Effects of auditory priming on physiological parameters of stress following an acute, loud, auditory stimulus

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ABSTRACT

Elevated stress levels and constant exposure to music are commonplace to present day college students. Although the relationship of relaxing music and chronic stress have been well studied, the specific effects of auditory priming with music of different tempos followed by a sudden onset of a stressful stimuli have not been closely analyzed. This research sought to better understand the complex influence music can have on a response to a stressful stimulus--specifically the role of tempo on physiological stress. The study participants were randomly assigned to one of three groups and presented with fast- or slow-tempo musical priming or silence followed by an acute, loud auditory stimulus. Electrocardiogram, galvanic skin response, and muscle tension data were recorded pre- and post-stimulus. Analysis of this data revealed the variable with the most reliable and significant results were from the Galvanic Skin Response. There was a significant increase in max skin response between the priming and post stimulus time periods ($p=0.0001$ for fast-tempo; $p=0.0003$ for slow-tempo; $p=0.01$ for no music). Muscle tension did not yield significant results. Some heart rate changes were significant, but not all. Specifically, the change in heart rate from baseline to the priming phase significantly increased in the slow tempo group ($p= 0.02$) and there was a significant decrease in heart rate between the priming and post stimulus phase in the fast tempo group ($p=0.04$). Different reactions to stimuli based on type and/or presence of auditory priming did not show any significant results. From this, we concluded GSR accurately depicts physiological changes in humans when presented with stressful stimuli, but muscle tension and heart rate need to be further studied. Auditory priming should be further studied in a more controlled setting and with a larger and more varied group of participants.

INTRODUCTION

Priming is a phenomenon of implicit memory that involves the introduction to one stimulus affecting the response to a later stimulus, without explicit recollection of the first (Tulving & Schacter, 1990). This effect has been described in many systems, such as word recognition in the visual system (Tulving, E., Schacter, D., & Stark, H., 1982). However, priming in the auditory system with music is less understood. Specifically, the relation between auditory priming and physiological measurements of stress has not been well-studied.

Stress is represented by a wide range of physiological responses that occur as a result of homeostatic upset. These reactions cause downstream effects on numerous body systems that can last for short or long durations. For example, prolonged stress is known to have deleterious effects on the cardiovascular system and has been associated with numerous cardiovascular ailments, such as increased heart rate and rise in systolic blood pressure (Vrijotte, van Doornen, & de Geus, 2000). In addition, there is experimental evidence that shows psychological stressors influence cutaneous tissue’s ability to regulate sweat. Because stress-induced sweat is triggered by autonomic activation, the amount of sweat produced is a function of hormone concentration (Reddy, 2013). Therefore, increased levels of stress induce high hormone concentrations, specifically cortisol and adrenaline, and result in an upregulation of sweat production. Stress and anxiety can also affect skeletal muscle by causing muscle over-activity and increased muscle tension (Sainsbury & Gibson, 1954).

The relationship between stress and music has been a subject of interest for quite some time. It has been been found that relaxing music can reduce measurements of stress such as heart rate, blood pressure, and cortisol levels (Knight & Rickard, 2001). Further, previous research has shown that stimulative or fast-tempo music elicits higher levels of skin conductance, heart rate, and respiration than classical music (Labbe, Schmidt, Babin, and Pharr, 2007). Thoma et al. demonstrated that listening to relaxing music before participating in a psychosocial stress test resulted in higher cortisol concentrations and faster recovery from autonomic nervous system responses than those that listened to the sound of rippling water or those that did not have any acoustic stimulation before the test (2013).

Thoma et al. provides evidence correlating music priming with physiological stress response. Given this data, we sought to explore the effect of various forms of auditory priming (i.e., fast or slow tempo) on the response to a stressful stimuli: an acute, loud, auditory stimulus (AS). We hypothesized that subjects exposed to an AS will have increased physiologic measures of stress. That is, there would be an increase in heart rate, galvanic skin response, and muscle tension following the presentation of the startling stimulus. Further, we predicted that subjects who undergo fast tempo auditory priming would have a less drastic response to the AS in the physiologic measurements of stress (heart rate, galvanic skin response, and forearm muscle tension) than subjects exposed to no music at all or relaxing music; with relaxing music having the most dramatic response (see Figure 1). We hypothesized the slow-tempo group would be less prepared for the AS due to the initial relaxing effect of the priming slow-tempo music. In effect, priming with slow-tempo music would reduce measurements of stress, resulting in a more drastic difference between the priming and post-stimulus measurements. For the fast-tempo group, we hypothesized that priming would slightly increase physiological measurements of stress, and thus the change from priming to post-stimulus would be reduced. This study represented a novel investigation into the relationship between tempo of auditory priming and physiologic response to a stressful stimuli.

According to research by Hamilton and Fagot, undergraduate women reported higher levels of stress under induced stress conditions identical to undergraduate men (1988). Due to the relevance of this research to our study, we recruited equal numbers of male and female participants and examined differences between genders within the parameters studied.

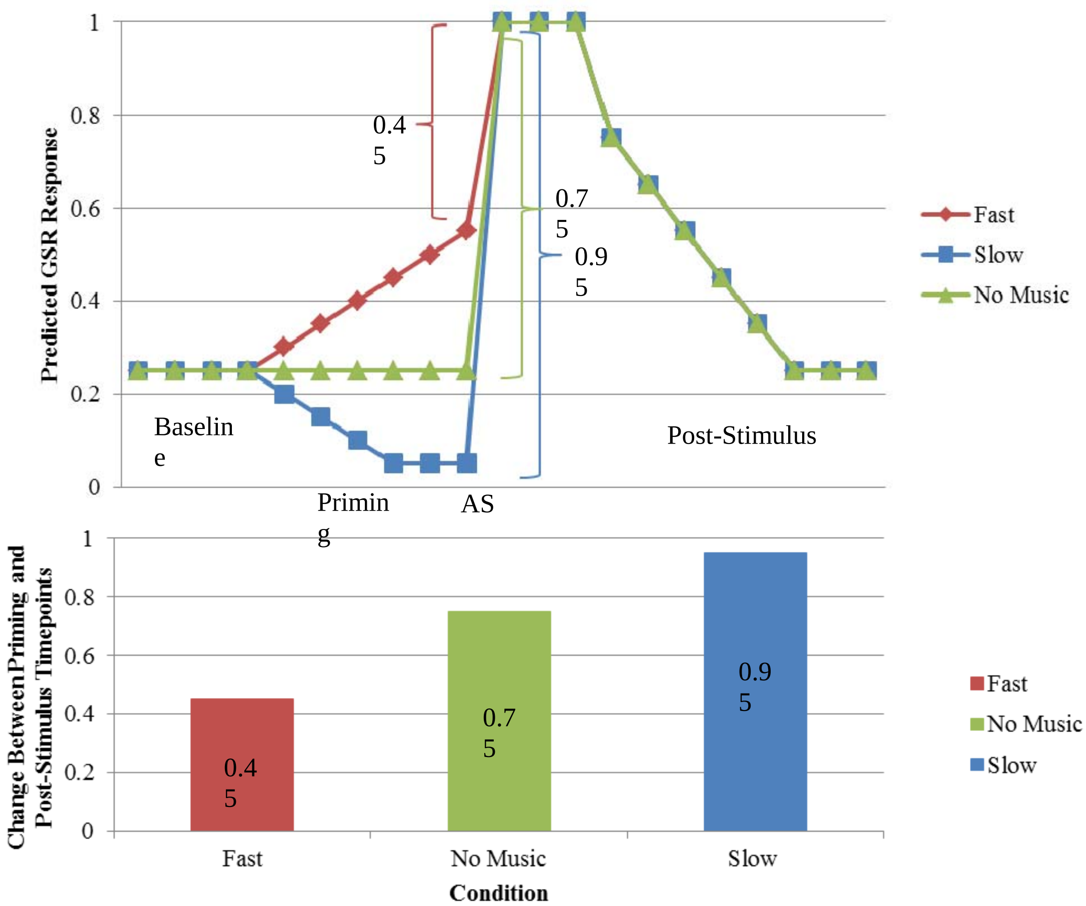

Figure 1. Predicted responses for measures across conditions. It is hypothesized that subjects exposed to an auditory stimulus will have increased physiologic measures of stress. Subjects who undergo fast tempo auditory priming will have a less drastic change in response to the AS in the physiologic measurements of stress (heart rate, galvanic skin response, and forearm muscle tension) than subjects exposed to no music at all or relaxing music; with relaxing music having the most dramatic response.

METHODS

Experimental Design and Procedure. The experiment examined the effects of auditory priming on the acute stress response to an AS. Subjects were placed in a room and asked to complete a modified version of a well-known and established stress indicator test called the Perceived Stress Scale (PSS) (Cohen, Kamarck, & Mermelstein, 1983). *See Appendix, Figure 1*. This test was used to evaluate the basal level of stress that the subjects are feeling that day, as well as approximate the stress level of subjects over the previous month. Thus, we were able to control for any variability among subjects in initial stress levels, which allowed for a more accurate interpretation of the results. Following completion of the PSS experimenters placed the appropriate data-acquirement equipment and calibrations were performed. The subjects were given a pair of Denon® model AH-NC732 headphones and were divided into three groups: fast-tempo music, slow-tempo music, and no music. Baseline measurements were taken for 30 seconds then the subject was presented with either 1 minute of music (classified as either slow-tempo or fast-tempo; see *Auditory Priming: Music*) or silence (as a control). Following 1 minute of auditory priming (or absence thereof), an AS (80 decibels) was presented. Physiological measurements for 30 seconds post-stimulus were obtained during which the initial auditory priming music continued to play in order to analyze the physiologic response to the auditory stimulus. See *Figure 2* below for detailed experimental design.

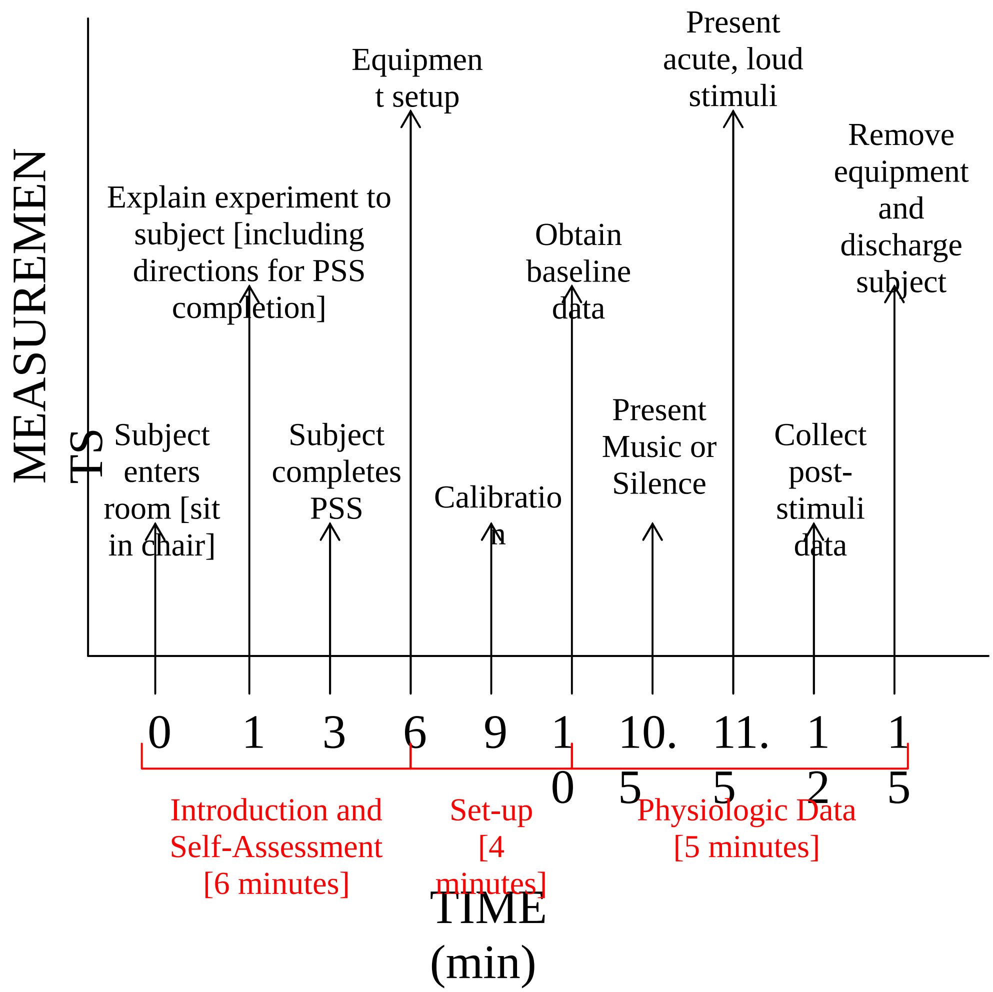

Figure 2. Temporal summary of experimental design. Subjects will enter experiment room at time=0 min (x-axis) will undergo a series of events (y-axis) until completion of the experiment at time=15 min.The experiment is divided into three phases: Introduction and Self-Assessment (left, t=0-6 min), Set-Up (middle, t=6-10 min), and Physiologic Data (t=10-15 min).

Experiment Groups. Subjects were randomly assigned into the following groups (n=36 total, n=12 for each group):

- slow-tempo music + AS
- fast-tempo music + AS
- no music + AS

We examined physiologic variables at three time points: baseline (30 s), auditory priming (1 min), and post-AS (30 s). Thus, we were able to examine changes in physiologic parameters of stress within each subject during each of the phases, and compared these changes between priming groups (slow vs. fast-tempo) and with negative control (no music priming).

Participants. The subjects for the experiment were 36 University of Wisconsin-Madison undergraduate students and teaching assistants that participated in Physiology 435. The undergraduate students were not compensated monetarily nor with course credit upon completion of the study. The participants were randomized into the three treatment groups using GraphPad software.

Perceived Stress Scale. A modified Perceived Stress Scale (Cohen et al., 1983) was used to determine stress levels of subjects upon arriving to our facilities, as well as an approximation of stress during the last month. Statements 1 and 4 were considered negative statements and were scored as indicated on the scale (i.e., 0=least amount of stress; 5=most amount of stress). Statements 2 and 3 are positive statements and are scored inversely (i.e., 0=most amount of stress; 5=least amount of stress). Therefore, higher scores on the stress scale indicated a higher level of stress. Subjects were classified in the following manner: Scores 3 and below indicated low stress levels, scores 4-6 suggested average stress levels, and scores 7+ were indicative of high stress levels. Further, subjects were asked to rate their level of stress on the day of the experiment on a 1-10 scale with 1 being the least amount of stress to 10 being the most amount of stress.

Auditory Priming: Music

Auditory priming was conducted with slow tempo music (below 72 BPM) and fast tempo music (above 94 BPM) in accordance with the research completed by Oakes (2003). The music used for auditory priming was the beginning of the song “Savior”, an instrumental track by the band Cellofourte. The song was manipulated using GarageBand software into two separate tracks: a fast-tempo track and a slow-tempo track. The fast track was given a tempo of 120 BPM, and the slow track was given a tempo of 70 BPM. An AS (an air horn track sampled from Soundbible, a free domain sound file website) was presented in each track at the 60 second mark with a volume of 80 dB.

Physiologic Measurements of Stress.

A. Electrocardiogram (ECG). An ECG was used to measure heart rate (beats per minute; BPM) as a function of time. Heart rate was monitored before the experiment, during music presentation (priming phase), and post-AS. Changes in heart rate were analyzed in subjects during baseline (30 s), priming (1 min) and post-AS (30 s).

B. *Galvanic Skin Response*. Electrodermal activity was measured on the non-dominant index and middle finger to examine sweat response as a function of time. Changes in GSR were analyzed in subjects during baseline (30 s), priming (1 min) and post-AS (30 s). Increased skin conductance (i.e., more sweat), was used as a positive measure of stress.

C. *Muscle Tension.* A dynamometer was placed in the dominant hand in order to obtain a muscle tension measurement in the forearm. Subjects were asked to hold the dynamometer and apply light pressure throughout the experiment. Muscle tension (measured as force applied to the dynamometer) was monitored during baseline (30 s), during music presentation (priming phase, 1 min) and post-AS (30 s). A larger change in force applied to the dynamometer served as a positive indicator of greater stress.

Data Analysis. The BIOPAC® Student Lab system, manufactured by BIOPAC® Systems, Inc., Goleta, California, was used to record the following measurements in all subjects: a) heart beat (BPM), b) galvanic skin response (µSiemens), and c) muscle tension (PSI). Two systems were used, both model MP36s (Serial numbers: E1203002713 and E1204002760). Changes in these three measurements following the presentation of the AS were compared to baseline levels and auditory priming levels. Changes across three groups were compared (fast-tempo music + auditory stimulus; slow-tempo music + auditory stimulus; no music + auditory stimulus). Microsoft® Excel was used to perform the appropriate statistical tests (i.e., two-sample T-tests) to examine any significant differences between groups.

Positive Control. We tested each piece of equipment to ensure that proper measurements could be made. For the hand dynanometer, we used a stimulus of maximum hand force and recorded increases in muscle tension (Figure 3a). Additionally, we used a stimulus of 30 sec of exercise in and observed increases in GSR (Figure 3b) and HR (Figure 3c).

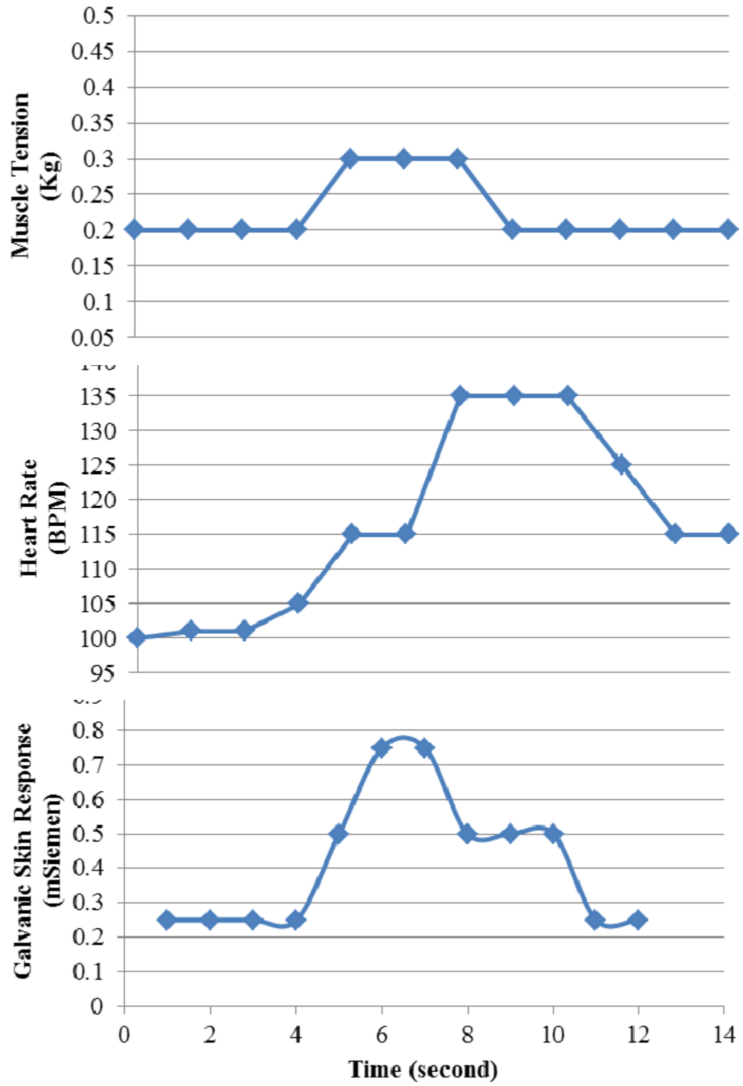

Figure 3. Positive controls for measurements including: heart rate, muscle tension and galvanic skin response. Each measurement was tested with a stimulus known to evoke a stress response.

RESULTS

Stress Levels

We found that the PSS scores compared to the self-report scores per subject (*n=36*) showed a strong correlation (Fig. 4a). However, there were no significant differences in stress levels between groups in either the PSS (p=0.243) or SR (p=0.904) (Fig. 4b). The PSS showed moderate stress levels in each group (mean fast-tempo=5.83; mean slow-tempo=4.67; mean no music=4.50; Figure 4b), which was also seen in the SR (mean fast tempo=5.25; mean slow tempo=4.83; mean no music=5.17; Fig. 2b). Given this, we concluded stress levels between subjects did not skew any of the physiological differences of stress we examined in this study.

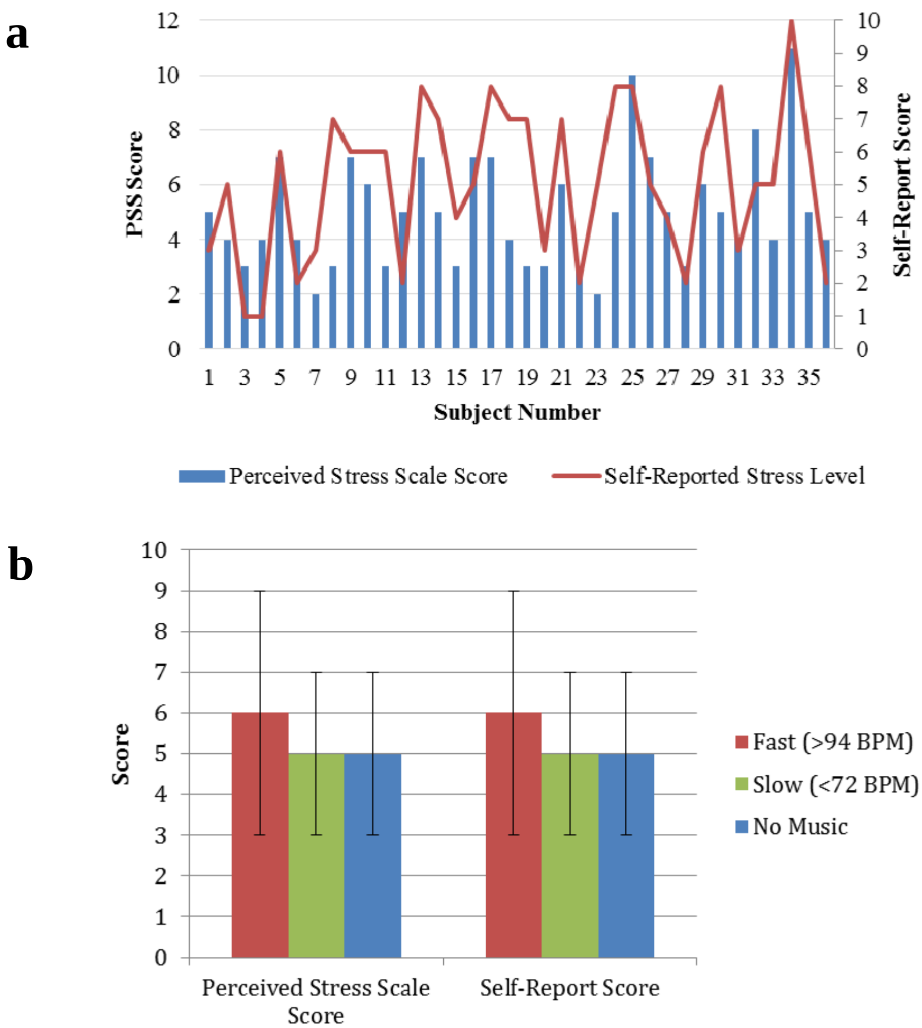

Figure 4. Stress levels as determined by PSS and self-report did not vary between conditions. *a,* PSS score compared to self-report score per subject (*n=36*) showed a strong correlation between the two measures (*p = 0.81*). ***b,*** Subjects did not show a statistically significant difference on PSS score or self-report score across conditions (*p = 0.84 and p = 0.90, respectively*).

Electrocardiogram (ECG)

Mean heart rate (BPM) was measured during baseline, auditory priming, and post-stimulus phases for all groups. During the auditory priming phase, heart rate increased significantly in the slow-tempo group (p=0.02), yet not significantly in the fast-tempo or no music (Fig. 5a). Following presentation of the AS, heart rate decreased significantly in the fast-tempo group (p=0.04). Heart rate also decreased in the slow-tempo group following AS although only a trend was evident in this group. Interestingly, the heart rate did not change from the priming phase to the post-stimulus phase. Further, the average of mean change in heart rate between the priming and post-stimulus phase was significantly reduced (p=0.019) in the fast-tempo group (mean change=4.42 BPM) compared to the slow tempo-group (mean change=8.78 BPM) and to the no music group (mean change=8.66 BPM) (Fig. 5b).

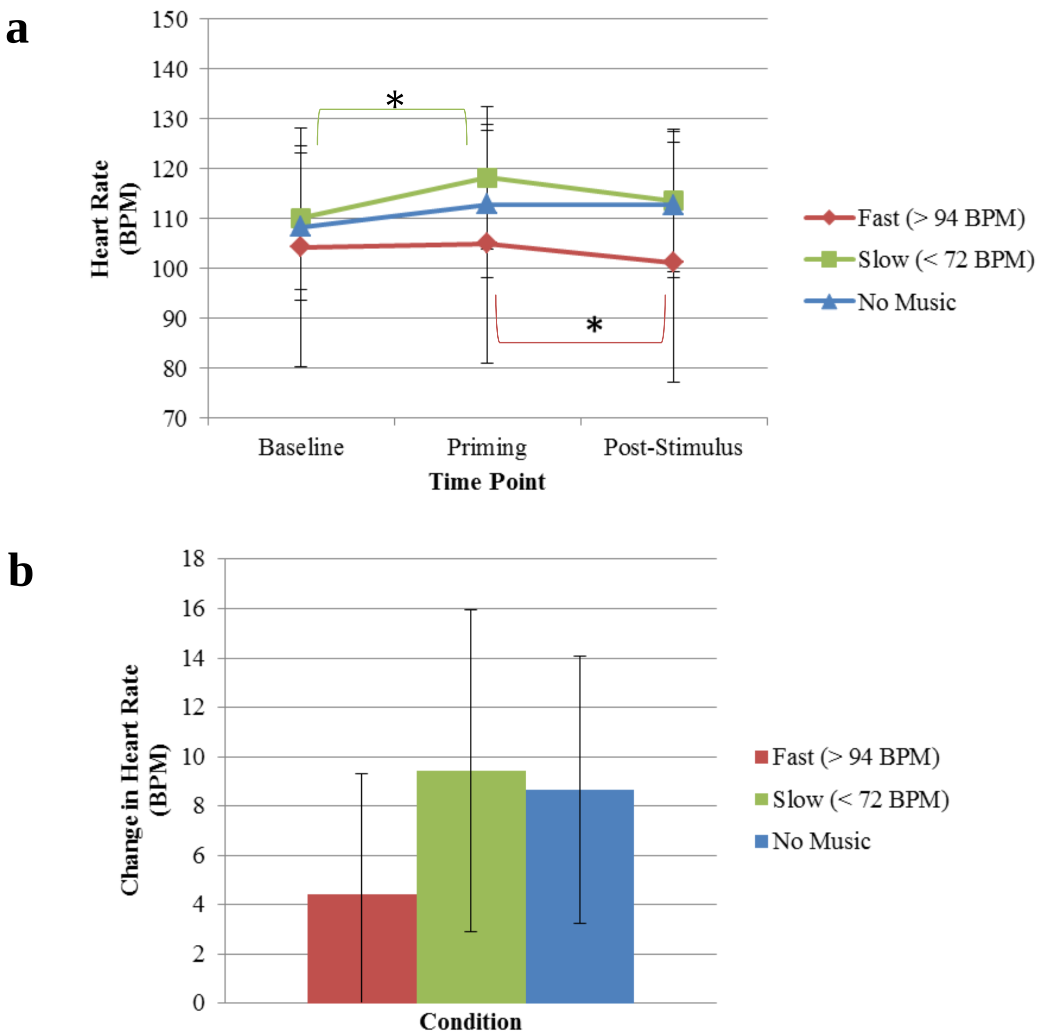

Figure 5. Auditory priming correlates to a change in heart rate after presentation. *a,* Average of mean heart rate across time points. Presentation of the auditory priming music increased heart rate in all conditions and significantly so in the slow tempo group (*p=0.02*). Following the auditory stimulus, heart rate decreased in both groups with priming and reached significance in the fast tempo group (*p=0.04*). ***b,*** Average of mean change in heart rate between priming and post stimulus time points. The mean change in heart rate was greatest among individuals in the slow condition (=9.42), followed by no music (=8.66) and smallest among for the fast condition (= 4.42). None of the groups showed a significant difference from each other (ANOVA: *p = 0.50*).

Galvanic Skin Response

Maximum galvanic skin response (GSR, µSiemens) was examined during baseline, auditory priming, and post-stimulus phases for all groups (Fig. 6a). We chose to compare max GSR, instead of mean GSR, because the GSR response to the AS was evident as a single, short, steady increase in skin conductance that was "washed out" when taking the mean. Max GSR did increase significantly from baseline to the auditory priming phase in the fast-tempo group (p=0.01), but did not reach significance in the slow-tempo group (decrease) or no music group (increase). However, all groups max GSR increased significantly from the auditory priming phase to the post-stimulus phase (p=0.0001 for fast-tempo; p=0.0003 for slow-tempo; p=0.01 for no music). Between groups, there was a trend for reduced change in max GSR from the auditory priming phase to the post-stimulus phase (Fig. 6b): the fast-tempo group (max GSR change=0.37 µS) was reduced compared to the slow-tempo group (max GSR change=0.53 µS) and the no music group (max GSR change=1.28). However, this trend did not reach statistical significance.

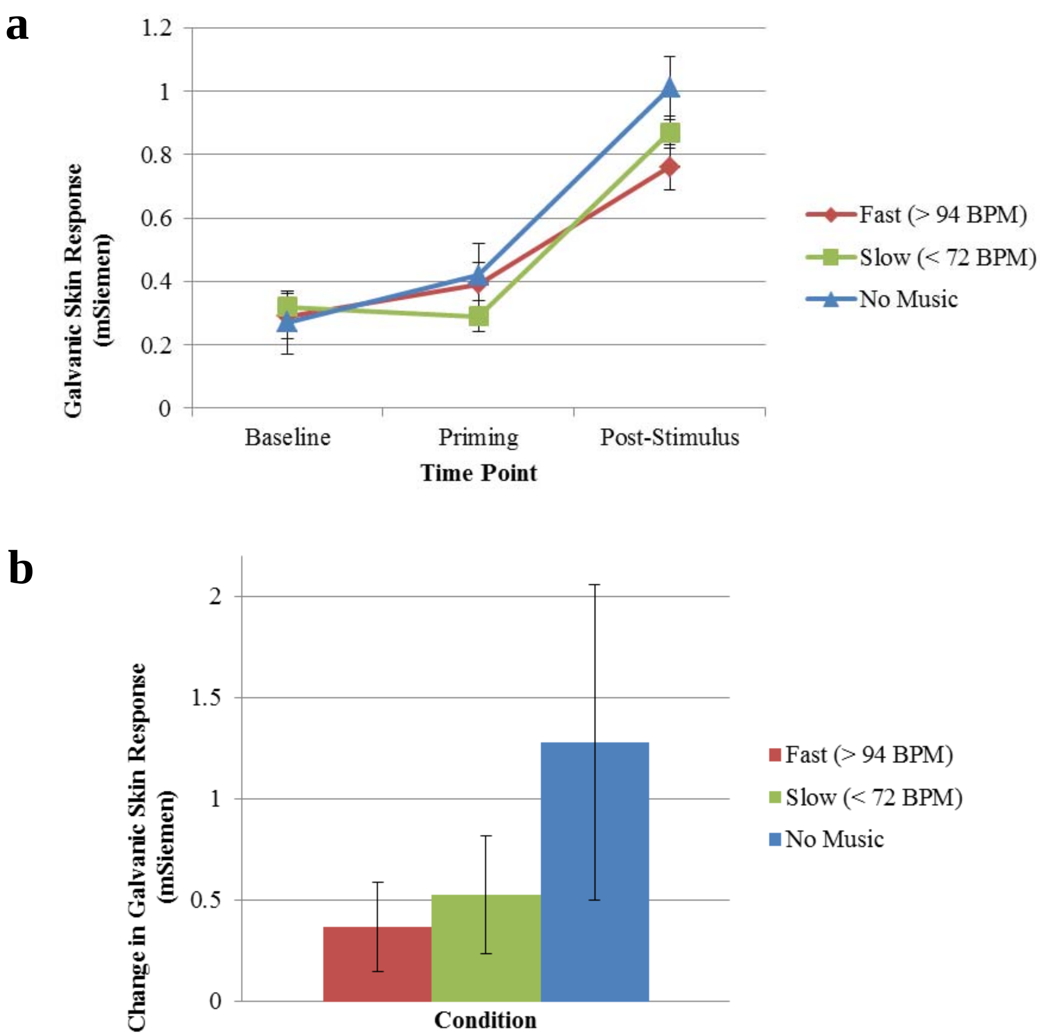

Figure 6. Auditory priming correlates to a change in galvanic skin response after presentation. ***a,*** Average of max galvanic skin response across time points. Presentation of the auditory priming music increased GSR in no music condition and significantly so fast tempo group (*p=0.01*) The slow tempo group showed a decrease in GSR during priming. Following the auditory stimulus, GSR increased significantly in all treatments (fast: *p=0.0001*, slow: *p=0.0003*, no music: *p=0.01*). ***b,*** Average of max change in galvanic skin response between priming and post stimulus time points. The max change in GSR was greatest among individuals in the no music condition (=1.28), followed by slow music (=0.53) and smallest among for the fast condition (= 0.37). None of the groups showed a significant difference from each other (ANOVA: *p = 0.23*).

Muscle Tension.

Mean forearm muscle tension was measured (MT, kg) during baseline, auditory priming, and post-stimulus phases for all groups. Mean MT showed an increase in no music and fast-tempo groups from baseline to the auditory priming phase. Although small, there was a trend in the change from the auditory priming phase to the post-stimulus phase, yet this trend failed to reach statistical significance. The slow-tempo group showed a decrease in mean MT (Fig. 7a). The mean change in MT was smallest in the fast-tempo group (0.02kg) when compared to the slow-tempo group (0.03kg) and the no music group (0.04kg) (Fig. 7b). However, these changes were minute and did not reflect statistical differences between groups.

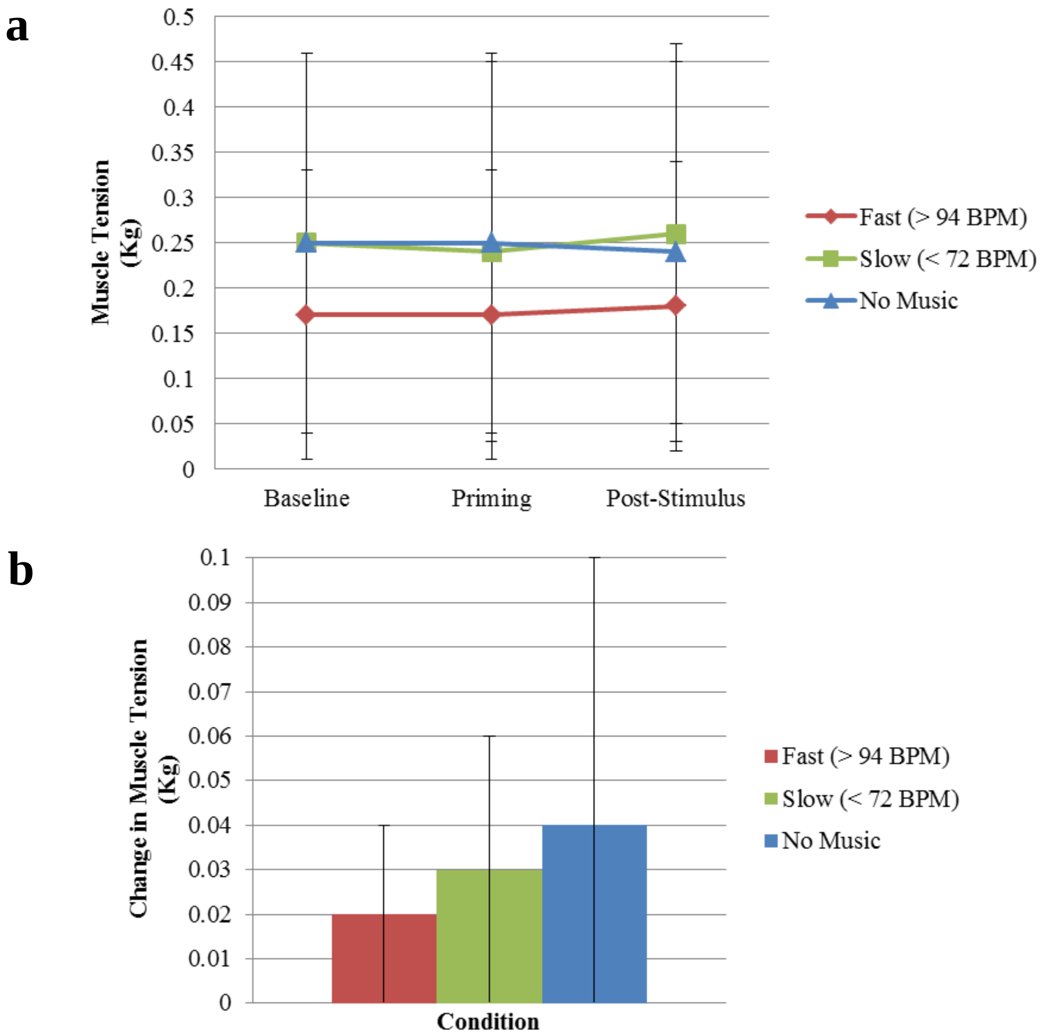

Figure 7. Auditory priming correlates to a change in muscle tension after presentation. ***a,*** Average of mean galvanic skin response across time points. Presentation of the auditory priming music increased muscle tension in no music and fast tempo conditions. The slow tempo group showed a decrease in muscle tension during priming. Following the auditory stimulus, muscle tension increased slightly the slow tempo treatment and decreased in the other two conditions. ***b,*** Average of mean change in muscle tension between priming and post stimulus time points. The mean change in muscle tension was greatest among individuals in the no music condition (=0.04), followed by slow music (=0.03) and smallest among for the fast condition (= 0.02). None of the groups showed a significant difference from each other (ANOVA: $p = 0.39$).

Gender Differences

No significant differences between males and females were discernible across any of the three parameters; heart rate, GSR or muscle tension. Paired t-tests did not reveal any apparent variation between genders.

DISCUSSION

Stress Response and External factors

One very interesting piece of information we came across in our study was the difference in self-assessment scores of the subjects at different points in time. During our second week of recording, the scores on the Perceived Stress Scale (PSS) were notably higher. The next lab date, which occurred two weeks later, showed greatly reduced PSS scores. This data correlated strongly with the presence of two external factors, a Physiology 435 exam date and Spring Break. During the second week students reported higher PSS scores. That lab date occurred two days before a Physiology 435 exam. Self-report by the subjects revealed a great deal of exam-related stress. On the next lab date, students recorded much lower stress levels. This may have been due to Spring Break occurring the previous week. Although causation could not be proven, the existence of these (as well as many other) external factors could have had a confounding effect on the quantitative data we collected. Were this research to be expanded, such external factors should be taken into consideration and control measures would have to be implemented.

Electrocardiogram

The ECG results supported and contradicted different parts of our initial hypothesis. Surprisingly, the mean heart rate increased significantly during the priming phase in the slow-tempo group. This disagreed with previous studies where slow-tempo music had a relaxing effect on heart rate (Amini et al., 2013). However, this phenomenon could simply reflect the response to presenting music to the subjects. Also, the music was presented for a short period of time (1 min), which may not have been enough for a relaxing effect to occur. Studies that presented 10 minutes of relaxing music did not see significant decreases in heart rate, which could signify that more time was required to see a change (Chiasson et al., 2013; Thoma et al., 2013). As predicted, the mean change in heart rate from the priming phase to the post-stimulus phase was reduced in the fast-tempo group compared to the slow-tempo and no music groups, although this change did not reach statistical significance. This trend supported our original hypothesis that auditory priming with fast-tempo music would better prepare the subjects for the AS and thus showed a reduced change in heart rate compared to slow-tempo music or no music priming. We anticipated that the slow-tempo music would see the greatest change in mean heart rate but given the large increase in heart rate from baseline to the priming phase, it was reasonable that the magnitude of change from the priming to the post-stimulus phase would be smaller. Future research is warranted to investigate a prolonged priming exposure; the data presented here investigated an acute priming phase (1 min). It would be interesting to see the effects of chronic exposure (e.g., 1 hour).

Galvanic Skin Response

Max galvanic skin response data from baseline to priming supported previous research: fast-tempo music significantly increased GSR, slow-tempo did not. After presentation of the AS, all groups underwent a significant increase in max GSR. This supported our hypothesis that GSR would increase from the auditory priming phase to the post-stimulus phase. Although there were significant changes within the groups (i.e., between phases) this was not the case between groups. Though not significant, there was a reduced change in max GSR for the fast-tempo group compared to the slow-tempo group after the presentation of the AS; this data was in agreement with our hypothesis. Although this data did not reach significance, there were a few factors that could have affected the result. We did not control for room temperature which could have affected the amount of sweat produced on the fingers. A colder temperature would cause decreased sweat production thus decreasing GSR across all groups. This could reduce the magnitude of change in max GSR between the phases. Similarly, we did not ask subjects to wash their hands prior to the experiment which could have further affected our results. However, we do believe the observed trend accurately reflected differences between the types of auditory priming. That is, fast-tempo priming caused a smaller change in max GSR relative to slow-tempo priming or no auditory priming.

Muscle Tension

The muscle tension data obtained did not reveal significant results. Our data were sporadic: some subjects responded violently to the stimulus and clenched the dynamometer, while others did not flinch. The subject's response may have been a function of other factors. This could be evidence that muscle tension does not have an acute response to stress. Research controlling for inherent startle responses or muscle physiology could elucidate the lack of correlation observed between priming tempo and muscle tension.

Gender

Our study consisted of 18 male and 18 female participants. As such, we examined differences between gender within each of the measurements. However, we found no statistically significant differences across measurements. However, future research is warranted in order to discern the role of gender on the relationship of music and stress.

Other Sources of Error

One possible source of error in the experiment may have resulted from the communication that occurred between subjects. Since all subjects were class members, our experimental design spread by word-of-mouth. The expectancy of our subjects to an upcoming stimulus could have had an impact on their reaction to the AS. Had the subjects not been capable of communicating to each other the nature of this experiment, such error could potentially be eliminated. Another potential source of error with our experiment was the decreased validity associated with our small sample size. Due to a small sample size of 36 participants, it is possible that our results might not fully reveal the relationships that exist between our variables. Another limitation that might have caused error in our data is the limited variability of individuals that were tested. All subjects were between 20 and 27 years of age and UW-Madison students. Such a limited demographic could have biased our data. There also may have been errors associated with the equipment used or the BioPac program that could have skewed our data.

Implications

Our study represented a novel investigation into the relation between auditory priming and physiological response to a stressful, auditory stimulus. We demonstrated differences in response to an AS between tempo of priming (slow vs. fast) as well as absence of priming (no music) in both heart rate and galvanic skin response. Although we did not reach statistical significance in these differences, the changes observed demonstrate that the tempo of auditory priming could affect the response to a stressful stimuli. This was in agreement with previous research from Oakes (2003), where priming with slow-tempo music had a greater relaxing effect on students while registering for classes (a stressful experience or many) than fast-tempo music. Taken together, our research created new scientific questions on the relationship between auditory priming and physiologic responses to stressful stimuli, and represented advancement in our understanding in this relation. Future studies are warranted to investigate this relationship to more fully understand this intriguing scientific phenomenon.

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APPENDIX

Perceived Stress Scale

Please indicate how often you felt or thought a certain way **during the last month**

Participant # ________ Date _________ Age __________
Gender (*Circle*): **M** **F**

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you felt that you were unable to control the important things in your life?.. **0 1 2 3 4**

2. In the last month, how often have you felt confident about your ability to handle your personal problems?.. **0 1 2 3 4**

3. In the last month, how often have you felt that things were going your way?.. **0 1 2 3 4**

4. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?................................. **0 1 2 3 4**

5. On a scale from 1 to 10, please rate your stress level **TODAY** (*Circle*):

1 2 3 4 5 6 7 8 9 10

Figure 1. Modified Perceived Stress Scale. The PSS Scale is modified and reprinted with permission of the American Sociological Association, from Cohen, S., Kamarck, T., and Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior, 24,* 386-396. Statements 1 and 4 are considered negative statements and were scored as indicated on the scale (i.e., 0=least amount of stress; 5=most amount of stress). Statements 2 and 3 are positive statements and are scored inversely (i.e., 0=most amount of stress; 5=least amount of stress).