

# Impact of Music Emotional Characteristics on Heart Rate in a Community Sample

Edward W. Zhu

*Science, Mathematics, and Computer Science Magnet Program,  
Montgomery Blair High School, Silver Spring, MD 20901, United States*

## ABSTRACT

Elevated heart rate is associated with an increased risk of cardiovascular mortality. Although prior research suggests that music has an impact on heart rate, the differential effect of music has not been well understood. This study assessed the effect of music with varying emotional characteristics on heart rate, and evaluated how arousal (intensity) and valence (pleasantness), the two aspects of emotional characteristics, influenced heart rate. Five participants were recruited to this quasi-experimental study. Each participant's heart rate was continuously monitored with an Apple Watch while they listened to music representing five distinct emotional characteristics, along with a no-music control condition. Linear mixed models were used to estimate the effects of each music on heart rate, accounting for the clustering of repeated heart rate measures within each participant. Compared with the control session, stormy and romantic pieces significantly increased heart rate while dreamy and nostalgic pieces significantly decreased heart rate. Further analyses suggested that high arousal was positively associated with and pleasantness was negatively associated with heart rate; no significant interaction between arousal and valence was observed. These findings suggest that specific emotional characteristics of music differentially influence heart rate and may have clinical implications for the use of music in stress reduction, rehabilitation, and exercise settings.

**Keywords:** Emotional characteristics; music; heart rate; arousal; valence

## INTRODUCTION

For the past 30 years, research into the role of music in healthcare has steadily increased. Numerous studies have demonstrated that music positively affects a wide range of physiological responses, including reducing stress (1-3), slowing the progression of dementia and

other neurological diseases (4, 5), and lowering the risk of heart disease (6-8). Heart rate is a critical indicator of the function of cardiovascular system (9). Elevated heart rate has been associated with an increased risk of cardiovascular mortality (7, 8, 10, 11). For example, one study reported that an increase of 10 beats per minute (BPM) in heart rate was associated with a more than 14% increase in cardiac mortality for women and a 17% increase for men (12).

Most studies have found that listening to music reduces stress and lowers heart rate (7, 8, 10, 11). However, some studies have reported heterogeneous responses, with music listening leading to increases in heart rate (13). One possible explanation for these

---

**Corresponding author:** Edward W. Zhu, E-mail: ewzhu2002@gmail.com.

**Copyright:** © 2026 Edward W. Zhu. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

**Accepted** April 8, 2026

<https://doi.org/10.70251/HYJR2348.42336343>

inconsistent findings is that the effect of music on heart rate varies depending on specific musical features. For example, several studies reported that music with faster tempo and greater dynamics may increase heart rate, whereas music with slower tempo and softer dynamics may decrease it (8, 14, 15). In contrast, other studies suggest that the effect of music on heart rate does not depend on tempo (13). Heart rate may be influenced by individuals' emotional perceptions of music, which integrate multiple acoustic features into a unified emotional experience (16). Despite this, few studies have directly assessed the effect of emotional characteristics of music on heart rate.

According to Thayer's Mood Classification Model (17), emotional characteristics of music can be defined along two dimensions: arousal (intensity or energy level) and valence (pleasantness or mood). For example, stormy music is characterized by high arousal and negative valence, creating feelings of tension and intensity. Romantic music is associated with moderate arousal and positive valence, reflecting emotional warmth and expressive intimacy. Joyful music is characterized by high arousal and positive valence, conveying energetic and uplifting emotions. Dreamy music is defined by low arousal and positive valence, creating a calm and peaceful experience. Nostalgic music typically involves low to moderate arousal and neutral to slightly positive or mixed valence, evoking reflective emotions associated with memory.

The mechanisms through which emotional music characteristics influence heart rate are complex. One explanation is provided by the Arousal and Mood Hypothesis (18), which suggests that music elicits physiological responses through the amygdala—a group of nuclei that responds to emotional stimuli and communicates with the autonomic nervous system (ANS). The ANS regulates heart rate by balancing two opposing branches: the sympathetic and parasympathetic nervous systems (19, 20). Activation of the sympathetic nervous system increases heart rate, whereas activation of the parasympathetic nervous system inhibits cardiac activity and decreases heart rate (19). High arousal music, often characterized by fast tempo, has been shown to increase heart rate, possibly through activation of the sympathetic nervous system (21-23). Several studies have also examined the role of valence. One study reported decreased heart rate in response to unpleasant music and increased heart rate in response to exciting music (13), while another found that unpleasant music elicited a greater decrease in heart rate than pleasant music (16).

However, most prior research has examined either arousal or valence in isolation. Few have explicitly disentangled these dimensions to assess their independent effects on heart rate. In addition, limited research has investigated potential interactive (synergistic) effects between arousal and valence in shaping heart rate responses.

To address these gaps in the literature, the present quasi-experimental study examined how different emotional music characteristics—stormy, dreamy, romantic, joyful, and nostalgic defined based on arousal and valence—affect heart rate in a community sample. It was hypothesized that (1) music with high arousal, such as stormy and joyful pieces, would increase heart rate through heightened emotional activation and amygdala engagement. Conversely, music with low to moderate arousal, such as dreamy and nostalgic pieces, would decrease heart rate by inducing calmer, reflective emotional states and reduced amygdala activation, mediated by the autonomic nervous system, (2) valence influences heart rate, with positive valence increasing heart rate and negative valence reducing heart rate, and (3) the effect of arousal on heart rate is moderated by valence, e.g. the influence of arousal on heart rate is stronger among the music pieces with positive valence than the influence of arousal on heart rate among the music pieces with negative valence.

## **METHODS AND MATERIALS**

### **Participants and procedure**

A quasi-experiment was conducted in this project. The study protocol was approved by the Institutional Review Board of the *Journal of High School Science*. Informed consent was obtained from all participants or their parents or legal guardians, and assent was obtained from minor participants. Data were de-identified before analyses to protect participant confidentiality. Participants were recruited through convenience sampling via personal contacts in the local community. Prior to the experiment, participants completed a pre-study assessment to collect sociodemographic information and medical history. The eligibility criteria for participation included: (1) age over 12 years, (2) no history of cardiovascular disease, (3) no heart dysfunction or condition requiring medication or surgery, and (4) no hearing impairment. The final sample consisted of five participants, aged 16 to 52 years, including two females and three males. Three participants identified as White and two as Asian.

During the experiment, each participant listened to five different music pieces and a silent control in a

random order. A five-minute break followed each piece to allow the participant’s heart rate to return to resting levels. Music was played using 2<sup>nd</sup> Generation Apple AirPods at a standardized volume. Each music piece, as well as the silent control, lasted approximately five minutes; pieces shorter than five minutes were looped to reach the full duration. To minimize motion-related noise, participants remained seated in the same chair in a quiet indoor room. Environmental conditions (e.g., temperature, noise, and lighting) were standardized, and participants were instructed to minimize movement and maintain normal breathing throughout the experiment. Participants wore an Apple Watch (Series 9.0, 46mm, Black Aluminum Case) throughout the experimental period to continuously monitor heart rate. The watch was set to “Workout Mode” approximately two minutes before starting the experiment to ensure accurate heart-rate assessment. Heart rate data were recorded approximately every five seconds. The total duration of the experiment for each participant was approximately 55 minutes including breaks. After the experiment, heart rate data were exported to R using the third-party app ‘AutoExport.’” (24). Heart rate measurement with the Apple Watch has been demonstrated to provide accurate and reliable readings in previous studies (25).

**Measures**

Dependent variable

Heart rate: Heart rate was collected in real time using the Apple Watch’s workout algorithm. It was measured in BPM every 5 seconds for each participant during all experimental and control conditions. Implausible values (e.g., heart rate below 40 or above 200 BPM) were checked and then the data were visually inspected for potential motion-related noises, e.g. abrupt increases or decreases in heart rate or sudden signal loss and recovery. No implausible values or apparent motion-related noises were observed in this study.

Independent variable

Emotional characteristics of music: This categorical variable included six categories: stormy, dreamy, romantic, light and joyful, nostalgic, and control (no music). The emotional characteristics was defined based on Thayer’s Mood Classification Model using two axes: arousal and valence. Two additional variables were created including (1) the arousal variable on a 3-point likert scale (0= low, 1=moderate and 2= high), and (2) the valence variable on a 3-point likert scale (0= negative, 1=moderate and 2=positive). Two music professionals independently assessed each piece for emotional characteristics, arousal and valence, separately. Any disagreements were discussed and resolved before final classification. A detailed list of music emotional characteristics, levels of arousal, levels of valence for each piece is shown in Table 1.

Time variable

Heart rate was recorded continuously throughout this study. The time of each measurement was recorded to determine when each music category or control condition started and ended within each participant.

**Data analysis**

Descriptive analyses were conducted, with heart rate summarized as mean (SD) under each of the six conditions (five musical emotional characteristics and the control condition). Analysis of Variance (ANOVA) was used to assess difference in heart rate across conditions, followed by Tukey’s Honest Significant Difference (HSD) test for post-hoc pairwise comparison. Linear mixed models were then used to examine the relation between the six conditions and heart rate, accounting for the clustering of repeated heart rate measures within each participant by including a random intercept at the participant level. Separate linear mixed models were also used to assess the effects of arousal and valence on

*Table 1. Emotional characteristics of each piece of music in the quasi-experiment study.*

Piece Title	Emotion Characteristics	Arousal	Valence
Chopin’s Nocturne Op. 9 No. 2	Dreamy	Low	Positive
Rachmaninoff’s Musical Moment No. 4	Stormy	High	Negative
Rachmaninoff’s Rhapsody on a Theme of Paganini Variation 18	Romantic	Moderate	Positive
Mozart’s Eine kleine Nachtmusik	Light and Joyful	High	Positive
Ravel’s Pavane pour une infante défunte	Nostalgic	Low	Moderate

heart rate as well as their interaction. Nakagawa's  $R^2$  was calculated to quantify the percentage of variance explained by mixed-effects models, with conditional  $R^2$  representing the proportion of variance explained by both fixed and random effects (26). The data were analyzed in R version 4.5.1

**RESULTS**

**Selected sample characteristics**

A total of five participants contributed 1,837 heart rate observations. The mean age was 32 years (SD = 18.9), with 40% female and 60% male participants. The repeated measurements generated a longitudinal dataset with multiple observations per participant, supporting both descriptive and mixed-effects analyses.

**Mean heart rate by each music emotional characteristics**

The average heart rate was 70.75 BPM (SD=10.08) during the control condition, 75.21 BPM for stormy music (SD=9.46), 67.69 BPM for dreamy (SD=8.51), 71.82 BPM for romantic (SD=13.41), 71.61 BPM for light and joyful (SD=11.51), and 69.82 BPM for nostalgic (SD=10.27, Table 2). ANOVA indicates significant differences between the six conditions,  $F(5, 1831)=16.87$ ,  $p<0.001$ . Post-hoc pairwise comparison based on Tukey's HSD test indicated that heart rate under stormy condition was significantly higher than the heart rate under control or other conditions; heart rate under dreamy condition was significantly lower than control, romantic, or light and joyful conditions, but was not significantly different from heart rate under nostalgic condition; no significant difference in heart rate was found between control, romantic, light and joyful and nostalgic condition.

An example of heart rate over time under different music emotional characteristics conditions and control condition for one of the five participant was illustrated in Figure 1. During the control condition, heart rate

was relatively stable with minimal variation. During the stormy and romantic music conditions, heart rate increased initially and then gradually decreased. During the light and joyful conditions, heart rate was consistently higher than in the control condition. In contrast, heart rate during the dreamy, and nostalgic conditions was comparable to the control condition. Overall, heart rate showed greater variability within each music condition than during the control condition. It should be noted that this figure represents a single participant and does not reflect patterns averaged across all participants.

**Linear mixed models examining the impact of music emotional characteristics on heart rate**

The impact of music emotional characteristics on heart rate, based on the linear mixed model, is shown in Table 3. Compared to the control condition, the stormy piece increased heart rate by nearly 4 BPM ( $b=3.89$ ,  $SE=0.37$ ,  $p<0.001$ ). In contrast, the dreamy piece

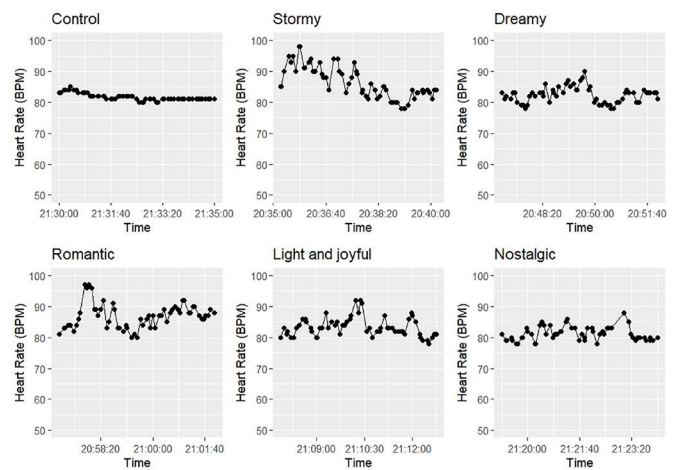


Figure 1. Example of heart rate responses to different music emotional conditions for a single participant.

Table 2. Mean heart rate (BPM) across the music emotional characteristics (N=5, with 1837 heart rate observations).

	Control (n=298) <sup>+</sup>	Stormy (n=318) <sup>+</sup>	Dreamy (n=298) <sup>+</sup>	Romantic (n=319) <sup>+</sup>	Light and joyful (n=306) <sup>+</sup>	Nostalgic (n=299) <sup>+</sup>	P value
Average heart rate*	70.75 <sup>B</sup>	75.21	67.69 <sup>A</sup>	71.82 <sup>B</sup>	71.61 <sup>B</sup>	69.82 <sup>AB</sup>	<0.001
Mean(SD)	(10.08)	(9.46)	(8.51)	(13.41)	(11.51)	(10.27)	

Note: \*Heart rate in the number of beats per minute (BPM). P value was based on Analysis of Variance (ANOVA). The groups sharing the same letter are not statistically significantly different based on Tukey's post-hoc pairwise comparisons.

**Table 3.** Heart rate in relation to music emotional characteristics based on a linear mixed model to account for the clustering of heart rates within each participant. (N=5 with 1837 heart rate observations in total).

	<b>b</b>	<b>SE</b>	<b>P value</b>
Control (silence)		Reference	
Stormy	3.89	0.37	< 0.001 ***
Light and joyful	0.60	0.38	0.115
Nostalgic	-0.85	0.38	0.026*
Dreamy	-3.07	0.38	<0.001***
Romantic	0.91	0.37	0.015*

Note: *b* indicates coefficient estimate, *SE* indicates standard error. Nakagawa's *R*-squared for Mixed Models: conditional  $R^2=0.82$ . \* indicates  $p<0.05$  \*\* indicates  $p<0.01$  \*\*\* indicates  $p<0.001$ .

significantly decreased heart rate by approximately 3 BPM ( $b=-3.07$ ,  $SE=0.38$ ,  $p<0.001$ ). The romantic piece was associated with a modest but significant increase in heart rate of about 1 BPM ( $b = 0.91$ ,  $SE = 0.37$ ,  $p = 0.015$ ), whereas the nostalgic piece significantly reduced heart rate by about 1 BPM ( $b = -0.85$ ,  $SE = 0.38$ ,  $p = 0.026$ ). The light and joyful piece did not produce a significant change in heart rate ( $p=0.115$ ).

**Linear mixed models examining the impacts of arousal, valence and their interaction on heart rate**

The linear mixed model assessed the impact of arousal and valence on heart rate, using only observations of heart rate during music conditions. There are independent effects of arousal and valence on

heart rate. Each unit increase of arousal (e.g. from low to moderate or from moderate to high) increased heart rate by 1.76 BPM ( $SE=0.15$ ,  $p<0.001$ ), holding valence constant, and each unit increase of happiness in valence (e.g. from negative to moderate or from moderate to positive) decreased the heart rate by 1.32 BPM ( $SE=0.16$ ,  $p<0.001$ , Model 1 in Table 4), holding arousal constant. No significant interactions were found between arousal and valence ( $b$  for the interaction term= $0.09$ ,  $SE=0.22$ ,  $p=0.671$ , Model 2 in Table 4), indicating that the impact of arousal has similar effect at each level of valence and also the impact of valence has similar effect at each level of arousal.

**DISCUSSION**

The main finding of this study is that emotional characteristics of music have distinct effects on heart rate. First, music pieces with high arousal, such as stormy and romantic, significantly increased heart rate, whereas music pieces with low arousal, such as dreamy and nostalgic, significantly decreased heart rate, regardless of valence. Second, valence also influenced heart rate with negative valence always had higher heart rate than positive valence and this influence was not moderated by arousal level: during high-arousal music, negative valence (stormy) increased heart rate more than positive valence (light and joyful), while during low-arousal music, neutral valence (nostalgic) resulted in a smaller decrease in heart rate compared to positive valence (dreamy).

Overall, the study provides preliminary evidence supporting the Arousal-and-Mood hypothesis, particularly highlighting the dominant role of arousal in

**Table 4.** Heart rate in relation to arousal and valence and their interaction based on linear mixed models to account for the clustering of heart rates within each participant. (N= 5 with 1539 heart rate observations under music conditions only).

	<b>Model 1</b>			<b>Model 2</b>		
	<b>b</b>	<b>SE</b>	<b>P value</b>	<b>b</b>	<b>SE</b>	<b>P value</b>
Arousal	1.76	0.15	<0.001***	1.63	0.34	<0.001***
Valence	-1.32	0.16	<0.001***	-1.47	0.38	<0.001***
Arousal*valence				0.09	0.22	0.671

Note: Model is restricted to the heart rate observations under music conditions. Nakagawa's *R*-squared for Mixed Models: Model 1: conditional  $R^2=0.80$ ; Model 2: conditional  $R^2=0.80$ . *b* indicates coefficient estimate, *SE* indicates standard error. \* indicates  $p<0.05$  \*\* indicates  $p<0.01$  \*\*\* indicates  $p<0.001$ .

music-induced changes in heart rate. High- or moderate-arousal characteristics (stormy and romantic) increased heart rate, while low-arousal characteristics (dreamy and nostalgic) reduced heart rate. These findings are consistent with previous research (13, 14, 16, 21, 22, 27). Specifically, high arousal in stormy music may evoke feelings of fear or stress, and high arousal in romantic music may evoke romantic attraction, both potentially activating the sympathetic nervous system and increasing heart rate—preparing the body for a fight-or-flight response during stormy music or emotional engagement during romantic music. In contrast, low arousal in dreamy and nostalgic music may enhance parasympathetic activity, resulting in slower heart rate.

Surprisingly, this finding contrasts with prior literature, which reports that pleasant music increases heart rate (16, 28). In the present study, although arousal emerged as the primary driver of heart rate changes, valence showed an additional and somewhat unexpected pattern: negative valence was associated with higher heart rate compared to positive valence, holding arousal constant. This finding should be interpreted with caution and warrants replication in studies with a broader range of valence and larger sample sizes. One possible explanation is that negative valence may trigger threat- or fear-related responses and increase emotional tension, thereby activating the sympathetic nervous system and elevating heart rate. In contrast, positive valence may stimulate vagal activity and engage the parasympathetic nervous system, promoting the release of acetylcholine and reducing heart rate. Positive valence may also be associated with lower levels of stress hormones, such as cortisol, which could further contribute to reduced heart rate (29, 30).

This study has several strengths. First, it assessed the impact of music emotional characteristics on heart rate within the framework of the Arousal-and-Mood hypothesis in a community sample. Second, it assessed both the independent effects of arousal and valence on heart rate as well as their interactive effects. Third, heart rate was objectively measured with the Apple Watch and recorded at short intervals (every 5 seconds) throughout the experimental period.

Several limitations should be noted. First, this is an exploratory quasi-experimental study with a small number of participants. Although repeated observations were collected for each participant, the effective sample size is limited to the number of participants ( $n=5$ ), which restricts the ability to estimate between-subject variability. The small sample size and use of a

convenience sample also limit the generalizability of the findings. Future studies should include larger and more diverse samples, and explore potential moderating factors by sociodemographic variables. Second, although music conditions and the control were presented in a randomized order to minimize systematic bias, residual or carryover effects could still have influenced heart rate measurements. For example, lingering physiological responses from a previous condition or participant fatigue, as well as incomplete recovery during the 5-minute washout period, may have affected responses in subsequent conditions. Third, heart rate is influenced by respiration, posture, anticipation, and individual baseline variability. Respiration rate and heart rate variability were not measured or controlled in this study, and a standardized resting baseline was not established before each condition. These factors may have introduced noise or confounded the effects.

This study contributes to the literature on the differential effect of music on heart rate. Given the exploratory nature of the study, the potential clinical implications should be considered preliminary. First, low-arousal music, such as dreamy and nostalgic pieces, was associated with reduced heart rate, suggesting a potential role in stress reduction or anxiety management (8, 11). Second, high-arousal music, such as stormy and romantic pieces, was associated with increased heart rate, which may have implications for contexts requiring emotional engagement or motivation, such as rehabilitation, exercises or workouts (27). However, these effects should be interpreted with caution as high-arousal music may inadvertently increase cardiovascular workload, particularly among individuals at risk for cardiovascular disease. Third, the finding that music with negative valence was associated with higher heart rate compared to positive valence warrants replication in larger and more diverse samples. If confirmed, this pattern may inform the consideration of emotional valence in the design of music-based interventions aimed at stress reduction.

## **CONCLUSION**

This exploratory quasi-experimental study examined whether music with different emotional characteristics differentially influences heart rate, focusing on the roles of arousal (intensity) and valence (pleasantness). The findings indicate that arousal was positively associated with heart rate and pleasantness was negatively associated with heart rate, with no significant interaction

between the two dimensions. These findings suggest that tailoring music based on its emotional characteristics could have potential applications in stress management, rehabilitation, or exercise contexts. However, these results are exploratory and should be interpreted with caution until confirmed in future studies with larger samples and a wide range of music in terms of valence and arousal.

## ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. Kelly Doran, University of Maryland at Baltimore, for her assistance with editing this research article.

## CONFLICT OF INTEREST

The author declares that there are no conflicts of interest related to this work.

## REFERENCES

1. Thoma MV, La Marca R, Bronnimann R, Finkel L, Ehlert U, Nater UM. The effect of music on the human stress response. *PLoS One*. 2013; 8 (8): e70156. <https://doi.org/10.1371/journal.pone.0070156>
2. de Witte M, Pinho ADS, Stams GJ, Moonen X, Bos AER, van Hooren S. Music therapy for stress reduction: a systematic review and meta-analysis. *Health Psychol Rev*. 2022; 16 (1): 134-59. <https://doi.org/10.1080/17437199.2020.1846580>
3. Wong MM, Tahir T, Wong MM, Baron A, Finnerty R. Biomarkers of Stress in Music Interventions: A Systematic Review. *J Music Ther*. 2021; 58 (3): 241-77. <https://doi.org/10.1093/jmt/thab003>
4. Reschke-Hernandez AE, Gfeller K, Oleson J, Tranel D. Music Therapy Increases Social and Emotional Well-Being in Persons With Dementia: A Randomized Clinical Crossover Trial Comparing Singing to Verbal Discussion. *J Music Ther*. 2023; 60 (3): 314-42. <https://doi.org/10.1093/jmt/thad015>
5. Balbag MA, Pedersen NL, Gatz M. Playing a Musical Instrument as a Protective Factor against Dementia and Cognitive Impairment: A Population-Based Twin Study. *Int J Alzheimers Dis*. 2014; 2014: 836748. <https://doi.org/10.1155/2014/836748>
6. Chafin S, Roy M, Gerin W, Christenfeld N. Music can facilitate blood pressure recovery from stress. *Br J Health Psychol*. 2004; 9 (Pt 3): 393-403. <https://doi.org/10.1348/1359107041557020>
7. Pittman S, Kridli S. Music intervention and preoperative anxiety: an integrative review. *Int Nurs Rev*. 2011; 58 (2): 157-63. <https://doi.org/10.1111/j.1466-7657.2011.00888.x>
8. Mir IA, Chowdhury M, Islam RM, Ling GY, Chowdhury A, Hasan ZM, Higashi Y. Relaxing music reduces blood pressure and heart rate among pre-hypertensive young adults: A randomized control trial. *J Clin Hypertens (Greenwich)*. 2021; 23 (2): 317-22. <https://doi.org/10.1111/jch.14126>
9. Olshansky B, Ricci F, Fedorowski A. Importance of resting heart rate. *Trends Cardiovasc Med*. 2023; 33 (8): 502-15. <https://doi.org/10.1016/j.tcm.2022.05.006>
10. Loomba RS, Arora R, Shah PH, Chandrasekar S, Molnar J. Effects of music on systolic blood pressure, diastolic blood pressure, and heart rate: a meta-analysis. *Indian Heart J*. 2012; 64 (3): 309-13. [https://doi.org/10.1016/S0019-4832\(12\)60094-7](https://doi.org/10.1016/S0019-4832(12)60094-7)
11. Yangoz ST, Ozer Z. Effects of music intervention on physical and psychological problems in adults receiving haemodialysis treatment: A systematic review and meta-analysis. *J Clin Nurs*. 2022; 31 (23-24):3305-26. <https://doi.org/10.1111/jocn.16199>
12. Raisi-Estabragh Z, Cooper J, Judge R, Khanji MY, Munroe PB, Cooper C, et al. Age, sex and disease-specific associations between resting heart rate and cardiovascular mortality in the UK BIOBANK. *PLoS One*. 2020; 15 (5): e0233898. <https://doi.org/10.1371/journal.pone.0233898>
13. Koelsch S, Jancke L. Music and the heart. *Eur Heart J*. 2015; 36 (44): 3043-9. <https://doi.org/10.1093/eurheartj/ehv430>
14. Trappe HJ, Voit G. The Cardiovascular Effect of Musical Genres. *Dtsch Arztebl Int*. 2016; 113 (20): 347-52. <https://doi.org/10.3238/arztebl.2016.0347>
15. Sharma PJ, Aditya; Singh, Kd; Kumar, Avnish; Sandhu, Gagneen; Sharma, Shivani. Musical Genres and Their Influence on Heart Rate Variability and Blood Pressure: A cross-sectional study. *European Journal of Cardiovascular Medicine*. 2024; 14 (5): 601.
16. Sammler D, Grigutsch M, Fritz T, Koelsch S. Music and emotion: electrophysiological correlates of the processing of pleasant and unpleasant music. *Psychophysiology*. 2007; 44 (2): 293-304. <https://doi.org/10.1111/j.1469-8986.2007.00497.x>
17. Thayer RE. *The Biopsychology of Mood and Arousal*. Oxford University Press. 1989. <https://doi.org/10.1093/oso/9780195068276.001.0001>
18. Thompson WF, Schellenberg EG, Husain G. Arousal, mood, and the Mozart effect. *Psychol Sci*. 2001; 12 (3): 248-51. <https://doi.org/10.1111/1467-9280.00345>
19. Appelhans BM, Luecken LJ. Heart Rate Variability as an Index of Regulated Emotional Responding. *Review of General Psychology*. 2006; 10 (3): 229-40. <https://doi.org/10.1037/1089-2615.10.3.229>

- doi.org/10.1037/1089-2680.10.3.229
20. Cechetto D. Forebrain control of healthy and diseased hearts. In Armour JA, Ardell JL, (eds). *Basic and Clinical Neurocardiology*. Oxford: Oxford University Press; 2004; p220-251.
  21. Bernardi L, Porta C, Sleight P. Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence. *Heart*. 2006; 92 (4): 445-52. <https://doi.org/10.1136/hrt.2005.064600>
  22. Darki C, Riley J, Dadabhoy DP, Darki A, Garetto J. The Effect of Classical Music on Heart Rate, Blood Pressure, and Mood. *Cureus*. 2022; 14 (7): e27348. <https://doi.org/10.7759/cureus.27348>
  23. Karageorghis CI, Priest DL. Music in the exercise domain: a review and synthesis (Part I). *Int Rev Sport Exerc Psychol*. 2012; 5 (1): 44-66. <https://doi.org/10.1080/1750984X.2011.631026>
  24. Sobers L. Health Auto Export - JSON+CSV [Mobile app]. App Store. [apps.apple.com](https://apps.apple.com). 2025.
  25. Khushhal A, Nichols S, Evans W, Gleadall-Siddall DO, Page R, O'Doherty AF, et al. Validity and Reliability of the Apple Watch for Measuring Heart Rate During Exercise. *Sports Med Int Open*. 2017; 1 (6): E206-E11. <https://doi.org/10.1055/s-0043-120195>
  26. Nakagawa S, Schielzeth H. A general and simple method for obtaining R2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution*. 2013; 4 (2): 133-42. <https://doi.org/10.1111/j.2041-210x.2012.00261.x>
  27. Karageorghis CI, Priest DL. Music in the exercise domain: a review and synthesis (Part II). *Int Rev Sport Exerc Psychol*. 2012; 5 (1): 67-84. <https://doi.org/10.1080/1750984X.2011.631027>
  28. Salimpoor VN, Benovoy M, Longo G, Cooperstock JR, Zatorre RJ. The rewarding aspects of music listening are related to degree of emotional arousal. *PLoS One*. 2009; 4 (10): e7487. <https://doi.org/10.1371/journal.pone.0007487>
  29. Lai H-L, Li Y-M. The effect of music on biochemical markers and self-perceived stress among first-line nurses: a randomized controlled crossover trial. *Journal of Advanced Nursing*. 2011; 67 (11): 2414-24. <https://doi.org/10.1111/j.1365-2648.2011.05670.x>
  30. Matias GP, Nicolson NA, Freire T. Solitude and cortisol: associations with state and trait affect in daily life. *Biol Psychol*. 2011; 86 (3): 314-9. <https://doi.org/10.1016/j.biopsycho.2010.12.011>