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Research Article

The Effects of Music Tempo on Arithmetic Cognition Testing, Heart Rate, and Perceived Stress

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Abstract

Thirty-one participants signed up for one 60-minute appointment. The participants took four Arithmetic Tests and rated their perceived stress for each test. The first was a pre-test which allowed the participants to practice the procedure, and no results were recorded. The second was the control test with no music played. The third and fourth tests were randomized to include the fast-tempo or the slow-tempo song. The data recorded was time (in seconds), heart rate, test score (percent correct), and Likert Scale score (number from 1-10) following each test. The data was all recorded in a secure, password-protected online excel sheet. A one-way ANOVA test was conducted to identify if there was a significant difference between the three groups of music tempo with each dependent variable measured. Statistical significance was found between fast music and slow music tempo for perceived stress.

Keywords

Music tempo, perceived stress, heart rate, Arithmetic test

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Abbreviations

Peak Heart Rate= PHR

Average Heart Rate= AHR

ACTH= adrenocorticotropic hormone

SNS=sympathetic nervous system

Introduction

Music has been a source of enjoyment for thousands of years with the creation of the first musical instrument being recorded nearly 40,000 years ago [1]. Throughout this span of time and advance in technology, music has grown to include a variety of styles and has become a normal part of American culture. Music is played almost everywhere people gather whether it is at the supermarket, at the gym, in the hallways at school, on the road while driving, on TV, etc. But why do people listen to music so often?

Scholars found in a recent study that the main reasons people listen to music are to positively affect their mood, increase motivation, process thoughts and emotions, and relate to others around them [2]. However, it is still inconclusive how and if listening to music truly improves mental health and cognitive performance. Scientific scholars know how music is processed by the brain. Sound waves outside the body pass through from the outer ear to the middle ear where the eardrum (and tiny bones) vibrate. Then, vibrations travel to the inner ear where the cochlea's hair cells process tone and pitch. These hair cells transfer the vibrations into electrical signals which are then passed on to the brain by the cochlear nerve. This nerve passes these signals along to the cerebral cortex of the brain. Once it reaches this region for acoustical information, other neurons pass the information to secondary regions of the brain where music is then further processed. The motor cortex and the cerebellum are the areas of the brain responsible for analyzing rhythm, and the nucleus accumbens, amygdala, and the cerebellum are the areas which process emotions experienced while listening to music [3]. The amygdala also sends signals to the hypothalamus for the body to activate the SNS to combat the potential stressor. The hypothalamus passes the activation message to the anterior pituitary gland, releasing ACTH to activate the adrenal glands, located above the kidneys. The adrenal glands release catecholamines, including epinephrine, which increase heart rate, blood pressure,

respiration rate, and oxygen to the brain to increase focus [4]. The outer portion of the adrenal glands, the adrenal cortex, also releases cortisol which is responsible for increased ATP production to keep the body energized and alert [5]. Several studies found music significantly decreased heart rate, blood pressure, and perceived anxiety among participants as well as increased positive, pleasurable emotions. This suggests how music can impact processing of the amygdala as well as the mesolimbic system, a portion of the brain involved in processing emotions and feeling motivation [6].

There are many components of music which are difficult to separate. These can include sound, melody, harmony, rhythm, texture, structure, dynamics, tempo, and articulation. Researchers are still studying which components of music directly impact the body's stress response and benefit brain functioning in problem solving. One of the more prominently researched components of music studied in relation to stress responses and cognitive processing is tempo. Music tempo can be defined as the speed of the musical piece, in beats per minute [7]. A moderate tempo of a musical piece is about 80 to 100 beats per minute, with anything lower being classified as a slow tempo and anything greater being classified as a fast tempo [8].

Although there are various studies comparing music tempo and stress, many have mixed results. A study conducted in 2017 measured 120 female participants' average heart rates and galvanic skin response (or GSR which is skin's conductivity measured with electrodes) when listening to a slow music tempo, a fast music tempo, and sitting in silence with earplugs in. When the body's stress response is activated, average heart rate and GSR, skin conductivity, increase which makes both dependent variables viable indicators of physiological measurements of stress. The participants were divided into three groups, each group conducting a baseline test without treatment, and a posttest with the treatment (silence, listening to slow music, listening to fast music). Researchers concluded that fast music tempo resulted in increased average heart rate compared to the baseline test ($p=.029$), slow music tempo resulted in decreased heart rate compared to the baseline test ($p=.002$), no music resulted in decreased heart rate compared to the baseline test ($p=.043$), fast music tempo resulted in increased GSR compared to the baseline test ($p=.001$), no music resulted in increased GSR compared to the baseline test ($p=.001$), and there was no significant difference for slow music tempo and measured GSR for the baseline and posttests [9]. Although the study did not measure

perceived stress, it was significant in finding how music tempo affected average heart rate which could be further investigated to learn more about how music tempo impacts the stress response.

Another study conducted in 2015 measured math and reading test performance scores, as a correct percentage, and heart rate variation while twenty participants listened to different genres of music. Each subject completed a reading comprehension quiz and solved algebraic math problems while listening to soft music, rock music, heavy metal music, and no music. Researchers concluded that there were not any statistically significant differences between music genres listened to, heart rate, and test performances [10]. A different study measured math test scores and music tempo among thirty-seven students. The students were randomly assigned to one of four music tempos, two were fast and two were slow, and instructed to complete a math questionnaire with 34 questions in three minutes while listening to the music. The researcher concluded that there was also statistical significance when comparing music tempo and the math test scores [11].

There are many published studies regarding the effects of music tempo and music genre on perceived stress, physiological stress, and cognitive testing performance. However, the results are mixed, and many investigate different components of music at the same time. This research experiment examines tempo of instrumental music compared to no music on Arithmetic Test scores, Arithmetic test time, heart rate, and perceived stress. The hypotheses of this experiment are three-fold: fast music tempos will result in decreased time and will have no effect on test scores, heart rate, and perceived stress. Slow tempo will result in increased time, have no effect on test scores, and will result in decreased heart rate and decreased perceived stress; and finally, no music will have no effect on test time and score but will result in increased heart rate and perceived stress.

Materials and Methods

Participants were recruited by researchers and the Applied Health Sciences department at Bethel University. Potential participants willing to participate were screened for meeting inclusion and exclusion criteria. All participants had to be between the ages of eighteen and twenty-four years old, could not have a diagnosed hearing or vision loss (needing to wear glasses or contacts was acceptable in this study but

conditions such as glaucoma, partial/full blindness, macular degeneration, diabetic retinopathy, partial/complete deafness, or those who identifying as "hard of hearing" pertained to this criteria), could not have a diagnosed learning disability or mental condition affecting learning or focus (including Autism Spectrum Disorder, ADHD, ADD, Down Syndrome, and Dyslexia), could not have had any past brain or spinal cord injury in their lifetime that limited reaction time or hand-eye coordination, and all participants had to be cleared of a concussion if it took place within six to twelve months of testing. Those eligible to participate completed the informed consent process. The investigator verbally summarized the contents of the informed consent and allowed participants to read through the document and ask questions before signing. Participation by participants was fully voluntary and participants were allowed to withdraw from the study at any time. Participants were informed of the confidentiality of their participation, and the risks and benefits of participating in the study. Participants who gave consent to be in the study were provided a copy of the signed document, containing the contact information of the investigators.

Data was collected in the Biokinetics Program lab spaces at Bethel University during one appointment. During this appointment, participants were told the purpose of the study and that they would complete the Arithmetic Tests, Perceived Stress Scales, and the self-assessment stress analyses. They also completed the Participant Questionnaire, pre-testing, and they were given a copy of the Emergency Action Plan. The participants completed a pre-study Arithmetic Test in order to familiarize themselves with the test. Researchers informed participants about the rules of the arithmetic test. Participants were told to complete the questions to the best of their ability while also working as quickly as possible. They were not allowed to look back at their answers to check or redo them. Before the completion of the Arithmetic Test but after instructing, participants completed the Perceived Stress Scale to determine their baseline stress score (scores ranged from 0-40). Total scores on the Perceived Stress Scale are categorized into low stress (0-13), moderate stress (14-26), and high perceived stress (27-40). These scores were kept as reference once the participants evaluated their stress for the next three trials in which they completed the Arithmetic test with no music, music with a fast tempo, and music with a slow tempo.

After the practice run, the participants were given a ten-minute break before they began the control trial. They were tested in a quiet, isolated room in which they were sitting at a desk and given a heart rate

monitor to keep track of their heart rate. Participants were told that this would be the first part of the test out of three parts. They were given the Arithmetic Test on paper, paper facing-down, and a pen. They were told they could start once the researcher says "go" and that they could not go back to check or change answers, and they were told to place pens down when done. The participants were also informed that they would take a self-assessment stress analysis once they completed the Arithmetic Test. This self-assessment was a Likert Scale, ranging from 1 to 10, with one being little to no stress and 10 being the most extreme feelings of stress. To begin the test, participants were given a countdown in which the researchers said, "three, two, one, go!" On the "go", participants flipped over the paper, the researchers started the timer, and they completed the test to the best of their ability. Once the participants set their pen down on the paper, the researcher stopped the timer and graded the test. The participants were not allowed to know their time or score. AHR and PHR were recorded, and the stress self-assessment was given.

After the ten-minute break, participants were given the same instructions as the first trial with the addition of being informed they would listen to music. The participants were informed that the music tempo was randomly selected for them and would be different the next trial. The selected music played for 45 seconds before they began the test so that the subject could adjust to the background noise and not interfere with test results. The same verbal cues were given to the participants to start and end the test as in the last two tests, and they wore the heart monitor throughout the test. When the researchers said "go", the participants flipped the paper over while music continued to be played at a consistent volume until the tests were completed. Once the participants completed the test, the researchers stopped the timer. The researchers recorded the time in seconds and the score of the test. The researchers recorded AHR and PHR. Following the test, the participants were handed the stress self-assessment in which they indicated the level of stress they felt while completing the test. A final 10-minute break was given before beginning the last trial.

During the last trial, the researchers repeated the steps from the previous trial. The researchers gave the same verbal cues for the participants to begin and end the test. They informed participants that they would be listening to a different tempo, and the music was played for 45 seconds before beginning the test. Following the test, the participants completed the stress self- assessment. Researchers recorded the test

scores, test times, AHR, PHR, and self-assessment scores. The researchers thanked the participants for completing their experiment.

All information about the participants obtained from this research were kept confidential. All tests and information regarding participants were locked in a secure cabinet in the Biokinetics department, and the recorded results online were kept in a password-protected file. The participants were not identified by name in any publication of research results unless a signed release form was provided. Any disclosure of the participants' information and results could only be shared with the subject's permission. In any future written reports or publications, no one will be identified, and only aggregate data will be presented. The data received from the research will be retained for two years after the completion of this study and will be accessible at the request of the participants.

Results

A one-way ANOVA test was conducted to identify significant differences between the three groups of music tempo with the physiological measurements of stress (AHR, PHR, perceived stress, test scores, and test times). Statistical significance was found between fast music and slow music tempo for perceived stress ($p < .001$). Perceived stress scores were as follows: control (3.64 ± 1.60); fast tempo (4.54 ± 1.54); slow tempo (2.87 ± 1.49). These values can be seen in figure 1. No significant differences were noted in all other variables. AHR (bpm): control (84.03 ± 9.16); fast tempo (83.70 ± 10.47), slow tempo (83.09 ± 10.86). PHR (bpm): control (93.29 ± 10.06), fast tempo (90.54 ± 11.48), slow tempo (90.12 ± 10.80). Test scores (percentage): control (95.39 ± 4.30), fast tempo (92.56 ± 17.12), slow tempo (92.78 ± 17.57). Test time (seconds): control (94.87 ± 32.83), fast tempo (98.50 ± 35.90), slow tempo (94.90 ± 33.64).

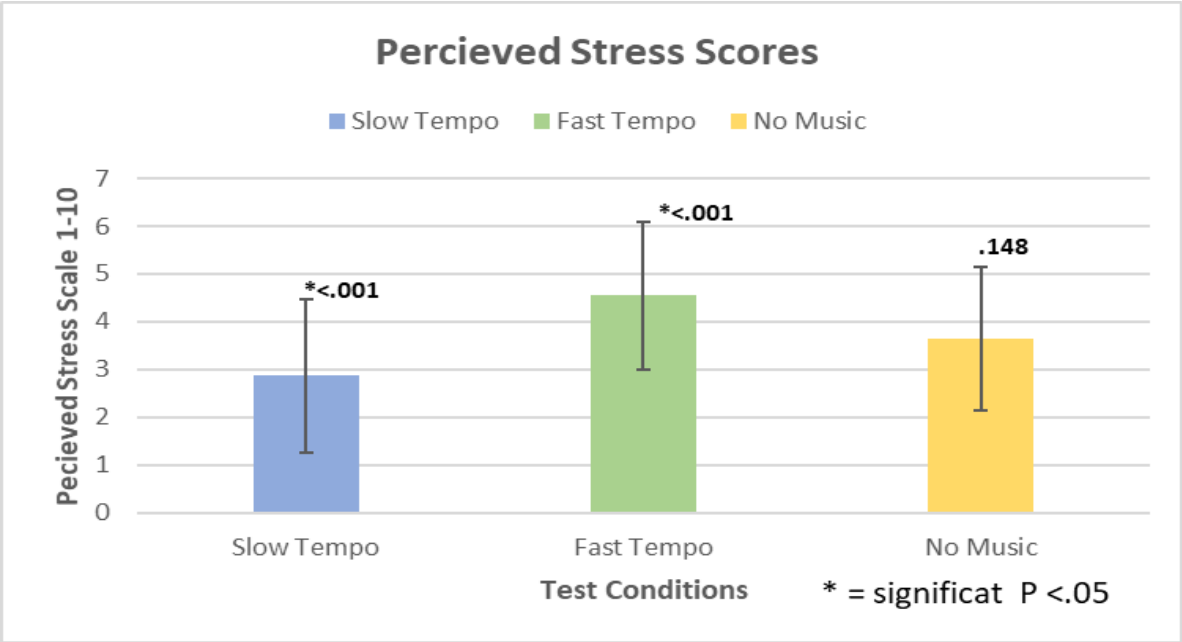

Figure 1

Perceived stress significance with no music, slow music tempo, and fast music tempo

Discussion

This research looked at how music tempo affects heart rate, perceived stress, and arithmetic testing scores and times. After conducting the research, it was found that even though the participants' perceived stress was lower during the slow tempo when compared to the fast tempo, there were no observed physiological effects of stress. This may be due to the music having a dual effect on other body systems such as the endocrine system and hormone regulation.

If one is looking to improve their performance in a simple arithmetic test or anything similar, music will neither improve or diminish their performance or their test taking speed. Slower tempo music can have a positive impact on lowering a person's perceived stress when completing tasks like the simple math test. One potential explanation for lower perceived stress levels could be due to the brain processing too much at once and the fast tempo music becomes more of a distraction. One thing that could be done for future research is adding a questionnaire to figure out why the participant felt the way that they did during the test.

A few of the weaknesses with our study was consistency with testing environment, Music preference, time of day person was testing at, and timing techniques. The two researchers did their best to keep the testing environment as consistent as possible, this was not always attainable however and at times the testing environment would vary slightly. Some of these inconsistencies was the amount of sound coming from neighboring rooms or hallways. The clutter in the lab space would also vary at times. Both factors could have affected how distracted the participants were during the test. Music Preference also could have negatively affected our studies. Instrumental music was the selected music type for the study due to past studies showing this music had positive effects on academic performance. If participants don't listen to instrumental music, don't like instrumental music, or don't normally listen to music at all when working, they may find the music to be more distracting than helpful. The time of day may have also affected participants' performance. Appointments consisted throughout the day and depending on when a person may be most mentally aware may vary from person to person. A handheld timer was used to keep track of the person's test time which may have affected our results as well.

A few of the positives from the test was the order of tests, and consistency with the tests taken. The order of the tests was very important for the study. The first test was always the practice test so participants had an idea of the types of questions that would be asked. The second test was always the control. The reason for this was that if the control with no music was the third or fourth test, participants may have past songs stuck in their head. Music trials were random for the last two tests. All participants completed the same 4 tests in a random order. This way the participants had all the same questions, and no participant had a harder test than the others.

Conclusion

There was significance in this study for perceived stress between the fast tempo music and the slow tempo music. The statistical significance suggested that there was a change in perceived stress linked to music tempo. It may not have made a difference in choosing to listen to music or not when completing a task, but the tempo of the musical piece may have impacted the perceived stress of the individual. There was evidence found in recent studies that slow music tempos of about 60 beats per minute can cause the brain to

link up with the beat of the song and give off alpha brain waves [12]. These waves were given off when the body was in a relaxed state such as when one was meditating or daydreaming [13]. It may be more beneficial for students who are stressed to listen to slow tempo music that they enjoy releasing these brain waves and decrease perceived stress. If people force themselves to listen to music they dislike, this could build up frustration and increase stress [12]. Perceived stress and physiological components of stress are different even though they usually occur at the same time. Scholars have also found that certain stressors can be processed in different parts of the brain and have different physiological effects. Psychosocial stress tends to be processed in the right superior temporal gyrus and the striatum is turned off while physiological stress is processed in the insula, striatum, and middle cingulate cortex. Because of these differences, the neural signals released are different from the two types of stress. Physiological stress lights up the sympathetic nervous system, releasing epinephrine and cortisol. Psychosocial stress causes the subject to focus on their emotions, such as how they perceive the stress, and their goals going forward [14]. The data of this experiment revealed that music tempo does impact perceived stress. However, future research is essential to examine the neurological differences between psychosocial and physiological stress as well as how the brain connects with certain tempos of music.

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