for Music Only Trials

t-Test: Paired Two Sample for Means		
	Control	*Classical genre*
Mean	76.55759306	77.70831394
Variance	123.5266457	131.572574
Observations	10	10
Pearson Correlation	0.905199329	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.73821114	
P(T<=t) one-tail	0.239596113	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.479192226	
t Critical two-tail	2.262157163	

t-Test: Paired Two Sample for Means		
	Control	*Rap genre*
Mean	76.55759306	79.11422961
Variance	123.5266457	102.1603422
Observations	10	10
Pearson Correlation	0.972971873	
Hypothesized Mean Difference	0	
df	9	
t Stat	-3.037128007	
P(T<=t) one-tail	0.007041611	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.014083222	
t Critical two-tail	2.262157163	

t-Test: Paired Two Sample for Means		
	Control	*Rock genre*
Mean	76.55759306	78.21895709
Variance	123.5266457	106.0771618
Observations	10	10
Pearson Correlation	0.927761259	
Hypothesized Mean Difference	0	
df	9	
t Stat	-1.26669178	
P(T<=t) one-tail	0.118531712	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.237063423	
t Critical two-tail	2.262157163	

t-Test: Paired Two Sample for Means		
	Control	*Pop genre*
Mean	76.55759306	79.3858728
Variance	123.5266457	136.998178
Observations	10	10
Pearson Correlation	0.935453971	
Hypothesized Mean Difference	0	
df	9	
t Stat	-2.16019584	
P(T<=t) one-tail	0.02952432	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.05904864	
t Critical two-tail	2.262157163	

Two- Tailed T-test for Trials with Music and Puzzles

t-Test: Paired Two Sample for Means		
	Control	*Classical*
Mean	75.69033	77.11531
Variance	96.09345	166.3528
Observations	10	10
Pearson Correlation	0.944565	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.92764	
P(T<=t) one-tail	0.1889	
t Critical one-tail	1.833113	
P(T<=t) two-tail	0.3778	
t Critical two-tail	2.262157	

t-Test: Paired Two Sample for Means		
	Control	*Rap*
Mean	75.6903283	76.98647886
Variance	96.09345114	97.93480271
Observations	10	10
Pearson Correlation	0.971132378	
Hypothesized Mean Difference	0	
df	9	
t Stat	-1.730568319	
P(T<=t) one-tail	0.058790059	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.117580118	
t Critical two-tail	2.262157163	

t-Test: Paired Two Sample for Means		
	Control	*Rock*
Mean	75.6903283	77.65096455
Variance	96.09345114	115.3098114
Observations	10	10
Pearson Correlation	0.955674021	
Hypothesized Mean Difference	0	
df	9	
t Stat	-1.940648678	
P(T<=t) one-tail	0.042110806	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.084221611	
t Critical two-tail	2.262157163	

t-Test: Paired Two Sample for Means		
	Control	*Pop*
Mean	75.6903283	79.66078534
Variance	96.09345114	135.4622961
Observations	10	10
Pearson Correlation	0.947785122	
Hypothesized Mean Difference	0	
df	9	
t Stat	-3.211405469	
P(T<=t) one-tail	0.005317463	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.010634926	
t Critical two-tail	2.262157163	

t-Test: Paired Two Sample for Means		
	Control	*Rest*
Mean	75.69033	76.30522
Variance	96.09345	177.5686
Observations	10	10
Pearson Correlation	0.899645	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.31286	
P(T<=t) one-tail	0.380758	
t Critical one-tail	1.833113	
P(T<=t) two-tail	0.761516	
t Critical two-tail	2.262157	

Song Titles and Authors Associated with Each Genre

Genre	Song and Author
Rap	Rap God by Eminem
Pop	Pop 101 by Marianas Trench
Classical	Moonlight Sonata 1st movement by Beethoven
Rock	Viking Death March by Billy Talent
Control	No music with headphones still on