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Effects of Genre, Emotional Response, and Perception of Music on Simple Cognitive Tasks

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Investigating the impact of music on cognitive performance is incredibly complex, in part because of the potential for wide variation in the qualities of the music and the type and complexity of the cognitive task being performed. This study examined how variations in genre, familiarity, and enjoyment of background music affected the performance of 41 individuals on somatosensory simple and choice reaction tests. Although no significant trends were found in parameters of reaction time, reaction time variability, choice reaction time, and percent of correct choices on choice reaction time, trends in the data suggest that further investigation into the effects of familiarity, enjoyment, and other such emotional components of music processing on cognitive performance may be a valuable direction for more extensive testing.

Introduction

Music is generally accepted to have a significant impact on cognitive performance; however, theories on the specific details and mechanisms of the effects of music on cognition vary widely among researchers. Existing research on the subject is rather contradictory, disagreeing on whether music positively or negatively affects cognition and the range of cognitive functions to which these effects may be applied.

One body of research suggests that music has the ability to improve performance on physically demanding tasks like spatial processing and motor coordination. Instruction in a musical instrument has been demonstrated as an effective intervention to improve manual dexterity and bimanual sensorimotor coordination across a wide range of ages [1,2]. For people who have neurological disorders or damage, interventions based on music listening, rhythm matching, and learning of an instrument have all been demonstrated to improve motor skills, with notable gains in upper-limb and hand function and general mobility [3]. Additionally, performance on tasks such as motor tracking of objects or images can be enhanced through the use of music that contains tempos that match the desired speed or rhythm of that task [4].

Other studies have linked music that evokes positive emotions to improvements in cognitive performance. Enjoyable music can alleviate the effects of stress, improve attention and reaction speed, decrease mind wandering during task performance, and improve motivation [5,6]. These gains in emotional and attentional regulation are theorized to help individuals maintain better focus and perseverance, which could promote more effective cognitive performance even on complex tasks like lexical processing [5].

Music-based interventions have also been shown to generate improvements in performance on higher-level cognitive tasks. Short- or long-term musical training can induce significant improvements in verbal intelligence and linguistic processing in children and prevent age-related declines in phonological fluency in adults [7-9]. Likewise, some studies have connected music-based interventions to increased plasticity and improvements in visual and verbal working memory [9-11]

. Notably, many of the studies that connect music to improvements in complex cognition use music as a therapeutic intervention separately from performance of the task rather than during the task itself.

Contrastingly, a significant body of research suggests that the capacity of music to distract an individual from a task actually reduces their cognitive performance, especially when music is played during execution of a complex task. Several studies have found that auditory distractions negatively affect performance on choice reaction time and serial pattern matching tests; decrease the efficacy of information processing; and impair memory storage and retrieval [12,13]. While some of these effects were inconsistent across different subject demographics, they suggest that auditory distractions, especially those presented at a high volume level, are detrimental to cognitive performance.

Regardless of the hypothesized effect of music on cognition, many studies have demonstrated that particular details about the music being played determine the level of effect on cognitive performance. For instance, one study suggests that 70 dB is the optimal sound level for background noise during simple cognitive tasks, whereas sounds played at higher than 80 dB or lower than 60 dB correlated with increases in reaction time [14]. Other studies have investigated whether varying musical elements like genre and intensity can change the extent to which music is beneficial or detrimental to cognition [5,15].

This study expands on previous research by investigating the extent to which genre, enjoyment, and familiarity of background music influence the effects of music on performance of simple cognitive tasks. Subject performance on simple and choice reaction tests was evaluated using the CorticalMetrics Brain Gauge system. The Brain Gauge comprises a computer mouse-like somatosensory testing device that uses vibrations delivered to the index and middle fingertips as prompts for simple or choice reaction tests. Our study comprises three primary hypotheses: 1) music of any genre will negatively impact performance in simple and choice reaction tests compared to those same tests performed in silent conditions; 2) details of the music being played, including the genre of the song and a subjects' enjoyment of and familiarity with each song, will not produce any differences in the subjects' overall performance on these tests; and 3) more frequent use of music while studying and higher perceived helpfulness of music use while studying will correlate with improved performance on these tests across all three genres.

Methods

Our study measured the cognitive performance of 41 individuals aged 18-22. Subjects' performance on simple and choice reaction tests was assessed while they listened to three songs of different genres.

A preliminary survey administered before testing asked subjects to rank five different music genres (classical, country, hip-hop, jazz, and rock) based on preference, with 1 being their least favorite genre and 5 being their preferred genre. Of the five genres, rock, hip-hop, and classical were selected as the three genres to be used for this study because the survey indicated them to be the most well-liked, the intermediately liked, and the least well-liked genres, respectively. One song was selected from each of the three genres to be presented to the subjects during testing. Monkey Wrench by Foo Fighters was chosen for rock, OCD by Logic for hip-hop, and Road to Perdition by Thomas Newman for classical.

The subjects were provided with a survey containing instructions for how to complete the testing. Subjects were asked to choose a quiet location with minimal distractions to perform all tests. They were also instructed to listen to the audio while using headphones set at a comfortable loudness level, which would vary depending on the preference of each subject, but would typically be about 70 dB [14]. Once they had prepared their testing environment, each subject was presented with all

three songs in a randomized order. For each song, the subjects entered their Subject ID into the Brain Gauge software and filled in the relevant subject information. Subjects then used the YouTube link provided in the instructions to listen to the given song. While the song was playing, subjects would perform 10 reaction time tests and 10 choice reaction time tests with the Brain Gauge.

Following the completion of the testing for a given song, subjects would stop the music and fill out a questionnaire to rate their level of enjoyment of the song and their level of familiarity with the song. Each category was rated on a scale from 1 to 5, with 1 being the lowest level of enjoyment or familiarity and 5 being the highest. In a separate survey, subjects were asked to rate how frequently they listened to music while studying and how helpful they found it to do so. As previously, categories were ranked on a scale from 1 to 5, with 1 being the lowest level of frequency or helpfulness and 5 being the highest.

Results

Brain Gauge Metrics

For each of the three songs, the Brain Gauge tests provided data on four metrics. The simple reaction test evaluated the average reaction time and reaction time variability for each subject across all trials for a given condition. The choice reaction time test measured the average choice reaction time and the percentage of trials in which the subject responded correctly. The reaction time, reaction time variability, choice reaction time, and choice reaction time percent correct were compared with control data (Figure 1). Control data were obtained by averaging results from four previous simple and choice reaction time tests in which subjects performed ten trials of each test in silent conditions.

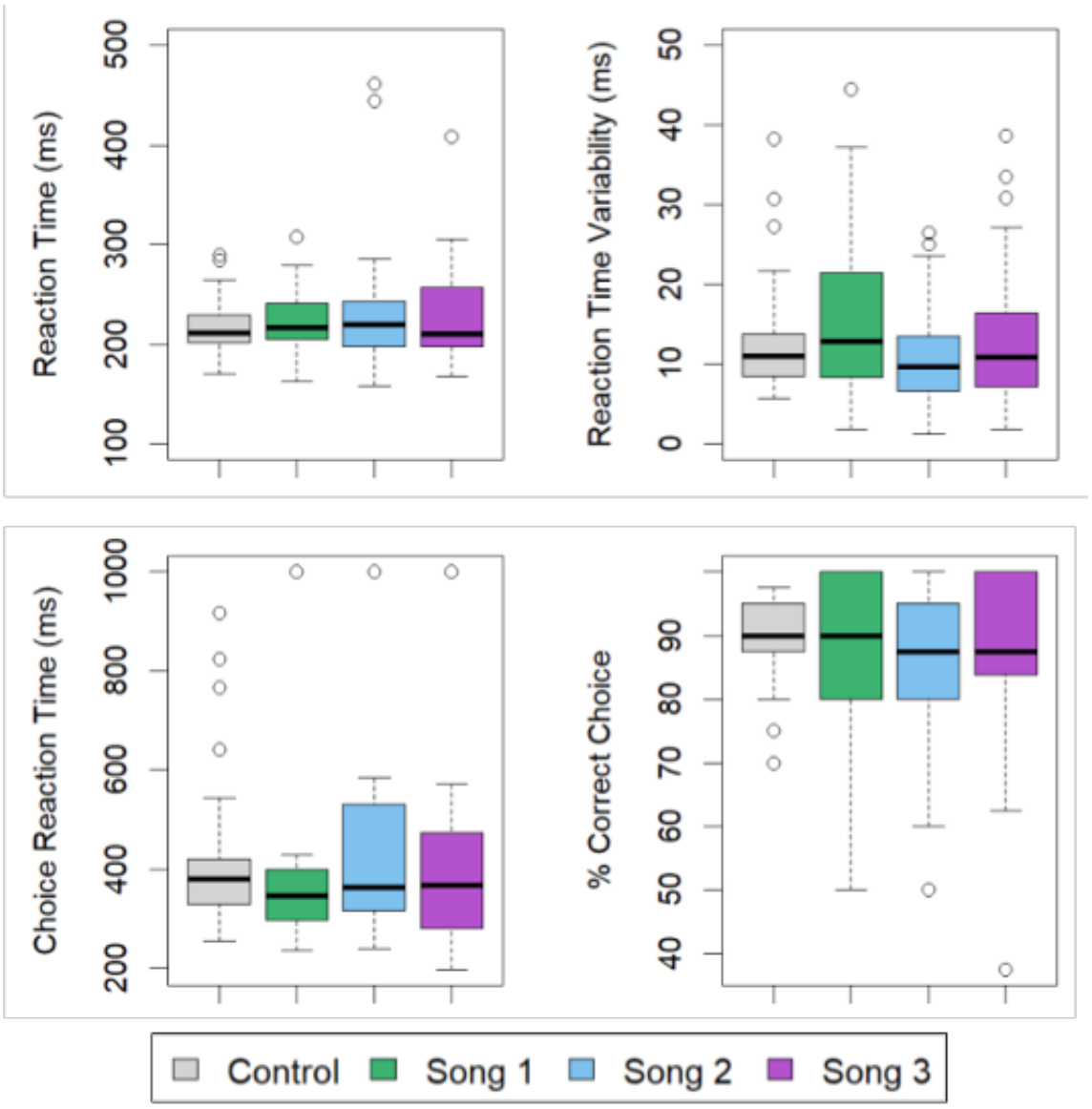

Figure 1. *All four Brain Gauge metrics are relatively similar across all four audio conditions.*

Comparing the three songs with each other and with the control does not reveal any significant differences in averages for simple reaction time, reaction time variability, choice reaction time, or percentage of correct choices during the choice reaction test. For the percentage of correct choices during the choice reaction time test, the lowest quartile for each of the three songs encompasses much lower percentages relative to the control. This decrease in overall accuracy during the choice reaction test indicates that listening to songs of any genre had a tangible impact on the ability of some subjects to make accurate rapid decisions. Still, the lack of significant change in average percentage of correct choices indicates that these effects applied to only a small subset of the subject group.

Enjoyment and Familiarity

Immediately after subjects finished performing a set of tests while listening to a particular song, they were prompted to rate how much they enjoyed the song and how familiar they were with the song. For each question, subjects chose from among five answer choices, which were assigned numbers such that 1 indicated the lowest level of enjoyment or familiarity and 5 indicated the

highest.

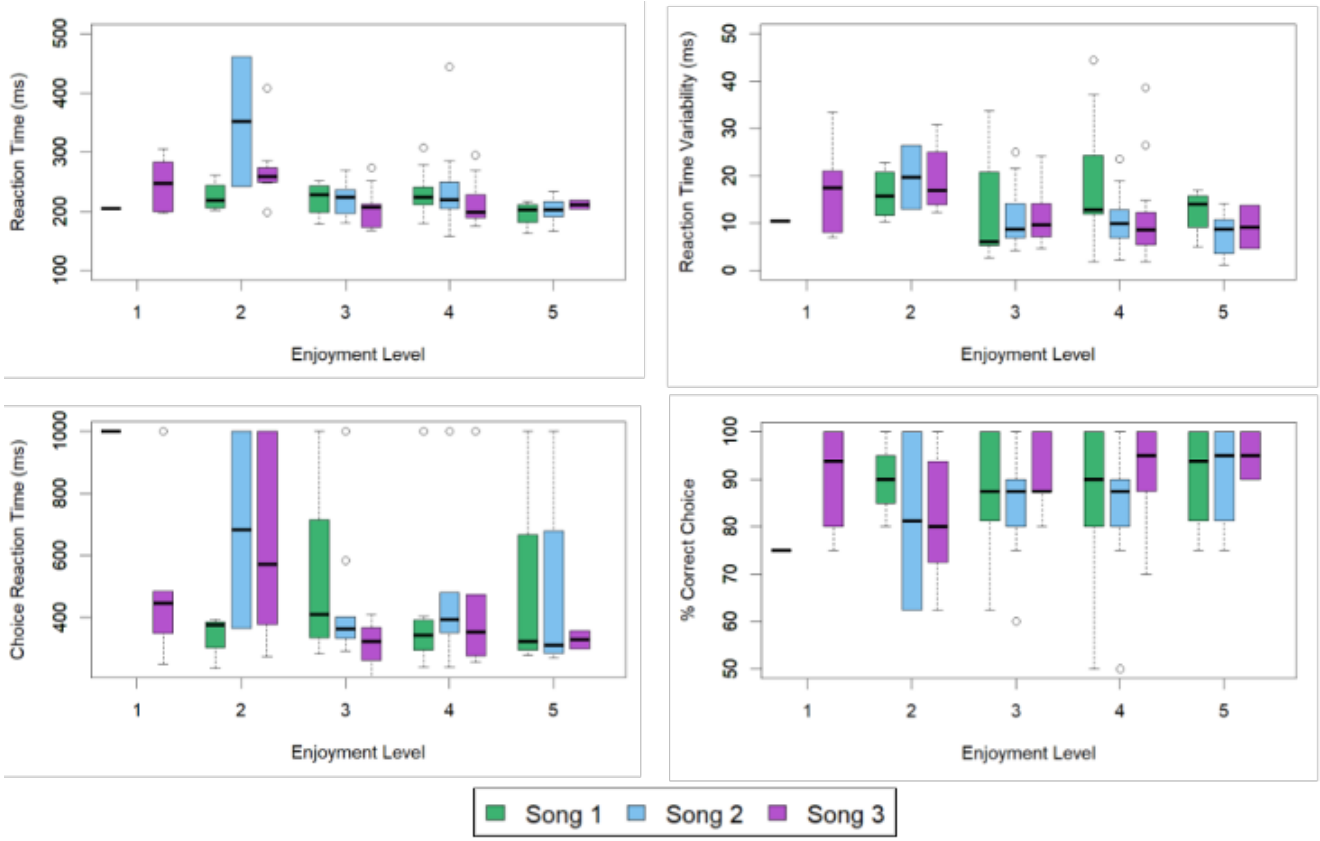

Figure 2. *All four Brain Gauge metrics show slight but noticeable trends in which increasing enjoyment levels correlate with improved cognitive performance.*

Comparing Brain Gauge metrics for each song while sorting the subjects by their enjoyment level reveals some emergent trends in which increased enjoyment of a song appears to improve cognitive performance (Figure 2). For a given song, the average simple and choice reaction times are often higher for subjects who rated their enjoyment level at a 1 or 2 and lower for those who rated their enjoyment level at a 3, 4, or 5. Wide variations in simple and choice reaction times prevent more precise characterization of this trend through statistical testing or modeling, but the connection between increased enjoyment of the song and improved reaction times remains noteworthy as an indication that song enjoyment plays a role in the impact of music on cognitive performance.

Similar patterns are seen for the other two metrics: subjects who rated their enjoyment of a song at 1 or 2 had a higher average reaction time variability and a lower average percentage of correct choices in the choice reaction test relative to subjects who rated their enjoyment at a 3, 4, or 5. These trends suggest that when subjects were listening to a song they enjoyed, they exhibited both improved focus and greater accuracy in rapid decision-making. As with the previous trends related to enjoyment level, wide variability in the data prevents statistically significant analysis of these trends. Nevertheless, the correlation between increased enjoyment of a song and improvements in focus and accuracy further supports the notion that the impact of music on cognitive performance depends on the person's enjoyment of that music.

While these trends may indicate some connection between enjoyment of a song and the impact of that song on one's cognitive performance, it is important to note that none of these trends were statistically significant at the $\alpha = 0.05$ level (with Holm-Bonferroni adjustment) based on the results of pairwise, two-tailed paired t-tests comparing performance on each metric across the three songs. Additionally, when the four metrics were normalized by subtracting each subject's control results

from their results for a given song, the aforedescribed trends were no longer present. No significant trends were observed between familiarity with the song and any of the parameters, regardless of whether or not the data was normalized relative to the control data.

Use of Music While Studying

A survey administered separately from the main testing was used to evaluate how often each subject listened to music while studying and the extent to which they felt that doing so improved the efficacy of their studying. For each of the two questions, subjects selected a number from 1 to 5, with 1 indicating the lowest level of frequency or helpfulness and 5 indicating the highest.

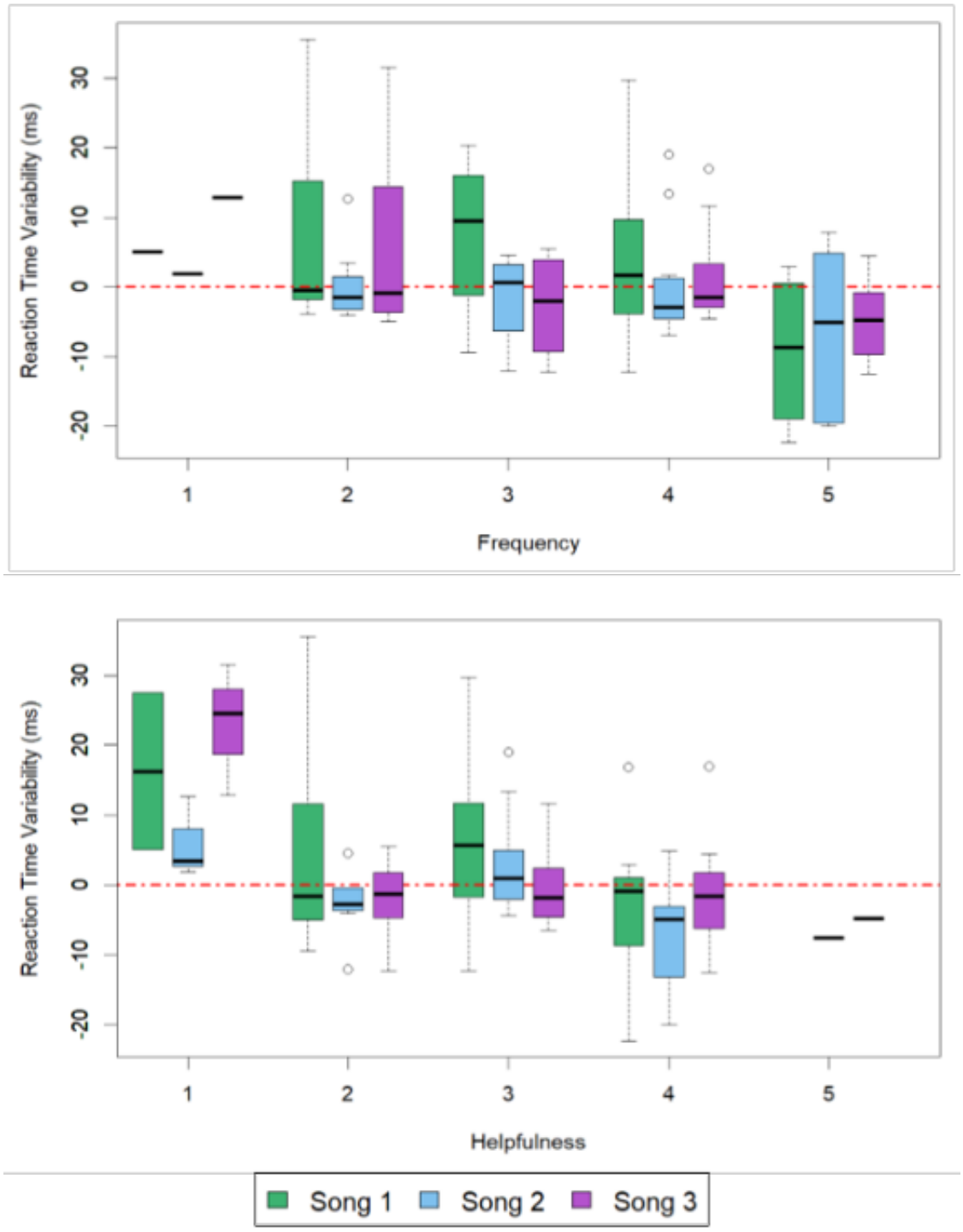

Figure 3. *Reaction time variability normalized against the control is noticeably lower for subjects who frequently listen to music while studying or consider it helpful to do so.*

Moderate trends in reaction time variability are evident in comparing Brain Gauge metrics for each song while sorting the subjects by how frequently they listen to music while studying and the extent to which they consider music helpful to their studying (Figure 3). Subjects who do not listen to music while studying (Frequency = 1) or did not consider it helpful to do so (Helpfulness = 1) exhibited reaction time variabilities greater than their control reaction time variability when listening to each of the three songs. These results suggest that for students who do not typically listen to music while studying or feel that music is detrimental to their studying, listening to music while performing even a simple cognitive task does noticeably impair their focus.

On the other hand, subjects who very frequently listen to music while studying (Frequency = 5) generally exhibited much less reaction time variability compared to their control reaction time variability. Among these subjects, very large decreases in reaction time variability were noticeable for both Song 1 and Song 2. This pattern indicates that rock and hip-hop, two genres often considered to be distracting, were generally not detrimental to focus for students who frequently listen to music while studying.

Subjects who considered listening to music to be moderately or very helpful to their studying (Helpfulness = 4 or 5) likewise tended to exhibit notable decreases in their reaction time variability while listening to music when compared to the control data. Combined with significant increases in reaction time for students who do not find it helpful to listen to music while studying (Helpfulness = 1), the results suggest that these students have a fairly good understanding of whether music is beneficial or detrimental to their ability to focus on cognitive tasks. While interesting, it is important to note that this result may not trasnfer from the simple cognitive tasks performed here to more complex tasks like studying.

Overall, these results demonstrate that students who frequently listen to music while studying and find it helpful to do so are better able to focus on a simple task while listening to music than their non-music-listening counterparts. Although not significant according to statistical testing or modeling, these trends are evident even when normalized to the control, which indicates a potentially relevant connection between a student’s propensity to listen to music while doing complex tasks and their ability to focus while listening to music. No other metrics exhibited significant trends related to the frequency or perceived helpfulness of listening to music while studying.

Discussion

Our first hypothesis predicted that music will serve as an auditory distraction that decreases subjects’ cognitive performance compared to silent controls. Figure 1 illustrates no significant differences in any of the Brain Gauge metrics when comparing the silent control with the three songs. These results disagree with our hypothesis and suggest that music does not serve as a significant auditory distraction during simple and choice reaction tests. This finding may be explained by the relative simplicity of the simple and choice reaction tasks. Perhaps a more complex task requiring higher-level cognition would have produced more noticeable changes when comparing silent controls with the three treatment groups. Additionally, the control data were collected approximately two months before the experimental data, so improvements in subject performance caused by administration of other simple and choice reaction tests within that time span may have masked any significant impacts of music as an auditory distraction.

The second hypothesis predicted that specific features of a given song, including genre, enjoyment, and familiarity, would not have a significant impact on cognitive performance. Such features of songs have been correlated with changes in more abstract mental processes like motivation and attention regulation, [5,6] but we did not expect them to have any influence on the relatively short,

simple tests performed in this study. Indeed, Figure 1 demonstrates no significant differences in Brain Gauge metrics between the rock, hip-hop, and classical songs used in this study, which supports this hypothesis with respect to genre.

Unexpectedly, subjects who indicated neutral to high enjoyment of a given song generally performed better on all Brain Gauge metrics on that song compared to subjects who did not enjoy that song, as shown in Figure 2. This relationship between enjoyment of a song and improved cognitive performance aligns with previous research asserting that songs evoking positive emotions improve cognitive performance [5,6]. Our results reinforce that the positive effects of enjoyable music on attention and other abstract mental processes are relevant even for relatively simple tasks.

Research supporting the cognitive benefits of enjoyable music also posits that familiarity may make music more enjoyable [6]. Our study did not find any significant connections between familiarity with a song and performance on simple and choice reaction tests; however, all three songs were given low familiarity ratings of 1, 2, or 3 by the vast majority of subjects, so it is likely that the songs used in this study were too obscure to allow for comprehensive evaluation of this variable.

In our third hypothesis, we predicted that greater frequency and perceived helpfulness of music use while studying would correlate with improvements on simple and choice reaction tests. While this prediction was not supported for the reaction time, choice reaction time, or percentage of correct choice metrics, Figure 3 shows fairly significant connections between these factors and reaction time variability. Considering that reaction time variability is often considered indicative of focus and attention, these results suggest that students who frequently listen to music while studying and find it helpful to do so often experienced improvements in focus when listening to music during testing compared to the silent control. By contrast, students who do not listen to music while studying or do not find it helpful to do so were more likely to exhibit increased reaction time variability and thus decreased focus relative to their silent control.

While analysis of the data revealed interesting anecdotal trends, none of the results were statistically significant, nor were there any particularly useful models for the four outcome metrics derived using stepwise selection with the parameters measured via the Brain Gauge and the surveys. The large amount of variability in the Brain Gauge test results made it difficult to draw statistically relevant conclusions even in cases where trends were evident. This variability could have been reduced by increasing the total number of simple and choice reaction time repetitions the subjects performed for each song; however, any increases in the length of each trial would also lead to increased fatigue, loss of focus, and/or early termination of testing by some subjects, all of which would have other negative effects on the quality of the data. The relatively small number of subjects further exacerbated the impact of large variability on any statistical analyses, but logistical challenges made it difficult to recruit additional subjects to address this issue.

Some features of the procedure followed by the subjects may have introduced errors that contributed to the variability of the data as well. Subjects were instructed to find a testing environment with minimal distractions, but we had no way of ensuring that all subjects were exposed to similar levels of ambient distractions. We also did not control for factors that could impact the physical and mental state of the subject at the time of testing, such as amount of sleep and subsequent number of hours awake; amount of caffeine, food, etc. consumed throughout the day; and levels of personal or academic stressors at the time of testing. Any such factors could have contributed to significant changes in each subject’s performance, particularly if the control data, which was obtained separately, was collected while the subject was in a different physical and/or mental state.

Another major limitation of this study was the inability to control the loudness of the audio being played. While subjects were instructed to use headphones and set their audio to a comfortable loudness level, we did not have any method to measure that volume level or to ensure that all

subjects chose the same volume level. Studies have shown that the impact of background audio on cognitive tasks is dependent on volume level [14], so subjects whose chosen volume levels deviated from the optimal range may have experienced more negative impacts on their performance on each test compared to those whose volume levels fell within the optimal range.

Other important considerations when analyzing the results of this study include distraction and fatigue that may have been introduced by the testing procedure. Subjects were expected to proceed through a fairly complex set of steps, which often required them to have multiple windows open or proceed through steps in a particular order. The instructions integrated within the survey were designed to try to minimize this confusion, but distractions associated with any complicated steps could have negatively impacted cognitive performance. Additionally, the time length inherent in having subjects repeat the testing and survey questions for three different songs could have introduced fatigue. Songs were presented in a randomized order to help control for this effect, but fatigue still likely had some influence on the cognitive performance metrics, particularly those normalized against the control for each subject.

To more effectively manage these limitations, future iterations of this study should aim to create a fully controlled testing environment that minimizes distractions and normalizes volume levels across subjects. Recruitment of a larger, more varied subject pool would reduce problems with the variability of the data and allow these results to be generalized beyond university students.

This work could also be expanded by inclusion of a larger variety of music genres and use of several songs within each genre instead of just one. Ideally, increasing the number of genres and songs tested would more effectively capture the substantial variation extant within and among music genres. Combined with a larger and more diverse participant pool, this experimental setup could be able to reveal trends related to genre, enjoyment, and familiarity that were not evident with the limited number of songs and genres used here.

Regarding the impact of music on cognitive performance, the qualitative variables measured in this experiment offer some interesting insights into human cognitive behavior despite providing no significant quantitative conclusions. The improvements in cognitive performance connected to factors such as higher levels of song enjoyment and greater perceived helpfulness of music while studying suggest that the emotional and perceptual elements of music are at least as important as more tangible factors related to genre in determining the impact of music on cognitive performance. This study thus validates that the interactions between emotions, music processing, and cognitive performance may be some of the most valuable avenues for future research.

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