Journal of Environmental Health and Sustainable Development

Investigating the Effects of Music and Temperature Changes on Heart Function and Human Error

Parvin Ahmadinejad [1], Abdolhamid Tajvar [2], Morteza Mortazavi [3], Sara Arjmand [1], Sanaz Nasiri Namin [4], Zahra Zamanian [1], Milad Derakhshanjazari [5]*

[1] *Department of Occupational Health and Safety Engineering, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran.*
[2] *Department of Occupational Health Engineering, School of Health, Hormozgan University of Medical Sciences, Hormozgan, Iran.*
[3] *Department of Occupational Health, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.*
[4] *Department of Occupational Health Engineering, School of Health, Kashan University of Medical Sciences, Kashan, Iran.*
[5] *Military Health Research Center, Life Style Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran.*

ARTICLE INFO

ORIGINAL ARTICLE

Article History:
Received: 22 November 2023
Accepted: 20 January 2024

***Corresponding Author:**
Milad Derakhshanjazari

Email:
derakhshan_milad@yahoo.com

Tel:
+98 21 87555523

Keywords:
Human Error,
Heart Function Tests,
Music,
Temperature.

ABSTRACT

Introduction: Exposure to music and temperature variations can influence physiological state and impact human error. This study aims to investigate the combined and independent effects of music and temperature changes on heart rate (HR) and human error.

Materials and Methods: This interventional study was conducted on 14 participants (7 men and 7 women) under controlled conditions in 2018. The subjects experienced four types of music (Rock, Rap, Pop, and Iranian traditional music) at the noise pressure level of 75 dB, along with temperatures of 20, 25, and 30 °C independently and in combination, within an acoustic room with controlled temperature conditions. HR and human error rate were measured using a HR meter and a researcher-made text with spelling mistakes, respectively.

Results: Using SPSS 19, data analysis revealed that exposure to traditional Iranian and rock music in temperatures deviating by 5 °C from 25 °C was associated with increased errors in detecting spelling mistakes ($p < 0.05$). Interestingly, traditional and rock music did not significantly affect HR across temperatures of 20, 25, and 30 °C ($p > 0.05$).

Conclusion: Listening to traditional Iranian and rock music in conditions with approximately 5 °C cooler or warmer than room temperature can have a positive and constructive effect on HR and reduce human error. The use of this type of music has potential implications for optimizing environmental conditions, especially in workplaces where such factors are critical.

Citation: Ahmadinejad P, Tajvar A, Mortazavi M, et al. ***Investigating the Effects of Music and Temperature Changes on Heart Function and Human Error.*** J Environ Health Sustain Dev. 2024; 9(1): 2171-9.

Introduction

Listening to music is one of the entertainments of today's society, and studies have shown that it has psychological, physiological and social effects on people [1]. However, the effects of music on people are debatable [2]. Previous studies have shown that music enhances people's attention in complex activities. For example, Corhan and Gunnard's study [3] found that exposure to rock music improved performance compared to other kinds of music. Also, Davis et al. found that during a difficult task, listening to music increased the

[DOI: 10.18502/jehsd.v9i1.15114]

speed of task response [4]. In addition, Ferguson et al. studied the effects of listening to music before performing karate. Their mean scores of performance were significantly higher after listening to white noise, regardless of the type of music (fast, loud, slow, soft). Music facilitates such performance because the stimulus is considered stimulating; it increases motivation, arousal, and perception of energy [5]. The type of work, the type of music (pop, rock, classical, rap, etc.), gender, and environmental conditions such as air temperature are among the factors that highlight the role of music in implementing the job [6].

In addition to music, air temperature is another significant environmental factor, affecting the cognitive performance of employees. Cognitive performance refers to cognitive abilities or mental processes, including our attention span, memory, reaction time, problem-solving ability, and so on. Increase of temperature would eventually lead to human's exposure to higher heat which is hazardous regarding people's health and reduces their performance due to thermal stress. Heat stress includes a series of conditions where the body is under stress from overheating [7,8] During exposure to heat stress, the amount of blood flow to the skin surface increases, so that the accumulated heat in the body is exchanged with the environment. But, the output of the heart increases with increasing blood flow to the surface of the skin, which results in increase in heart rate (HR) and blood pressure [7,9].

In recent decades, the effects of various environmental factors on human performance has been addressed in several studies, most of which only examined the effect of one factor [5,10]. Music exerts a general arousal effect on human HR which may be modulated by tempo [11]. On the other hand, the results from this study showed that exposure to high ambient temperature produced a significant increase in HR and human error [12,13]. While in real conditions, there are usually several factors that together affect human performance [14]. Listening to music has also become common, and people tend to listen to their favorite music while relaxing or at work. Since there is insufficient information about the combined effect of music and different environmental conditions in the workplace on employees' performance, this study is conducted to determine the combined and independent effects of music and heat on HR and human error.

Materials and Methods

This interventional study with factorial design and under controlled conditions was carried out on 7 men and 7 women in 2018. Physical, hearing and visual health were included in this study,and informed consent was obtained from the participants. Auditory system and visual status of the subjects were assessed using audiometric test and Snellen chart, respectively. Audiometric test examines both intensity and tone of sounds, balance issues, and other issues related to the function of the inner ear. Based on the results of this test, subjects with hearing system threshold less than 25 dB in speech frequencies (2-6 kHz) were included in the study. The Snellen chart has 11 lines of capitalized block letters, known as optotypes. At the top of the chart is only one letter — a large "E." As you move down the rows of the chart, the letters gradually get smaller. The participant is placed at a distance of 20 feet. Visual acuity (VA) is defined as sharpness of vision, measured by the ability to discern letters or numbers at a given distance according to a fixed standard. 20 of 20 vision is considered "normal", which means one can read a letter at 20 feet.

In order to control confounding factors and create the same conditions for the subjects, the experiment was carried out in an acoustic room equipped with a dual-purpose heating and cooling system (cold and heat generator). This room had an area of 12 square meters and its walls were sound and heat insulated. The inner walls were covered with sound absorbers and, reverberation time inside was about 0.5 seconds. The background noise inside the acoustic room was about 30 decibels, which was caused by its air conditioning system. This air conditioning system provided room temperature around 25 °C (Room temperature). Air temperature was about 5 °C cold or warm at room temperature, respectively.

[DOI: 10.18502/jehsd.v9i1.15114]

Because people in most Iranian cities face this temperature range in their working and living environments. On the other hand, because temperature was considered a variable in this research and its changes must be understood, 5-°C changes in temperature was considered. To verify the temperatures, a standard mercury thermometer was used in the acoustic chamber. This thermometer was a Zeal UK model with a graduated part engraved on the body, and the lower part was a liquid reservoir which extended along the length of capillary body and was about 30 cm long; the device's temperature measurement range was between -10 ℃ below zero to +110 ℃ above zero. The lighting of the room was 300 lux for all subjects.

Generally, most Iranian and non-Iranian people listen to the 4 types of music including Rock, Rap, Pop and Iranian traditional daily for a long time. The selected music was played by two speakers with a power of 500 watts, the equivalent noise pressure level in the chamber was adjusted using the TES 1358 noise level meter, and the speaker volume was set at a noise pressure level of 75 dB in network A. Then, based on previous studies [15] the subjects rested for about 15 minutes after exposure to each type of music. Figure 1 shows how to perform the test.

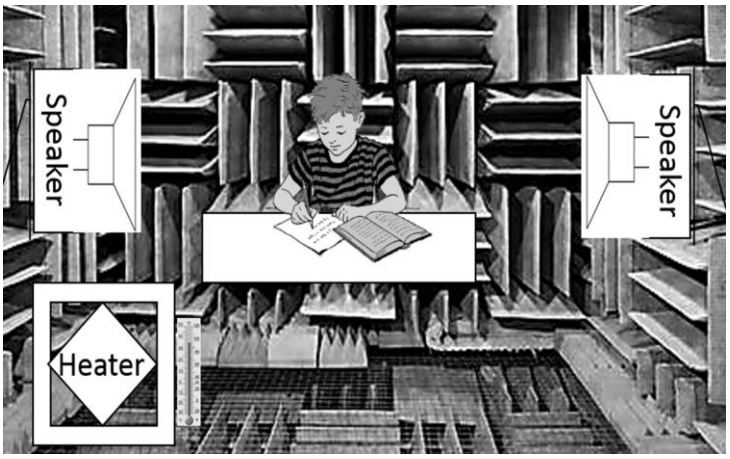

Figure 1: Test conditions

The subjects had enough rest before entering the tests. Moreover, they needed to avoid exposure to music, high temperature, and consumption of coffee, alcohol and fatty foods in laboratory conditions the night before the tests. Men wore cotton pants and shirts and women wore cotton coats and scarves.

To perform the test, the HR during test were measured using a POLAR S400 device (made in Finland). Heart rate was first mounted on the chest and the monitor was worn on the hand. Then, Baseline HR was recorded after 20 minutes of rest.

The subjects, then, entered the acoustic room and were asked to adjust the height of their chair to work surface. Then, the process of the experiments was explained to them.

First, the subjects were given a text with spelling mistakes. It should be noted that in this study, 19 researcher-made texts were prepared to measure human error, each of which had 1000 standard Persian words with 60 misspellings in every text. These texts were given to five expert teachers. Then they were asked to change the 100 words in the text into misspellings. Finally, among the proposed spelling errors, 60 common spelling errors of all the five teachers were selected for each text which were used as the text with spelling errors for the participants. To investigate the combined effect of music and temperature, each subject was exposed to a combination of different temperatures studied and types of music 5 minutes per each experiment.

In this study, the subjects were exposed to 3 temperature modes and 4 types of music

[DOI: 10.18502/jehsd.v9i1.15114]

independently and in combination. Therefore, the human error test of the studied subjects was investigated in three modes. First, they were exposed to all four types of music at a temperature of 18 °C. Then, experiments without music were performed at three temperatures of 20, 25 and 30 °C. Moreover, experiments were conducted in the combination of each music with the studied temperatures. Of course, each human error test was repeated three times in each of the mentioned conditions. In order to reduce random errors, one of the texts was randomly given to the participants in each of the modes of exposure to music and temperature.

Finally, data were transferred to a computer and stored. Considering that the dependent variables i.e. the number of errors, the time to complete the texts, and the heart rates, are of continuous quantitative type, the independent variables such as the type of music are qualitative variables, and the studied temperature is a discrete quantitative type. Therefore, one-way ANOVA test was used to analyze them. In addition, post-hoc test was used to analyze the relationship between the groups exposed to temperature and music with HR and human error characteristics. In this study, data analysis was done using SPSS 16 and the error coefficient was considered 0.05.

Results

In this study, the mean and standard deviation of age were 25 ± 1.94 years for men and 24.75 ± 0.95 years for women and the mean and standard deviation of weight were 73 ± 4.39 kg for men and 58 ± 6.41 kg for women. All the participants had Bachelor's degree. The value of clothing resistance coefficient (Clo) index, which shows resistance of clothing to the transfer of heat from the skin to the outer surface of the clothing, for men and women were 0.8 and 1, respectively. This means that men and women had the same conventional clothing in their groups. Men's clothing included pants, shirts, undershirts, and socks made of cotton fabric. Women's clothing included manteaus, shirts under the mantle, pants, socks, and scarves made of cotton fabric. Other details regarding the participants in this study are given in Table 1.

Table 1: Frequency and percentage of personal characteristics of the subjects according to gender

Frequency (%)				Demographic characteristics	
P-value	Female	P-value	Male		
P > 0.05	0 (%0) 6 (%86) 1 (%14)	P > 0.05	0 (%0) 5 (%72) 2 (%28)	≤ 20 21-25 26 ≤	Age rang (years)
P < 0.05	7 (%100) 0 (%0)	P < 0.05	7 (%100) 0 (%0)	Bachelor's degree Undergraduate	Level of Education
P < 0.05	0 (%0) 7 (%100)	P < 0.05	1 (%14) 6 (%86)	Yes No	Diet
P < 0.05	0 (%0) 7 (%100)	P < 0.05	1 (%14) 6 (%86)	Yes No	Diet
P < 0.05	7 (%100) 0 (%0)	P < 0.05	7 (%100) 0 (%0)	Yes No	Healthy hearing
P < 0.05	0 (%0) 7 (%100)	P < 0.05	0 (%0) 7 (%100)	Yes No	Aye disease
healthy hearing	5 (%72) 2 (%28)	-	0 (%0) 0 (%0)	Yes No	Menstruation

According to Table 2, the reading time of the studied text while playing traditional music is significantly different from pop and rock music (P < 0.05). However, the number of errors in detecting textual errors in the studied text while playing traditional music was significantly different from pop and rock music (P < 0.05). Because the time to finish reading the text was shorter when playing rock music, the highest number of errors was observed in this case. Other

[DOI: 10.18502/jehsd.v9i1.15114]

results related to the study of the combined effects of the type of music and three different temperature conditions regarding the error rate in detecting the number of errors in the text were presented in Table 2.

Table 2: Comparison of the number of errors in detecting textual errors and reading time regarding temperatures and music types

P-value	Number of errors in detecting textual errors	P-value	Time to finish reading the text (S)	Temperature (°C)	Music Type
P < 0.05	5	P < 0.05	237	18	Rock
	5		248	18	Rap
	4		243	18	Pop
	8		267	18	Iranian traditional
P > 0.05	3	P < 0.05	251	20	-
	3		254	25	-
	3		262	30	-
P < 0.05	14	P < 0.05	270	20	Rock
	12		264	25	
	16		278	30	
	9		253	20	Rap
	8		259	25	
	8		271	30	
	7		246	20	Pop
	7		243	25	
	8		261	30	
	14		275	20	Iranian traditional
	10		269	25	
	15		291	30	

The results of t-test showed that when playing traditional Iranian and rock music, increasing and decreasing the temperature by 5 °C compared to the temperature of 25 °C causes more errors in detecting spelling mistakes of the text ($p < 0.05$). Other results were shown in Table 3.

The results of this study showed that changing the type of music and temperature caused significant changes in HR, as shown in Figure 2 in sections A and B, respectively.

The results of HR regarding different types of music at three temperatures of 20, 25 and 30 °C are given in Figure 3.

According to Figure 1, by a 5 °C increase in temperature when exposed to any of the rock, rap, pop, and traditional types of music, the average HR increases by 1, 0.5, 0.5, 1.6 beats per minute, respectively.

Figure 4 also shows the HR during exposure to the studied temperatures and types of music by gender.

[DOI: 10.18502/jehsd.v9i1.15114]

Table 3: Double comparison of mean and standard deviation of individual errors at two temperatures regarding the type of music

Type of music	Test stage	Mean of the number of errors in detecting textual errors (standard deviation)	P-value
Iranian traditional	25 °C 20 °C	10 (3.12) 14 (3.73)	0.002
Pop	25 °C 20 °C	7 (1.21) 7 (3.17)	0.071
Rock	25 °C 20 °C	12 (1.51) 14 (3.42)	0.000
Rap	25 °C 20 °C	8 (1.3) 9 (2.12)	0.065
Iranian traditional	25 °C 30 °C	10 (3.1) 15 (3.36)	0.000
Pop	25 °C 30 °C	7 (1.32) 8 (3.61)	0.125
Rock	25 °C 30 °C	12 (1.48) 16 (3.7)	0.000
Rap	25 °C 30 °C	8 (1.25) 9 (2.05)	0.080

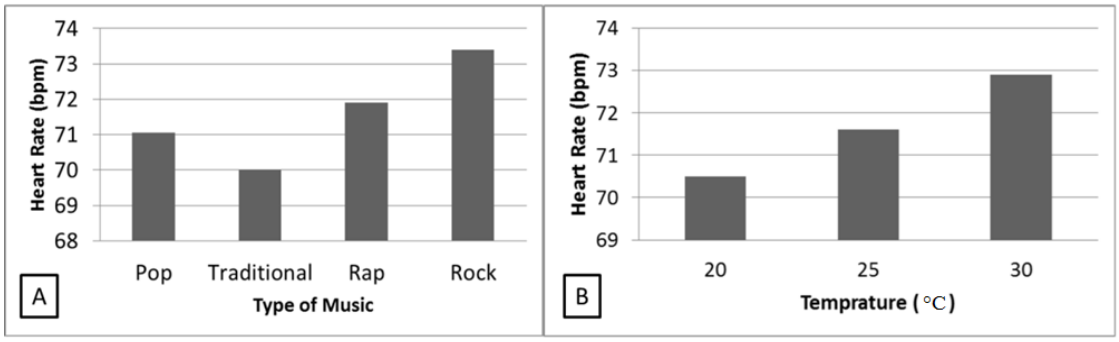

Figure 2: Quantitative changes in HR based on the type of music (A) and temperature changes (B)

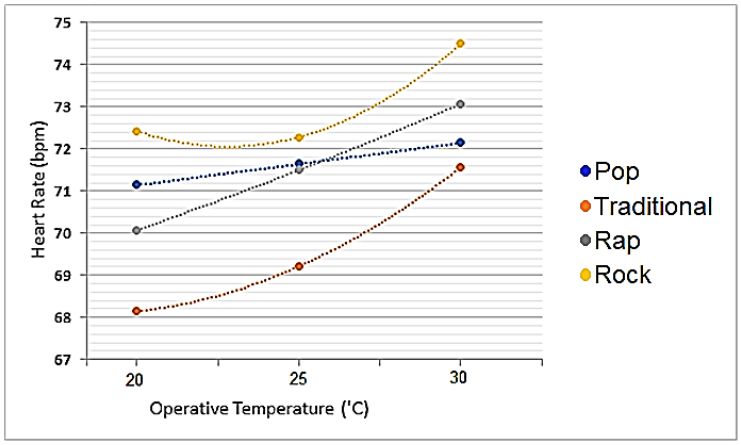

Figure 3: Mean of HR during simultaneous exposure to different types of music at the studied temperatures

[DOI: 10.18502/jehsd.v9i1.15114]

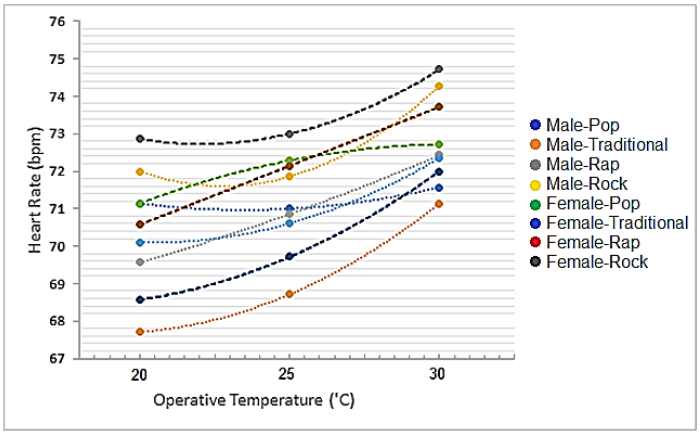

Figure 4: Mean of HR during exposure to the studied temperatures and types of music by gender

According to Figure 4, the results showed that men are less sensitive to changing the type of music. Therefore, by changing the type of music from traditional to rock, the HR of men changed less than women ($p < 0.05$).

Discussion

Some types of music such as Iranian traditional and Rock can affect the cognitive function of individuals while performing intellectual tasks, while some other types of music such as Pop and Rap produced no effect. The results of many studies were consistent with the results of this research [16-18]. According to Brian Dalton and David Bam's research, the effect of different types of noise and music on people's job performance depended on various factors such as the type of noise and music, its tempo, and its loudness [19].

Based on the current study, the highest negative impact on the cognitive function of the subjects was related to rock (emotional) music. When listening to this type of music, the subjects read the text in less time and made more mistakes. But, it can be concluded that this because of its excitement, this type of music makes people more excited. On the other hand, since all the participants were young, they were more affected by this type of music and made more mistakes in detecting textual errors. These results were consistent with the results of research by Kalian et al [16]. However, the results of this study contradicted with the results of the Kurhan and Gunard's research. They proved that rock music improved people's performance [3]. Of course, the difference in demographics of the participants in this study, the complexity of the work, or cultural factors, personality traits such as introversion, and extroversion can lead to such results. Regarding the possible reasons for the effect of personality type on performance, Jain et al. found that introverts performed better when playing soft music and extroverts performed better when playing louder and more emotional ones [20].

The reason for making more mistakes in detecting textual errors when playing traditional music, may be related to the rhythm of this type of music. When traditional music was played, the subjects spent more time since they felt more relaxed. Communicating with the song and engaging the minds of the subjects with the meanings and concepts of the song in traditional music may be another reason for the increase in human error caused by listening to this music.

The amount of temperature change affected the number of errors in detecting textual errors; however, when traditional Iranian and rock music were played and the temperature was increased and decreased by 5 °C compared to the comfortable temperature of 25 °C, more mistakes were made in detecting spelling mistakes

Consistent with the results of the present study, Manouchehr Omidvari et al. discovered that increasing both noise intensity from 75 to 93 dB and heat from 23.5 to 27.5 °C increased the error

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and reduced efficiency [21]. Furthermore, the results of Yao Chen's study showed that changes in ambient temperature from 25 to 40 °C increased HR [22]. This study also found that HR increased with increasing temperature. In the current study, however, exposure to traditional and rock music, which is a kind of harmonic sound, in combination with the studied temperatures, reduced human error and HR. This difference in the results was probably due to the cognitive effects of this harmonic sound on the attention of the participants whose feeling of the ambient temperature decreased. There had been no studies regarding the role of traditional music on human error. Only one study examined its effect on HR. Which showed the effects of music on cardiac function of young women. In other words, it seems that heart can synchronize with traditional Persian music in young women [23]. Based on this, it can be predicted that listening to music would activate many of the same brain regions. Probably, the harmonic sound of music causes mental relaxation, and considering that human's mental understanding of temperature can play a role in thermal comfort temperature, music changes people's tolerance to ambient temperature while listening to favorite music. This study had limitations which existed in other studies as well. Fatigue, personality traits, and interest in the participants' type of music during the research can be confounding factors which had not been considered in this study.

Conclusion

Listening to traditional Iranian and rock music in an environment with a -5 °C temperature cooler or warmer than the room temperature can have a positive and constructive effect on HR and reduce human error. Therefore, such music can be used as a background sound in hot or cold environments as well as workplace where human error and heart function are important factors in optimizing environmental conditions.

Acknowledgments

The authors would like to thank all the staff and students of Shiraz University of Medical Sciences for their cooperation.

Conflict of interest

The authors declared no conflict of interest.

Funding

This article was supported by Shiraz University of Medical Sciences, Shiraz, Iran.

Ethical considerations

Authors complied with the best practice regarding publication ethics specifically concerning the authorship (avoidance of guest authorship), dual submission, manipulation of figures, and competing interests. Authors adhered to publication requirements that the submitted work was original and had not been published elsewhere in any language.

Code of Ethic

Code no. IR.SUMS.REC.1397.989.

Authors' contributions

All the authors contributed to data collection, data analyses and manuscript writing.

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