Tempo and Autonomic Control of the Heart

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Music is a powerful stimulus and has been found to influence cardiovascular activity, including heart rate, blood pressure, respiration and heart rate variability. Previous research has used complex pieces of music which render it difficult to determine whether changes in a particular musical parameter are associated with the observed variations in cardiovascular activity. This study uses simple musical stimuli to overcome this issue, with the aim to investigate the effect of sudden changes in tempo on autonomic control of the heart. Heart rate, blood pressure, respiration rate, heart rate variability and baroreflex sensitivity are measured in four experimental conditions. The musical background and health status of all participants are ascertained to explore individual differences in cardiovascular responses. Preliminary findings demonstrate that heart rate during the four conditions is mediated by prior exposure, gender and age at which an individual starts formal music training. Relationship between music and physiology is complex. This study concludes that more controlled and simple musical stimuli can be used to examine the impact of music on autonomic control of the heart.


1. INTRODUCTION

Music is adept at touching the hearts of listeners and is exceptionally powerful at provoking a range of emotions (van der Zwaag, Westerink & van den Broek 2011). As listeners to music we often conceptualise feeling the music throughout the body, therefore implying that music influences human physiology as well as human psychology. With technological advancements in physiological research, better insights into how music directly influences the body are being revealed. Indeed, research investigating the impact of music on cardiovascular functioning is beginning to show that music has a profound impact on autonomic control of the heart.

The autonomic nervous system is a complex physiological system that controls the functioning of internal organs, including the human heart (Charkoudian & Wallin 2014, Porges 2011). The autonomic nervous system is composed of two sub-systems: the sympathetic nervous system which mobilizes energy resources to prepare individuals for action; and the parasympathetic nervous system which conserves energy resources to maintain homeostasis (Porges 2011). These sub-systems act in an antagonistic manner to influence the heart. Activity within the two sub-systems has been found to be influenced by musical parameters, including tempo (Bernardi, Porta & Sleight 2006, van der Zwaag, Westerink & van den Broek 2011), rubato (Mikutta et al. 2013) and dynamics (Bernardi et al. 2009). Fluctuations in activity in the sympathetic and parasympathetic nervous systems can be quantified by capturing heart rate, blood pressure and respiration rate, and by deriving heart rate variability and baroreflex sensitivity (Charkoudian & Wallin 2014, Patel et al. 2013).

1.1 Heart rate

Heart rate has been measured in many research studies to investigate the impact of changes in musical parameters on autonomic nervous system activity. For instance, Bernardi et al. (2009) investigated the impact of musical dynamics on cardiovascular activity and found that heart rate significantly increased when music became louder and was significantly reduced during moments of silence.

Heart rate is quantified as the number of beats per minute and regarded as an indirect measure of autonomic activity (Patel et al. 2013). A quicker heart rate is considered to be a result of increased sympathetic and decreased parasympathetic activity, whereas a slower heart rate is considered to be a result of increased parasympathetic and decreased sympathetic activity (Patel et al. 2013). Heart rate can be captured using photoplethysmography (PPG) or electrocardiograms (ECG) (Heathers 2013).
PPG is a less traditional method for capturing heart rate. This data capture method can be run on portable devices, including smartphones and tablets, therefore facilitating data collection outside of the laboratory (Heathers 2013). PPG uses an optical pulse sensor, such as an infrared sensor, to illuminate the skin and detect changes in light absorbency (Heathers 2013). Light absorbency changes over the time interval between consecutive heart beats as a result of changes in blood volume following the contraction and relaxation of the heart. For example, light absorbency decreases when the heart contracts, due to a sudden surge in blood volume in the arteries, and increases when the heart is at rest. Fluctuations in the voltage output of the sensor resulting from continuous variations in blood volume can then be analysed to derive heart rate and heart rate variability (see section 1.4).

A more traditional, and perhaps more reliable, method of capturing heart rate involves using ECG (Heathers 2013). ECG records the electrical activity of the human heart by placing electrodes on the upper torso of the human body (Heathers 2013). The resultant trace can then be analysed using computer programs to explore moment-to-moment variations in heart rate. Since the methodology for setting up, recording and analysing heart rate as captured by ECG is better established than that of PPG, the current study uses ECG to capture continuous readings of participant heart rate in four experimental conditions.

1.2 Blood pressure

Blood pressure is conceptualised as the amount of cardiac force exerted on blood vessels in the body when blood is being pumped around the body (Charkoudian & Wallin 2014, Patel et al. 2013). Blood pressure is expressed as two types: systolic blood pressure, which refers to the pressure in arteries when the heart contracts; and diastolic blood pressure, which refers to the pressure in arteries between heart beats (Charkoudian & Wallin 2014, Patel et al. 2013). Although the investigation of the impact of music on blood pressure has received considerably less interest than the impact of music on heart rate, there is evidence suggesting that systolic and diastolic blood pressures are sensitive to alterations in musical parameters.

For instance, Bernardi, Porta and Sleight (2006) found that systolic and diastolic blood pressures significantly increased when participants listened to music that had a fast tempo. In a follow-up study, Bernardi et al. (2009) demonstrated that systolic and diastolic blood pressures were highly responsive to large and small changes in musical dynamics: crescendos were associated with increases in blood pressure, and periods of silence were associated with reductions in blood pressure. These intriguing findings indicate that capturing continuous readings of blood pressure in a musical context is an informative method for producing a comprehensive account of the effect of music on the autonomic nervous system.

Blood pressure data can be captured using a finometer machine as well as the conventional upper-arm blood pressure monitor. However, unlike the upper-arm blood pressure monitor which involves the placement of a large cuff around the upper arm, the finometer requires a small cuff placed on the middle phalanx of the middle finger. This small cuff then inflates and deflates during air pressure measurement in a similar way to the upper-arm monitor. Additionally, in contrast to the upper-arm monitor which can only provide episodic readings, the finometer can provide continuous readings over ten minutes that have high temporal resolution. Therefore, the finometer is an appropriate non-invasive method for investigating moment-to-moment variations in blood pressure as a result of cardiovascular reactions to changing external circumstances.

In the current study, a finometer is used to explore the real-time fluctuations in blood pressure in four experimental conditions. An upper-arm blood pressure monitor is also used at specific time points in the study to provide intermittent readings that serve as a reference point for finometer readings.

1.3 Respiration

Respiration, like heart rate and blood pressure, is a product of neural interactions between the sympathetic and parasympathetic nervous systems (Charkoudian & Wallin 2014, Patel et al. 2013). As a result of these interactions, respiration has a dynamic and intimate relationship with heart rate and blood pressure and hence needs to be monitored when investigating cardiovascular responses to external stimuli (Charkoudian & Wallin 2014, Patel et al. 2013). For instance, deep, slow breathing is associated with a decrease in heart rate and blood pressure, whereas, fast, shallow breathing is associated with an increase in heart rate and blood pressure (Patel et al. 2013).

Since heart rate and blood pressure have been demonstrated to vary with changing musical parameters, it comes as little surprise to note that respiration has also been found to be influenced by musical parameters. For instance, after exposing participants to six musical excerpts of different tempos, Bernardi, Porta and Sleight (2006) found a positive correlation between respiration rate and
tempo. Furthermore, the data indicated that musicians had greater respiratory sensitivity to the different tempos than non-musicians. In a follow-up study, Bernardi et al. (2009) developed upon these findings by providing evidence of a positive correlation between respiration rate and sound intensity. The authors also found that musicians showed a stronger response to sound intensity than non-musicians. These findings indicate that respiratory responses to music may be mediated by musical background and warrants further investigation. The reported findings also demonstrate that the capture and analysis of respiration is a valid method for investigating the impact of music on autonomic control of the heart.

Respiration rate is conceptualised as the number of breaths per minute and can be measured using a pneumograph. A pneumograph is a tube placed around the upper torso that continuously measures chest movement as individuals inhale and exhale. The resultant traces can then be analysed to explore the relationship between respiration rate, heart rate, blood pressure and external stimuli. The current study uses a pneumograph to explore the impact of musical stimuli on moment-to-moment variations in breathing rate whilst participants experience four experimental conditions.

1.4 Heart rate variability

Heart rate variability is derived from heart rate recordings and quantifies the amount of variance in the time interval between consecutive heart beats (interbeat interval) as well as changes in activity within the sympathetic and parasympathetic nervous systems (Patel et al. 2013). Heart rate variability can be derived using two different types of analysis: time-domain analysis and frequency-domain analysis (Malik 1996).

Time-domain analysis is typically conducted on long-term (24 hour) recordings and quantifies the extent to which the interbeat interval changes over the course of the heart rate recording (Bilchick & Berger 2006, Malik 1996). Frequency-domain analysis is conducted on shorter duration recordings and uses spectral density analysis techniques to split the heart rate signal into different frequency components (Bilchick & Berger 2006, Malik 1996). The splitting of the signal facilitates the exploration of how shifts in the balance between the sympathetic and parasympathetic nervous systems influence changes in the interbeat interval (Malik 1996). Frequency-domain analysis with short-term recordings can identify two frequency components which are considered to represent different physiological mechanisms. A high frequency (HF) component, centred on 0.15-0.4Hz which represents parasympathetic activity; and a low frequency (LF) component, centred on 0.04-0.15Hz, which represents sympathovagal activity (combined sympathetic and parasympathetic activity) (Bilchick & Berger 2006, Malik 1996, Xhyheri et al. 2012). In order to assess sympathetic-parasympathetic balance, a LF/HF ratio can be calculated (Bilchick & Berger 2006, Malik 1996, Xhyheri et al. 2012). A high LF/HF ratio is indicative of increased sympathetic modulation of heart rate and a low LF/HF ratio is indicative of increased parasympathetic modulation of heart rate (Xhyheri et al. 2012).

Previous research has investigated the impact of changing musical parameters on heart rate variability. For instance Iwanaga, Kobayashi and Kawasaki (2005) investigated the impact of repetitive exposure to music on heart rate variability. After exposing participants to three conditions (no music, sedative music and excitative music) four times, the researchers found that HF component activity was highest for the sedative music and LF component activity was highest for the no music condition. HF component activity did not change with increasing repetition of the sedative music. However, HF component activity increased for excitative music and decreased for the no music condition with increasing repetition. LF component activity and the LF/HF ratio increased with increasing repetition for the sedative and excitative music conditions and decreased for the no music condition. These findings show that different types of music can impact activity in the sympathetic and parasympathetic nervous systems. The findings also demonstrate that the amount of exposure to musical stimuli can mediate autonomic responses to musical stimuli.

For the purposes of the current study, frequency-domain heart rate variability analysis was conducted. This analysis provided an indirect measure of moment-to-moment fluctuations in autonomic balance. Time-domain analysis could not be performed as the heart rate data was not collected for long enough to reliably derive the time-domain analysis parameters.

1.5 Baroreflex sensitivity

Blood pressure is regulated by a range of neural and vascular mechanisms including baroreceptors which detect changes in blood pressure and relay information to structures in the brainstem (Charkoudian & Wallin 2014). Increases in blood pressure lead to increases in activity in baroreceptor afferent nerves. This information is sent to the brainstem via neural pathways, and results in increased parasympathetic activity and the lowering of heart rate and blood pressure. This negative feedback system is known as the arterial baroreflex and functions to control blood pressure.
The arterial baroreflex and baroreflex sensitivity are important for regulating long-term and transient blood pressure changes and are highly sensitive to continuously changing sensory, emotional and cognitive demands (Charkoudian & Wallin 2014). Since music is considered to be an emotive, cognitive and sensory stimulus, one would assume that listening to music would lead to changes in the control of blood pressure. However, no research investigating the impact of musical parameters on baroreflex sensitivity has been conducted. In response to this area of inquiry, the current study derives baroreflex sensitivity by applying spectral density analysis techniques to the finometer blood pressure data to assess the impact of four experimental conditions on autonomic control of arterial blood pressure.

1.6 Reflections on previous research

It is clear from the research reviewed so far that music has a profound impact on autonomic control of the heart. In addition, the previous research highlights that in order to obtain a comprehensive account of the influence of music on cardiovascular functioning, numerous physiological measures need to be employed. However, the majority of previous research investigating the effect of changes in musical parameters on autonomic control of the heart have used complex, “real-world” musical stimuli which alter numerous parameters simultaneously. As a result, it is difficult to ascertain whether changes in a particular parameter are associated with the observed cardiovascular changes, and therefore call the reliability of these findings into question.

In order to overcome this issue, the current study develops and uses simple and tightly controlled auditory stimuli that manipulate one musical parameter at a time, in this case tempo. The study seeks to gain a comprehensive account of how sudden changes in tempo, in the form of stepped increases and decreases in tempo, impact autonomic control of the heart. Heart rate, blood pressure and respiration rate are continuously recorded and heart rate variability and baroreflex sensitivity are derived. Although the auditory stimuli may have limited ecological validity it is hoped that by adopting an experimental approach, more reliable conclusions can be reached regarding the impact of changes in tempo on cardiovascular functioning.

This paper will detail: the research aims in section 2 and the experimental methodology in section 3. In section 4, results from the heart rate data will be detailed and discussed, followed by a conclusion in section 5. The paper will end with acknowledgments in section 6 and references in section 7.

2. RESEARCH AIMS

The study aims to:

(i) Examine the effect of stepped increases and decreases in tempo on autonomic control of the heart

(ii) Explore individual differences and within-participant consistency in autonomic control of the heart during four experimental conditions

3. METHOD

3.1 Participants

The study is ongoing and uses an initial sample of 10 participants. The sample is comprised of six females and four males, mean age of 24.90 years, SD = 3.90, range 18 to 30. Two participants had no formal music training. For participants whom had undergone formal music training, five had started aged nine or under (mean age = 6.20, SD = 0.84) and three had started aged 10 or above (mean age = 13.00, SD = 3.61). No participants had been diagnosed with heart disease, diabetes, high blood pressure or severe auditory impairments and all lead an active lifestyle, mean number of hours of exercise per week = 6.00, SD = 5.01.

Due to the presence of cardiovascular circadian patterns, the study is conducted between 14:00 and 16:00 only. Participants are asked to avoid caffeine, nicotine and strenuous exercise for 12 hours before the study. They are also asked to have a light breakfast and lunch before testing. The study has been approved by the University of Leeds’ research ethics committee, and written informed consent is obtained from all participants prior to testing.

3.2 Materials

3.2.1. Auditory stimuli

The auditory stimuli is created using Python with the Pygame library, and subsequently recorded as a wave file using Audacity. A simple Python code was developed to generate the auditory stimuli using MIDI instruments, rather than a music composition program, such as Sibellius. This was because the code affords greater efficiency for
controlling musical parameters, including tempo, rhythm, volume and pitch.

The stepped increase and decrease in tempo conditions consist of five different tempos: 60bpm (Adagio), 90bpm (Andante), 120bpm (Allegro), 150bpm (Vivace), 180bpm (Presto). Each tempo plays for 60 seconds so that the stepped increase and decrease in tempo conditions are five minutes in duration. The tempos are organised in ascending order for the stepped increase in tempo condition and organised in descending order for the stepped decrease in tempo condition. The beats in each stimuli are unstressed i.e. have the same pitch and are played at the same volume, so that no specific metre or rhythm is expressed. The auditory stimuli are uploaded onto an MP3 player and presented to participants via wired over-the-head headphones.

3.2.2. Questionnaires
Participants complete a basic health and musical background questionnaire. The health questionnaire requires participants to provide information pertaining to their lifestyle and medical history. The musical background questionnaire requires participants to provide information about musical habits and any formal music training. The information obtained from the questionnaires will aid with the identification of individual differences in cardiovascular responses to four experimental conditions.

3.3 Apparatus

3.3.1. Auditory stimuli
A SanDisk Sansa Fuse+ MP3 player and Sony MDR-P180 wired over-the-head stereo headphones are used to play the auditory stimuli to participants.

3.3.2. Physiology equipment
A three-lead electrocardiogram (ECG) is used to monitor and record heart rate. This involves attaching electrode pads to the right collarbone and either side of the bottom of the ribcage. Respiration rate per minute is recorded using a pneumograph, a tube placed high around the chest of participants that records chest movement during breathing. Finally, a finometer and Omron upper-arm blood pressure monitor are used to measure blood pressure. The finometer involves attaching a small cuff onto the middle phalanx of the middle finger on the left hand which inflates with air during blood pressure measurement.

3.4 Procedure
Participants attend the University of Leeds on two occasions spaced at least seven days apart. Participants are randomly assigned to a group: Group A or Group B, and remain in the assigned group on both occasions. On each occasion participants experience four conditions: a five minute baseline (control) condition; a five minute stepped increase in tempo condition; a five minute stepped decrease in tempo condition; and a five minute recovery period. The order of presentation of the tempo conditions (either stepped increase or stepped decrease) is counterbalanced so that participants in Group A receive the stepped tempo increase followed by the stepped tempo decrease, while participants in Group B received the stepped tempo decrease first and then the stepped tempo increase.

At the beginning of the study a basic health and musical experience questionnaire is administered and participant height and weight is obtained. Details from these preliminary measures will be used to explore the presence of any differences between groups within the sample. Next, systolic blood pressure, diastolic blood pressure and heart rate are measured three times using the Omron blood pressure monitor. The average of each measure is computed and serves as a point of reference for finometer blood pressure readings.

The ECG, pneumograph and finometer are then attached to participants. Participants undergo an adaptation period of approximately three minutes until cardiovascular measures have stabilised, then the study commences starting with the baseline condition. At the end of the first, third and fourth conditions, the finometer is stopped to prevent the occurrence of ischemia in the finger, and systolic blood pressure, diastolic blood pressure and heart rate are taken three times using the Omron blood pressure monitor. The average is computed and the finometer restarted prior to the next condition. No break occurs between the second and third conditions.

Throughout the study, participants are made comfortable and remain semi-supine on a couch with pillows supporting the head. Participants are asked to remain still and to refrain from talking during data collection. The headphones are present in all conditions to ensure that the presence or absence of the headphones does not confound the cardiovascular data.

At the end of the study ECG, pneumograph and finometer recordings are stopped and the equipment detached from participants. The total duration of the study is 60 minutes.

3.5 Data acquisition and analysis
The auditory stimuli and all ECG, pneumograph and finometer signals are continuously acquired via a Power1401 (Cambridge Electronic Design Limited, Cambridge, UK). ECG, pneumograph and finometer data are analysed using Spike2 software.
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Heart rate variability is derived from the ECG recordings by applying spectral density analysis to a tachogram. This technique expresses heart rate variability as LF and HF components. Sympathovagal balance is evaluated by calculating the LF/HF ratio. Baroreflex sensitivity is calculated using Spike2 software by applying spectral density analysis to the finometer blood pressure recordings.

3.6 Statistical analysis

To examine the effect of stepped increases and stepped decreases in tempo on autonomic control of the heart a one-way repeated measures ANOVA (analysis of variance) is performed. To explore individual differences in autonomic responses during the four conditions, a mixed design ANOVA is used. Finally, to explore within participant consistency in autonomic control of the heart, a two-way repeated measures ANOVA is conducted. An alpha level of 0.05 is used in all statistical analyses. SPSS (www.ibm.com/software/analytics/spss/) is used for all statistical analyses.

4. RESULTS AND DISCUSSION

In the following section, results for the heart rate data collected in the first and second visits will be detailed.

4.1 Heart rate during the first visit

A one-way repeated measures ANOVA found that heart rate in visit one significantly differed between the four conditions, \( F(3,27) = 4.363, p = 0.013 \). As shown in Figure 1, heart rate was highest in the baseline condition and gradually decreased in the remaining conditions. Therefore, throughout the study participants became increasingly relaxed.

A mixed ANOVA was performed with condition as the within-subjects factor and age at which formal music training commenced as the between-subjects factor. No statistically significant main effect of age at which participants started formal music training on heart rate was found \( (p = 0.83) \). Additionally, the interaction between heart rate and age at which formal music training began was not statistically significant \( (p = 0.32) \). Nevertheless, heart rate responses during the second, third and fourth conditions differed between the two groups. A greater decrease in heart rate during the stepped increase in tempo condition occurred for those who started formal music training aged ten or above. Heart rate then continued to decrease during the remaining conditions. This is in contrast to those who started formal music training aged nine or below. For this group, heart rate decreased during the stepped increase and decrease in tempo conditions and increased during the recovery condition. As a result, it seems that those who started formal music training later in life showed a stronger response to the stimuli than those who started at a younger age. One possible interpretation of this finding could be that the age at which an individual starts formal music training may influence physiological responses to simple musical stimuli.

![Figure 1: Mean heart rate for the four conditions for both visits](image)

![Figure 2: Mean heart rate for males and females for the four conditions in visit one](image)

A mixed ANOVA was conducted with condition as the within-subjects factor and gender as the between-subjects factor. No statistically significant main effect of gender on heart rate was found \( (p = 0.28) \). However, a statistically significant interaction between heart rate and gender was identified, \( F(1,8) = 20.02, p = 0.01 \).
Figure 2 shows that heart rate decreased for both males and females over the course of the study. However, heart rate was consistently higher for females than males. Furthermore, females showed a weaker response than males, suggesting that male participants may have been more sensitive to the experimental manipulations. Interestingly, heart rate increased during the recovery condition for females and decreased for males. This finding implies that there may be important differences between males and females in how they cognitively appraise the final condition. Indeed, it appears that females became more aroused in the recovery condition, whereas males became more relaxed.

4.2 Heart rate during the second visit

A one-way ANOVA showed that heart rate in visit two did not significantly differ between the four conditions (p = 0.51). Similar to that observed during visit one, heart rate was highest during the baseline condition (see Figure 1). However, in the second visit, heart rate decreased during the stepped decrease in tempo condition and was lowest in the recovery condition. This suggests that prior exposure may have mediated heart rate responses to the auditory stimuli. Follow-up research that incorporates more visits into the study design should be conducted to further explore the impact of previous exposure to the conditions on heart rate.

A mixed ANOVA was conducted with condition as the within-subjects factor and age at which formal music training commenced as the between-subjects factor. The main effect of age at which formal music training started was not statistically significant (p = 0.21). Also, the interaction between heart rate and age at which formal music training began was not statistically significant (p = 0.37). Nevertheless, Figure 3 illustrates that those who started formal music training aged nine or below had a lower overall heart rate than those who started formal music training aged ten or above. This finding has important practical implications in terms of healthcare and music education. In addition, those who commenced music training earlier in life showed a pattern one would expect: a faster heart rate during the stepped increase in tempo condition and a slower heart rate during the stepped decrease in tempo condition. In contrast, those who started music training later in life showed an unexpected pattern: a slower heart rate during the stepped increase in tempo condition and a faster heart rate during the stepped decrease in tempo condition. Interestingly, both groups showed an increase in heart rate during the recovery condition, with those who started formal music training aged ten or above demonstrating a stronger response.

A mixed ANOVA with condition as the within-subjects factor and gender as the between-subjects factor was computed. No statistically significant main effect of gender on heart rate was found (p = 0.31), and no statistically significant interaction was identified (p = 0.21). Similar to visit one, females had a consistently higher heart rate compared to males during the study. Nonetheless, a response pattern different to that identified in visit one emerged. The difference in heart rate between males and females for the first three conditions was smaller than the difference that occurred in visit one. Moreover, heart rate in the recovery condition greatly increased for females and greatly decreased for males. This finding adds further support to the notion that there may be differences between males and females in how they appraised the final condition.

A two-way repeated measures ANOVA with condition and visit as within-subject factors found a statistically significant main effect of visit on heart rate, F(1.5) = 20.82, p = 0.006. Indeed, as illustrated in Figure 1, heart rate was consistently higher in visit two than in visit one, suggesting that participants were more aroused during the second visit. This is surprising given that participants already knew what to expect in terms of the study procedure. Although no statistically significant interaction between heart rate and visit was identified (p = 0.37), heart rate decreased during the stepped decrease in tempo condition and increased during the recovery condition in visit two. The opposite pattern was seen in visit one. This finding provides more support to the idea that prior exposure to the four conditions may have mediated heart activity.
5. CONCLUSION

The current study intends to explore the effect of sudden changes in tempo on autonomic control of the heart, whilst examining individual differences and within-participant consistency. This is achieved by capturing heart rate, respiration, blood pressure, heart rate variability and baroreflex sensitivity. As well as administering a basic health and musical background questionnaire.

Although these findings come from a small sample size, they demonstrate that sudden changes in tempo have a profound impact on heart rate. In addition, the findings illustrate that the relationship between auditory stimuli and autonomic control of the heart is complex. Not all individuals show the same response pattern to the same conditions and familiarity appears to mediate autonomic activity. In addition, the results show that autonomic control of the heart is highly sensitive to simple musical stimuli. Since previous research has used complex auditory stimuli that alter numerous musical parameters simultaneously, this study provides evidence that more controlled musical stimuli can be used to examine the impact of music on autonomic control of the heart. Due to the use of simple, tightly controlled auditory stimuli, a clear relationship between tempo and autonomic control of the heart can be established.

With a greater sample size and the analysis of the heart rate variability, respiration, blood pressure and baroreflex sensitivity data, the study hopes to provide a comprehensive account of the impact of sudden changes in tempo on autonomic control of the heart. Results from this study have the potential to advance theoretical understanding of the impact of tempo changes on human cardiology. In turn, this has important practical impact in a variety of contexts, including healthcare, education and consumer environments.

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7. REFERENCES


