

Temporal Factors of Listening to Music on Stress Reduction

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ABSTRACT

Listening to music has been studied as a method for combating the rapidly increasing stress levels of adolescents. Previous studies yielded inconsistent results and neglected specific factors including the time relative to the stressor and the duration of time in which participants listened to music. We conducted a survey and lab experiment to investigate the impact of these factors on the stress-reducing effect of music. The survey contained questions regarding music preference, stress, and use of music for stress reduction. In the lab experiment, the math task of the Trier Social Stress Test (TSST) was used to simulate stress in participants. Three experimental groups listened to music for either five minutes before the stressor, five minutes after the stressor, or ten minutes after the stressor; with the control group not listening to any music. Heart rate variability was continuously monitored with a wearable device, Empatica, and used to derive stress levels. The survey received 251 responses and 42 students participated the lab experiment. The results showed that listening to music before the stressor resulted in significantly lower stress levels than listening to music after the stressor ($p < 0.01$). This finding, contrary to our survey results, revealed that the “preventive” effect of listening to music prior to the stressor was more effective than the “remedial” effect that followed after the stressor. .

CCS CONCEPTS

• **Human-centered computing** → *Ubiquitous and mobile computing systems and tools; Personal digital assistants.*

KEYWORDS

mobile device; health; stress reduction

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1 INTRODUCTION

Overexposure to stress is detrimental to both mental and physical health. Recent research indicates that there is an increasing number of adolescents being negatively affected by stress. According to the American Psychological Association (APA), adolescents have been reporting stress levels similar to adults, surpassing levels considered healthy [2]. During the school year, teens’ stress was reported to be even higher than average adults’. Furthermore, 34% of teens reported expecting their stress to increase in the next year. This is over twice the number of those who reported their stress levels decreasing in the past year (16%).

Previous studies have examined listening to music as a stress reducer, however results have been varied: while many studies found that listening to music was effective in reducing stress, others found no impact or even a negative impact.

Review of Literature

Work by Khalfa S. found that the stress levels of participants in the experimental group, who listened to music after the administration of a stressor, were significantly lower than the stress levels of the control group [8]. This study measured stress with salivary cortisol and used the Trier Social Stress Test (TSST) as the stressor.

On the other hand, Thoma et al. did not observe a statistically significant difference in cortisol-derived stress levels between the experimental group and the two control groups [17].

A recent work by Pisarczyk also found no significant difference in stress levels measured by the State-Trait Anxiety Inventory (STAI) between experimental and control groups [15].

Measurement of stress. Past experiments used various techniques to measure the stress levels of participants. One of the

most basic methods was through participants' self-reports. Participants would be asked to indicate their stress levels through a series of questions or on a scale. For example, State-Trait Anxiety Inventory (STAI) is a commonly used measure [16]. Self-reported measurement is often qualitative and could be very subjective.

On the other hand, biological indicators have provided a quantitative and objective measurement of stress. Stress hormones have been measured in saliva, and indicate activity in major stress systems, including the hypothalamus-pituitary-adrenal (HPA) axis and the sympathetic nervous system (SNS) [17]. Salivary cortisol is secreted by the HPA axis, and Salivary alpha-amylase is secreted by the SNS, each of which provides a measure of stress.

Another measurement used in recent studies is heart rate variability (HRV). HRV is the variation in time intervals between heartbeats [5]. It can be non-invasively measured continuously using wearable devices such as smartwatches.

Specific factors. A possible explanation for the uncertainties found in previous experiments is that there are many factors involved in listening to music which impact its effectiveness in stress reduction. Some specific variables which could play influential roles in the stress reducing process may have been overlooked. Without a clear understanding of the correlated factors, it is difficult to effectively use music as a stress reducer. In order to discover these critical factors, a few recent studies examined a range of factors as independent variables.

A study [6] investigating the effect of factors such as valence, listener's preference, and familiarity on music's stress reducing effect showed that the effects of listening to music on stress reduction were mainly correlated to the valence of music, and partially mediated by listener's preference. A different experiment found that it was more effective to let participants choose the music they listened to by comparing the results of music chosen by participants as opposed to pre-selected music ([4]). Another experiment [10] studied the impact of the listener's purpose for listening to music and recorded the stress levels of participants as they listened to music for "relaxation", "activation", and "distraction". It was found that listening to music for the purpose of "relaxation" is associated with a decrease in both self-reported stress levels and stress reported by cortisol concentration. A follow up study examined the impact of social context (listening to music alone vs. in the presence of others) on music's effectiveness for stress reduction [11]. Four situations were compared: resting alone, resting with others, listening to music alone, and listening to music with others. The results showed that listening with other people helped reduce stress the most.

In summary, these experiments revealed that the effectiveness of music on stress reduction is correlated with some specific factors. Time related factors were not studied.

Problem

Previous studies did not pay attention to the impact of the temporal factors, which involve when music is listened to and for how long it is listened to. Previous experiments only used these factors as controlled variables, and the way they were controlled varied from experiment to experiment. For example, in one study, participants listened to music for 10 minutes before the stressor was administered [17], while in a different study, participants listened to a four and a half minute music excerpt immediately after the stressor [6], and another experiment played music along with the stressor for 5 minutes [4]. In their discussion, Pisarczyk admitted that "the study most likely would have benefited from having a longer duration in which participants listened to music [15]." Since previous research did not evaluate the time factor, its impact is unknown. Therefore, it is possible that the inconsistent results may have been due to the differing specifications of time-related variables. Clarifying the impact of time-related factors could help devise an effective and efficient stress reduction method using music. Furthermore, the advancements in stress measurement methods make the study of temporal factors feasible. Stress levels can be measured continuously using wearable devices monitoring physiological parameters, such as heart rate variability and skin conductivity. Therefore, the present study investigated these factors using the Empatica device [3].

In order to determine whether time is a factor in the stress reducing affect of music, a survey and experiment were conducted. It was hypothesized that listening to music before a stressor would produce lower stress levels than listening to music after the stressor because it would prepare the brain for the stressor (hypothesis 1). It was also hypothesized that listening to music for a longer duration of time would be more effective in reducing stress because there would be greater exposure to the "treatment" (hypothesis 2).

2 METHODOLOGY

The study was performed using a two-phase approach, including a survey and a lab experiment. The survey phase analyzed how music is used for stress reduction through self-reports. The survey insights were then used to guide the design of lab experiment phase. The lab experiment assessed the impact of time factors in music as stress reducing using HRV-derived stress measurements.

Survey

The survey was distributed through SurveyMonkey and gathered information about music and stress in general. Data

involving specific variables was gathered to help develop the lab experiment in the second phase of the study. It took approximately 15 minutes to complete. Responses were collected over the course of four months.

Participants. The survey was distributed through social media, which allowed us to reach a wide array of participants while maintaining an extra degree of anonymity. All participants were adolescents in middle or high school. In total, the survey received 251 responses (61 male, 148 female, 8 other, and 34 preferred not to say). The use of human participants was approved by an institutional review board (IRB) at Yorktown High School.

Survey Content. The survey was comprised of five main sections: informed consent, demographic information, music, stress, and music for stress reduction. Questions about demographic information were asked in order to make sure the participants fit the eligibility criteria and to gather basic data about the participants. The questions about music were asked in order to obtain the participants' general music preferences. These answers were also used to guide the design of the lab experiment because the conditions in the experiment were modeled to be similar to how most people reported listening to music in a natural setting. The questions about stress intended to assess stress in the lives of participants and how it affects them. In the music for stress reduction section, questions about if and how the participants used music for stress reduction were asked, especially about time related factors, such as when and how long they listened to music when trying to reduce stress. All questions served to achieve a greater understanding of music listening and stress in adolescents and were used to help develop the lab experiment in the second phase of the study. The conditions in the experiment were modeled to be similar to how most people reported listening to music in a natural setting.

Lab Experiment

A series of one-on-one trials were conducted to examine the impact of the temporal factor (including time relative to the stressor and the length of time in which music was listened to) on the effectiveness of music as a stress reducer. Each trial took approximately 20 minutes.

Participants. A total of 42 students participated in the lab experiment. Participants were recruited from middle and high schools in Westchester County. The trials were administered in a classroom at the school. Participants were informed that they could stop participating at any time if they felt uncomfortable. They were randomly assigned to one of 4 groups: the control group (group C) did not listen to music, one experimental group (group M1) listened to music for 5 minutes before the stressor, another experimental group (group M2)

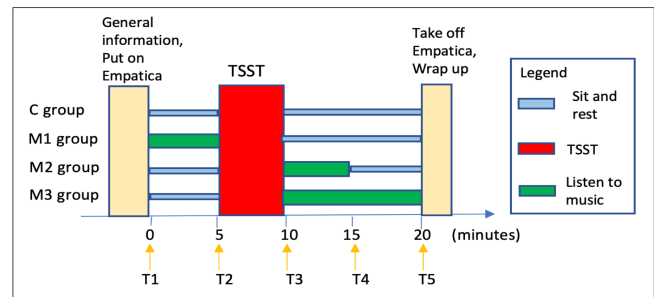


Figure 1: Procedure of Lab Experiment

listened to music for 5 minutes after the stressor, and the other experimental group (group M3) listened to music for 10 minutes after the stressor.

Stressor. The math component of the Trier Social Stress Test (TSST), a standard artificial stressor, was used to simulate conditions of stress in participants. In this task, participants were told to count backwards from 1,022 in steps of 13. Upon making a mistake, they would have to re-start from 1,022.

Listening to Music. Participants were told to bring a smart phone and earbuds before the experiment. When it was the time for a participant to listen to music, they chose their preferred music for relaxation and listened with earbuds at the volume level they preferred.

Procedure. When the participants arrived, they were given a summary of the procedure of the experiment. The HRV measurement device, Empatica E4, was put on their wrist. In the next 5 minutes, the C, M2, and M3 groups rested in silence while the M1 group rested while listening to music. At T2, the participants stopped listening to music and began to undergo the stressor (math task) for five minutes. After the stressor, participants in groups C and M1 rested in silence while participants in the M2 and M3 group listened to music for 5 minutes. After the 5 minutes, the M3 group continued to listen to music for another 5 minutes while all three other groups rested in silence. The protocol is shown in Fig. 1.

Measurement. Physiological data, such as heart rate and skin conductivity, were monitored with the Empatica E4 [3] (See Fig. 2). The device was put on the wrist of the participant at the beginning of each trial. Time tags for time points T1 to T5 were added by pressing a button on the Empatica device. After the experiment, the collected data was used to derive the stress levels of participants using the models built by Mishra et al. [14]. We used the same model built by Mishra et al. directly on our data. We did not use any of our data for training.



Figure 2: Empatica: wearable device

Informed Consent and Possible Risks/Discomforts

For both phases of the study, participants were given a summary of what they would be asked to do and indicated consent on a form. If they were under the age of 18, a parent or guardian was required to indicate consent for them to participate. They were informed that their participation would be voluntary and they were able to stop participating at any time if they felt uncomfortable, and that no personally identifiable information would be associated with their data. There were no potential risks for the survey. In the lab experiment, a possible discomfort to the participants was the math task, which was taken from a standard stress test. However, this discomfort was not any worse than that experienced by average students on a typical school day. To minimize this risk, participants were made aware that they were allowed to leave at any time. Both phases of the study were reviewed and approved by IRB.

Data Analysis

Most survey results are categorical and their distributions are reported. The difference analyses are performed using chi-square tests. For responses with continuous values, the mean and standard deviation are reported and difference analyses are performed with t-tests.

For the lab experiment, the direct heart rate data at a frequency of 1 Hz were processed with a 60 second window with 15 seconds overlap for HRV analysis [14] and stress probabilities were generated to represent stress levels, with values from 0 to 1. The difference in the average of each minute of HRV-derived stress data and the self-reported stress levels between the different groups were analyzed with a t-test. All the t-tests and chi-square tests were performed with an alpha value of 0.05 for statistical significance.

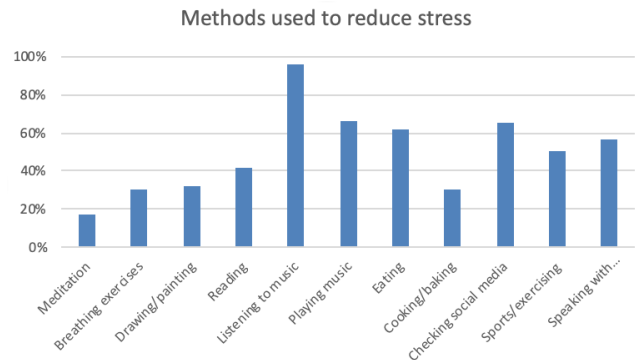


Figure 3: Methods Used to Reduce Stress

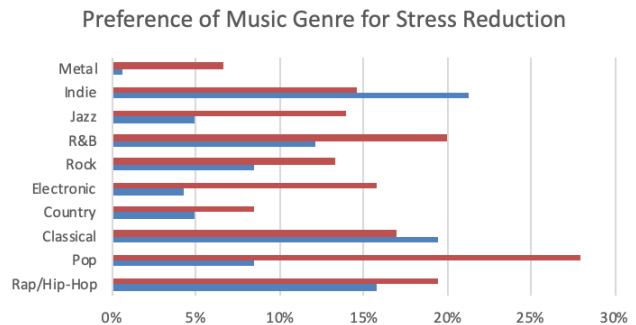


Figure 4: Preference of Music Genre for Stress Reduction

3 RESULTS OF SURVEY

Music for stress reduction

Listening to music was found to be the most popular method for stress reduction. Almost all participants (95.8%) reported listening to music to reduce their stress (Fig. 3).

In the response to the question regarding genre preference for stress reduction, there was no genre which received a notable majority (Fig. 4). The most preferred genre was indie with only 21% “yes” and 15% “no”. The results suggest that different people listen to different music for stress reduction.

Time-related factors

When asked how useful they felt listening to music before, during, or after a stressful event was, participants showed large preference towards listening to music after a stressful situation ($***p < 0.001$), as shown in 1.

However, 59% of participants regarded listening to music before a stressor as “very useful” or “useful”. In response to the question “How long does it take for music to reduce your stress?”, 56% percent of participants indicated that it would take 15 minutes or less for music to reduce their stress levels (Fig. 5).

Table 1: Usefulness of when to listen to music

when	very useful	useful	moderate useful	slightly useful	not at all
before	37	54	31	24	8
same	34	32	29	30	29
after	66	47	22	10	9

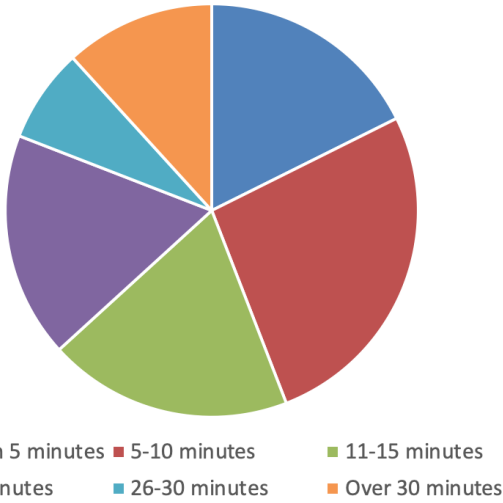


Figure 5: Amount of Time Spent Listening to Music for Stress to be Reduced

4 RESULTS OF LAB EXPERIMENTS

Stress level for groups

Participants. 42 participants (17 male, and 25 female) were tested over the course of two months. The participants were randomly assigned to one of four groups: control (10 participants), M1 (10), M2 (11), and M3 (11).

Stress levels

The average self-reported stress levels of each group, ranging from 1 (least stressed) to 5 (most stressed), are shown in Fig. 6. There were five time points (T1 to T5) during which the participants reported their stress levels. The difference in stress level among different groups was not statistically significant.

The average stress levels derived from HRV of each group, ranging from 0. to 1., are shown in Fig. 7. Stress levels were calculated for each minute.

The averaged value of each group provides an overview of how the stress levels changed throughout the timeline of the experiment. The correlation test between self-reported stress and HRV-derived stress showed that they are not correlated

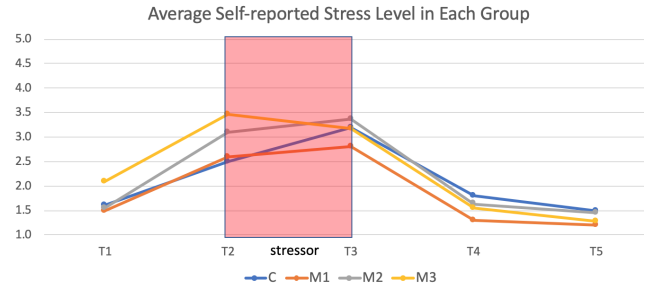


Figure 6: Average Stress Levels from self-report. Stress on a scale of 1 to 5 were reported by participants at T1 to T5

Table 2: Impact of Stressor

t-test	<i>t</i> -value	<i>p</i> -value
(T2, T3) of C	-8.84	<0.001
(T2,T3) of M1	-4.43	<0.001
(T2, T3) of M2	-1.25	0.021
(T2, T3) of M3	-11.5	<0.001

($r = 0.87$, $***p < 0.001$). Therefore, in the following analysis, only stress data derived from HRV will be focused on.

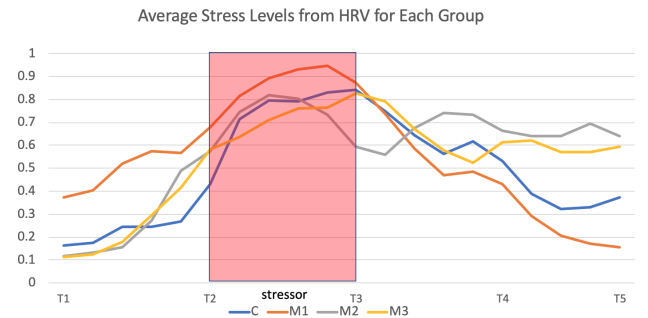


Figure 7: Average Stress Levels from HRV. Stress measurements were calculated for each minute and represented on a scale of 0 to 1.

Impact of stressor

To evaluate the impact of the TSST math task as a stress inducer, the stress levels before the stressor (at T2) and after the stressor (at T3) were compared for each group. The result (Fig. 2) showed that the task significantly increased the stress levels of all groups ($t < 0$, $*p < 0.05$). The distribution of stress levels in the four groups is shown in Fig. 2

Impact of listening to music before stressor

The impact of listening to music before the stressor (M1 group) on stress levels was tested by comparing the stress

Table 3: Impact of listening to music before stressor

t-test	<i>t</i> -value	<i>p</i> -value
(C, M1) at T2	-2.78	0.006
(C, M1) at T3	-0.88	0.380
(C, M1) at T4	2.21	0.028
(C, M1) at T5	2.01	0.050

Table 4: Impact of listening to music after stressor

t-test	<i>t</i> -value	<i>p</i> -value
(C, M2) at T4	-1.50	0.138
(C, M2) at T5	-1.10	0.273
(C, M3) at T4	-2.22	0.032
(C, M3) at T5	-0.10	0.921

levels of the control group and the treatment group M1 at T2, T3, T4 and T5 (Table 3). It was found that listening to music increased the stress levels at T2 ($t > 0$, $**p < 0.01$), then yielded similar, with no statistically significant difference, stress levels at T3 ($p = 0.38$), and significantly reduced stress levels at T4 and T5 ($t < 0$, $*p < 0.05$).

Impact of listening to music after stressor

The impact of listening to music after the stressor (M2 and M3 groups) was tested by comparing the stress levels of the control group and the M2 and M3 groups at T4 and T5 (Table 4). The test found that only the stress levels of M3 were significantly lower than the control group at T4 ($t > 0$, $*p < 0.05$). The impact of listening to music after stressor was not confirmed in the experiment.

Impact of listening to music before vs after stress

The impact of the time relative to the stressor during which participants listened to music could be determined by comparing the stress levels of M1 and M2 group at T4 and T5 because both groups listened to music for 5 minutes (first two data rows of Table 5). The result revealed that listening to music before the stressor was more effective in stress reduction than listening after the stressor ($***p < 0.001$). These findings corroborated hypothesis 1.

Impact of the duration of music listening

In order to assess whether stress reduction was affected by the length of time during which music was listened to, the stress levels of M2 and M3 groups at were compared at T5 (the last data row in Table 5). Participants who listened to music for 10 minutes did not display significantly lower stress levels than those who only listened to music for 5 minutes ($p = 0.054$). Therefore, the hypothesis 2 was rejected.

Table 5: Impact of listening to music before vs. after stressor

t-test	<i>t</i> -value	<i>p</i> -value
(M1, M2) at T4	-3.62	<0.001
(M1, M2) at T5	-4.32	<0.001
	(a)	
(M2, M3) at T5	1.99	0.054
	(b)	

5 DISCUSSION

Phase 1: Survey

Based on the survey data, our finding that adolescents are constantly negatively affected by stress is consistent with the findings of previous studies. The main cause of stress reported by the student participants was academic work. Stress was regarded as "overwhelming" by more than 70% of participants, and 81% of participants indicated that they would like to find a solution to overcome their stress. This data supports the concern in previous reports [2] and further verifies the urgency of finding an effective approach to stress reduction.

The survey also provided helpful information for the design of the lab experiment during the second phase of this project. First, music preference varies among people, as the survey found that there were no genres preferred by more than 25% of the participants. Past studies typically had all subjects listen to the same piece of music [15]. Therefore, this was a potential limitation in the design of such previous works. In the present experiment, participants chose their own music to make the scenario more similar to one which typical adolescents would realistically experience. Second, one of the temporal factors focused on in the study was the time (relative to the stressor) in which music was listened to. In a previous experiment, participants only listened to music before the stressor [17]. In another study, participants instead only listened to music after the stressor [8]. These two studies yielded differing results on the effectiveness of music in reducing stress. The survey showed that while more people reported a preference for listening to music after a stressor, a notable portion of people also reported that they thought listening to music before a stressor would be helpful.

The lab experiment further compared the impact of listening to music before versus after the stressor. Additionally, the survey found that the length of time for which participants typically listened to music in order to reduce their stress varied, ranging from less than 5 minutes to more than 30 minutes, with over half of the participants indicating ranges 15 minutes or lower. This finding influenced the design of the lab experiment in deciding how long participants would

listen to music for. Previous studies did not give clear answers about how the duration of music listening affects stress levels. This question was further researched in the second phase of this study.

In summary, the survey gathered data about adolescents' usage of music for stress reduction and confirmed hypothesis 1a that adolescents use music both before and after a stressful situation as a method for stress reduction. Specific questions regarding music preferences revealed that different people tend to listen to different music for stress reduction, which confirmed hypothesis 1b. These details helped influence the design of the lab experiment. Therefore, the objective of the survey was achieved.

Phase 2: Lab experiment

The objective of this study was to examine the effectiveness of music as a stress reducer and how time-related variable may affect it. The specific factors that were assessed were 1) when music was listened to, relative to the stressor and 2) the duration of time for which participants listened to music. It was hypothesized that 2a) there would be a greater impact on stress reduction if music was listened to before the stressor than after, and 2b) listening to music for 10 minutes would reduce stress more than for listening for 5 minutes. Listening to music before the stressor (M1 group) led to significantly lower stress levels than listening to music after the stressor (M2 group). Therefore, hypothesis 2a was corroborated by the findings from this experiment. In the survey results, more participants reported that they preferred listening to music after a stressor. The experiment findings suggest that listening to music before rather than after a stressor when possible could improve stress management.

No significant difference was found between the group which listened to music for 5 minutes (M2) and the group which listened for 10 minutes (M3) at the end of the experiment (T5). Hypothesis 2b was not supported by this data. Moreover, the stress levels of the experimental groups were not lower than those of the control group as was hypothesized.

Listening to music was found to be effective in recovering from stress only when music was listened to before the stressor ($*p < 0.05$). This result contradicted the findings of a previous study [17], in which participants who listened to music before the administration of the stressor demonstrated similar stress levels to the control groups. Since most of the controlled variables were similar in the past study and the present experiment, the reason for the different output could be attributed to the experiment design. This study allowed participants to choose their own music, while the other experiment pre-selected music for the participants. This design was based on the findings of the phase one survey, which showed that different people use different music for stress

reduction. The lab experiment confirmed the effectiveness of this design. This design should be applied to future experiments which study music as a method for stress reduction to ensure that the treatment is effective. Research in this area may benefit from the new method used in this study.

One previous work showed that the main factor was music itself, and that user preference was secondary [7]. However, the results in this study may suggest that user preference of music played a bigger role in stress reduction than previously thought. These results confirmed the preventive effects of music on stress, which only 59% of survey respondents were aware of. The findings of this study show that people should listen to music before stressful events as an effective way to deal with their stress.

When music was listened to after the stressor, the stress levels were even higher than the control group. In the survey, more than 75% participants reported that they thought listening music after a stressful event was a helpful way to reduce stress, which differed from the findings of the lab experiment. When the stress levels of the control and M1 groups were compared, stress levels for M1 were higher at T2, were similar at T3, and finally became lower at T4 and T5. This showed a delayed process of stress reduction. The higher stress levels in M2 and M3 at T4, compared with the those of the control, could be viewed as T2 for M1 relative to when the music was listened to. It can be speculated that the stress levels of the M2 and M3 groups would be lower than the control group at T5+5 or T5+10 minutes.

This lab experiment was the first work which monitored stress as well as stress recovery continuously through commercial physiological sensing while studying the differing effects of music on stress. The findings can be used to validate the effectiveness of stress interventions.

Future Research

In the future, diversity of the survey participants should be improved by utilizing different distribution methods in addition to social media and contacting more schools around the country.

In the lab experiment, at least 10 more minutes should be added after T5. Due to the possible delay effect, a stronger stress-reducing effect of music in M2 and M3 group may be observed in the added minutes. Another direction for future research to explore is different durations of time for listening to music before the stressor. Additionally, another self-reported stress measurement time should be added between T2 and T3 to acquire a measure of psychological stress during the TSST. Stress should be self-reported on a broader range to gain more specific insights into psychological stress.

In addition to heart rate, the Empatica also recorded skin conductivity (EDA/GSR) data, which was used as a stress indicator in some studies. Further data analysis on EDA/GSR

should be performed and possibly used to derive stress measurements. Combining multiple physiological stress indicators could produce a stress diagnosing method with enhanced accuracy.

Results from this study could be used to develop an artificial intelligence stress prevention application, which would give users real time stress feedback and send notifications reminding them to listen to music and do other relaxing activities. Integrating the user's personal calendar would enable the application to predict upcoming stressful events.

Future work could utilize the findings of this experiment to identify solutions which are more effective in reducing stress. It is important to spread awareness about effective stress solutions as overwhelming stress is a widespread problem which affects growing numbers of people [2].

6 CONCLUSIONS

This study included two phases. The first phase was a survey that looked into music and stress for adolescents, with 252 participants. It consisted of three sections: music, stress, and music for stress reduction. The data collected from the survey supported the two hypotheses: music is used to reduce stress before and after the stressor, and different adolescents listen to a wide variety of music for stress reduction. The survey completed the objectives and revealed that stress is an urgent issue for adolescents and that music is a commonly used method to reduce stress. The survey results also provided details about the genres of music that are listened to, the methods it is commonly listened to through, the time relative to the stressor in which it is listened to, and the length of time during which it is listened to. These results helped influence the design of the second phase lab experiment.

Based on the survey results, a lab experiment was designed to investigate the impact of time related factors (duration and time relative to the stressor) of listening to music on stress reduction. In total, 42 students participated in the experiment and their stress levels were measured subjectively through self-reports and physiologically through a wearable Empatica device. The findings with HRV-derived stress confirmed the hypothesis that listening to music before the stressor would have a better effect on stress reduction than listening after the stressor. However, the findings rejected the hypothesis that listening to music for a longer duration (10 minutes rather than 5 minutes) would produce a greater stress reducing effect. In fact, no stress reduction was observed for the groups who listened to music after stressor compared to the control. A possible reason is that the impact may have had a delay and consequently was not observed during the time frame of the experiment trial. The results pointed out possible directions for feature research which

could include a longer observation time to alleviate uncertainties and also build on the findings to investigate more effective stress solutions.

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