The Journal of Science and Medicine
2022: Special Issue: Undergraduate Student Research
Student Articles: Corresponding Editor Mark Tommerdahl

The Disparity of Expected and Real Effects of Background Noise on Focus.

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The goal of this study was to investigate the relationship between actual performance and anticipated performance of individuals on reaction time tests taken under three conditions: the absence of background sound, listening to a song of their choice, and listening to a podcast of their choice. Prior to taking the reaction time tests, individuals completed a survey that asked whether they predicted the presence of a background auditory stimulus would significantly improve or worsen their performance. Afterwards, participants were instructed to take a reaction time test using the Cortical Metrics Brain Gauge while listening to either music, a podcast, or no background sound in three different trials. This study showed that there is a significant correlation between song reaction time variability (RTV) and expectation as it was found that individuals who expect to do better with the presence of their preferred background sound actually have increased focus (decreased RTV) in the presence of music. This finding is important as it highlights the effects and value of music on focus. It has a real-world application as many individuals use music while undergoing cognitive tasks (i.e. driving, studying, etc.), depicting the importance in better understanding the effects it has on people.

Introduction

There have been numerous studies on the effect of listening to music while completing varying tasks, but the consensus of whether music is beneficial or detrimental to a person's ability to focus is unclear. It is common in learning environments to use background music to enrich student capacity to retain information and remain goal-oriented. However, past research has suggested that the influence of music on learning is dependent on the type of task being performed as well as the type of music [1]. A pilot study conducted by Li et al. found that learner's self-selected background music often enhanced learning outcomes as opposed to distracting them from the task. The study also discovered that background music was more beneficial during less demanding learning tasks Aside from the type of task being performed, the benefit or harm of background music may depend on a plethora of characteristics and more recent studies have attempted to determine the impact of lyrics, tempo, volume, and mode as it relates to learning. Unfortunately, many of these studies remain inconclusive. Several other factors were proposed as confounding variables in assessing the effect of music like an individual's musical perception abilities, habits of listening to background music, and emotional reactivity to music [2]. These variables raise the question of whether it is the properties of music that affect learning outcomes or differences in the individuals listening to the music.

There is still scientific uncertainty in music's effect on task completion, but there is an overall positive public perception on the role of background music. A study by Kotsopoulou and Hallam (2010) investigated student's self-perceptions of music's effect on studying. The sample population indicated that music was not played while studying extensively or memorizing material but was most often played during critical thinking or writing tasks. This suggested that students were aware of the beneficial effect of music on certain types of tasks and its impairment on others. Mostly, students reported that music was used to relax, alleviate boredom, and aid concentration

[3]. The question is then posed of whether these self-perceptions are accurate. Students that habitually listen to music while studying may overestimate the effect that music has on their academic achievements.

The Dunning-Kruger effect is a phenomenon in which people tend to hold an overly favorable view of their abilities. This cognitive bias may relate to individuals overestimating the effect of music on their ability to focus. Individuals who normally listen to music while studying may assume a greater improvement on their ability to focus as a result of background music when there actually isn't a significant difference between their learning outcomes with or without it. Likewise, students who do not normally use background music during studying may assume a greater level of impairment on learning outcomes due to the presence of music.

This experiment aims to measure the effect of music on focus based on individual habits along with the ability of individuals to accurately predict those effects. Before the experiment, subjects filled out a survey asking for their demographics, regular study habits, and prediction of whether they will perform better, worse, or the same with background noise. Subjects were subsequently asked to perform the same reaction time test under three conditions: (1) absence of background noise, (2) presence of self-selected background music, and (3) presence of self-selected podcast. Focus was measured via reaction time variability using the Brain Gauge. Changes in reaction time variability between each trial were then compared to the changes expected by the student to see if they accurately predicted the effect that background noise would have on their ability to focus. We hypothesized that participants would expect a statistically significant difference in their reaction time variability between reaction time tests done with background noise compared to those done without background noise, but the true reaction time variability would not significantly change between the two conditions.

Methods

Participants:

The sample included 43 subjects between the ages of 20 and 25. There were 21 female identifying subjects, 21 male identifying subjects, and one non-binary identifying subject. 28 of participants were White, 1 was Black/African, 9 were Asian, 3 were Hispanic or Latinx, and 2 were Arab or Middle Eastern.

Materials:

The primary outcome measures were assessed through the Cortical Metrics Brain Gauge. We ran one battery three times to test both reaction time and reaction time variability under the various experimental conditions. A Google Form pre-survey was used to assess subject expectations prior to assessment.

Procedure:

Participants were invited to participate in an online pre- survey created through Google Forms. The survey consisted of the following questions:

1. What is your age?
2. What is your ethnicity?
3. What is your gender?
4. How do you think background sounds affect your focus?
    1. Significantly increases focus
    2. Significantly decreases focus
    3. No significant impact

5. Do you usually listen to something while studying? If Yes, please select all that fit best below. If not, please select no.
    1. No
    2. Music with Words
    3. Music without words
    4. Speaking (eg. Podcast or Sports Commentary)
    5. Non-Speaking (eg. rain sounds, haircut autonomous sensory meridian response (ASMR))
    6. Other (self-describe)

Students were then given the information via email to access the battery with the tests using the CorticalMetrics Brain Gauge. The tests consisted of three trials, which assessed reaction time and reaction time variability. Each participant was presented with the three different conditions in an order that was randomized based on their subject ID number. The conditions included: (1) absence of background noise, (2) presence of self-selected background music, and (3) presence of self-selected podcasts. The entire testing period took around a total of 12 minutes.

Analysis:

Data was analyzed through R statistical software and formatted in Excel to compare the reaction time and reaction time variability with pre-survey responses via various ANOVA tests and a classification model. To ensure the order of testing wasn't a confounding variable, we first used a factorial ANOVA to determine if the order of testing, a two-level variable corresponding to whether the song-trials came directly after control-trials or not, influenced the results. Then, we used factorial ANOVA to determine if any demographic data correlated with experimental results. Finally, we used three methods to determine how expectation affects reaction time and reaction time variability. First, we used a factorial ANOVA to determine if expectation influenced our results. Then, we used an ANOVA test to determine if expectation significantly affected over/underestimation of performance, measured in terms of the difference between each experimental group and the control. Finally, we attempted to create a classification model, using Random Forest Generation, to predict whether an individual will over or under-estimate their performance. These three metrics together allow us to infer whether certain groups of people tend to over/underestimate their performance in certain conditions.

Results

Participant Responses

When asked about the impact of background sounds on their focus, 21 participants (48.83%) responded “Significantly decreases focus,” 12 participants (27.91%) responded “No significant impact,” and 10 participants (23.26%) responded “Significantly increases focus.” There appeared to be no gender bias for any option (ie. exactly half +/- one participant was male/female for each group).

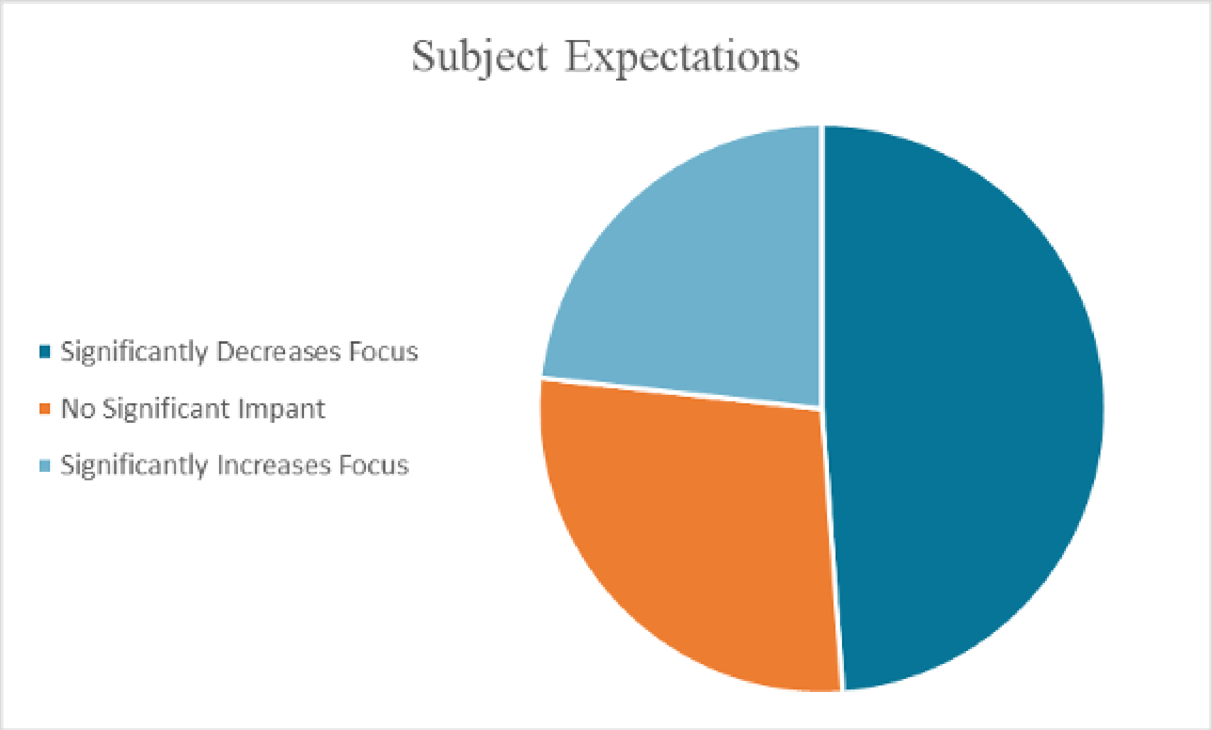

Figure 1.

The following describes the distribution of the participant's usual studying background choice within each of the aforementioned groups. Of the 21 participants that responded with "Significantly decreases focus," 42.86% did not listen to anything while studying, 23.81% solely listened to music without words, 9.52% solely listened to music with words, and the remaining 23.81% listened to a variety of music, podcasts, and/or other (including 9.52% that only listened to ASMR and 4.76% that listened to all the options). Of the 12 participants that responded with "No significant impact," 41.67% solely listened to music with words, 25% solely listened to music without words, 16.67% did not listen to anything while studying, and the remaining 16.67% listened to a variety of music and spoken background noise. Of the 10 participants that responded with "Significantly increases focus," 40% listened to a variety of music and spoken background noise (of which half listened to music with and without words and half listened to music and spoken background noise), 30% solely listened to music without words, 30% solely listened to music with words, and 0% did not listen to anything.

Data Validation

A plot of Cook's Distance of the Control RT average vs all other averages was used to estimate the influence of each data point. The red line indicates the 50th percentile of an F distribution with the same degrees of freedom as the sample (df1 = 1, df2 = 39). Subjects 24, 40, and 45 were removed as they surpassed this threshold and therefore were considered outliers.

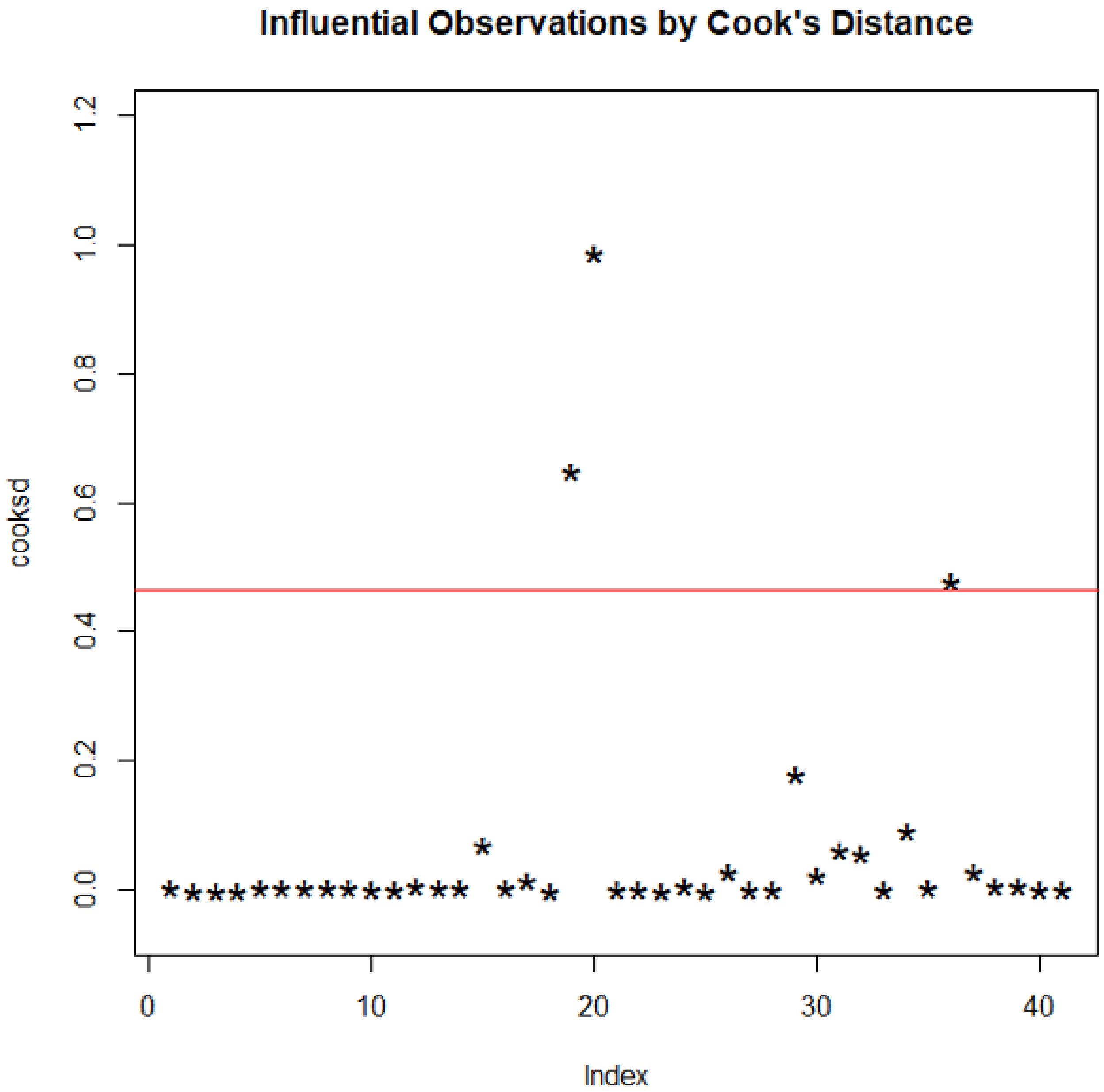

Figure 2. *Cook's Distance Plot*

Primary Analysis

To determine whether there is an association between our variables (gender, ethnicity, expectation, background norm, control RT, control RTV vs song RT, song RTV, podcast RT, and podcast RTV) we tested all the possible combinations to compare the means of each variable and determined if there was statistical significance through a one-way ANOVA test. The confounding variables (gender, ethnicity, expectation, background norm) seemed to not interfere with our results as we did not find any statistical differences in the data due to these confounding variables. However, we found statistical significance between control RT vs control RTV, control RT vs song RT, control RTV vs song RT, control RT vs song RTV, control RTV vs song RTV ($p < .05$). There was also statistical significance between control RT vs podcast RT, control RTV vs podcast RT, control RT vs podcast RTV, and control RTV vs podcast RTV ($p < .05$).

One-Way ANOVA Tests

	Control RT	Control RTV	Song RT	Song RTV	Podcast RT	Podcast RTV
Gender	0.586432955	0.751408319	3.517031e-01	5.378310e-01	1.682220e-01	0.1646270586
Ethnicity	0.189890838	0.748733169	4.458499e-01	5.481044e-01	3.279268e-01	0.3066258202
Expectation	0.949770306	0.956286851	9.502338e-01	7.010462e-01	9.085733e-01	0.9996841820
Background Norm	0.875001296	0.439599776	5.523316e-01	2.759747e-01	7.777497e-01	0.3798155855
Control RT	0.000000000	0.002036002	5.037556e-18	5.788431e-03	3.587257e-14	0.0030420135
Control RTV	0.002036002	0.000000000	8.185329e-03	6.937889e-05	2.307157e-02	0.0007572478

Figure 3. *One-Way ANOVA tests between control and experimental conditions*

Box Plots

We visualized the reaction time vs each condition (control, song, podcast) and reaction time variability vs the same conditions via boxplots. It was shown that songs decrease reaction time and reaction time variability, while podcasts do the opposite.

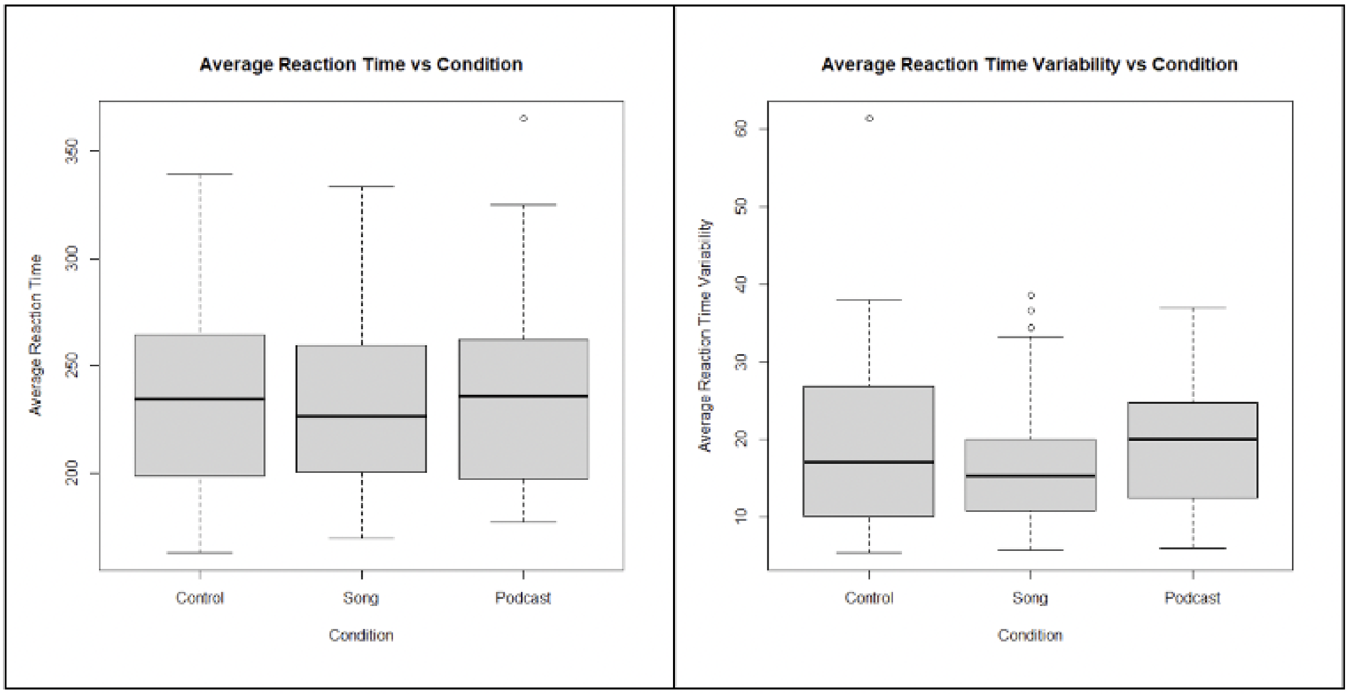

Figure 2a. Box Plot of Reaction Time vs Condition

Figure 2b. Box Plot of Reaction Time Variability vs Condition

Figure 4.

Factorial ANOVA Tests

To determine if gender, order, normal background noise, serve as a confounding variable on reaction time and reaction time variability, we conducted factorial ANOVA tests. It was found that song reaction time variability varied with ethnicity ($p < .05$). Also, there was a statistically significant interaction between podcast RT and gender, song reaction time variability and expectation, podcast RT and normal background noise, and song RTV and normal background noise ($p < .05$).

	Control RT vs. Pr(>F)	Control RTV vs. Pr(>F)
Song RT	1.346912e-16	0.006591349
Song RTV	3.340493e-01	0.004472954
Podcast RT	6.068675e-02	0.683715351
Podcast RTV	1.956495e-01	0.477571705
Gender	3.864894e-01	0.485602657
Song-RT*Gender	3.556889e-01	0.754002705
Song-RTV*Gender	3.391145e-01	0.703682235
Podcast-RT*Gender	1.297042e-02	0.411779722
Podcast-RTV*Gender	3.674983e-01	0.773106789

Figure 5. *F Test of Impact of Gender*

	Control RT vs. Pr(>F)	Control RTV vs. Pr(>F)
Song RT	3.178298e-13	0.006389107
Song RTV	4.125937e-01	0.004381063
Podcast RT	1.106507e-01	0.677406781
Podcast RTV	2.720072e-01	0.468718516
Ethnicity	6.465964e-01	0.996407966
Song-RT*Ethnicity	9.536884e-01	0.894609810
Song-RTV*Ethnicity	8.691953e-01	0.048324232
Podcast-RT*Ethnicity	9.155685e-01	0.767121378
Podcast-RTV*Ethnicity	1.566585e-01	0.266368919

Figure 6. *F Test of Impact of Ethnicity*

	Control RT vs. Pr(>F)	Control RTV vs. Pr(>F)
Song RT	1.373127e-15	0.004091559
Song RTV	3.919294e-01	0.002676322
Podcast RT	9.451905e-02	0.665119704
Podcast RTV	2.506407e-01	0.450619443
Order	3.884909e-01	0.351297019
Song-RT*Order	4.906007e-01	0.357192312
Song-RTV*Order	8.419497e-01	0.115852867
Podcast-RT*Order	8.487385e-01	0.900113913
Podcast-RTV*Order	3.433828e-01	0.356689142

Figure 7. *F Test on Impact of Order*

Control RT vs.

	Pr(>F)
Song RT	1.373127e-15
Song RTV	3.919294e-01
Podcast RT	9.451905e-02
Podcast RTV	2.506407e-01
Order	3.884909e-01
Song-RT*Order	4.906007e-01
Song-RTV*Order	8.419497e-01
Podcast-RT*Order	8.487385e-01
Podcast-RTV*Order	3.433828e-01

Control RTV vs.

	Pr(>F)
Song RT	0.004091559
Song RTV	0.002676322
Podcast RT	0.665119704
Podcast RTV	0.450619443
Order	0.351297019
Song-RT*Order	0.357192312
Song-RTV*Order	0.115852867
Podcast-RT*Order	0.900113913
Podcast-RTV*Order	0.356689142

Figure 8. *F Test on Impact of Background Norm*

Control RT vs.

	Pr(>F)
Song RT	3.056342e-12
Song RTV	3.581274e-01
Podcast RT	7.737537e-02
Podcast RTV	2.197259e-01
Background Norm	3.571945e-01
Song-RT*Background Norm	4.034209e-01
Song-RTV*Background Norm	5.750485e-01
Podcast-RT*Background Norm	6.086917e-01
Podcast-RTV*Background Norm	1.106399e-01

Control RTV vs.

	Pr(>F)
Song RT	0.001752193
Song RTV	0.001138489
Podcast RT	0.610754648
Podcast RTV	0.377145885
Background Norm	0.852211093
Song-RT*Background Norm	0.117921509
Song-RTV*Background Norm	0.031371331
Podcast-RT*Background Norm	0.044468435
Podcast-RTV*Background Norm	0.925536511

Figure 9. *F Test on Impact of Expectation*

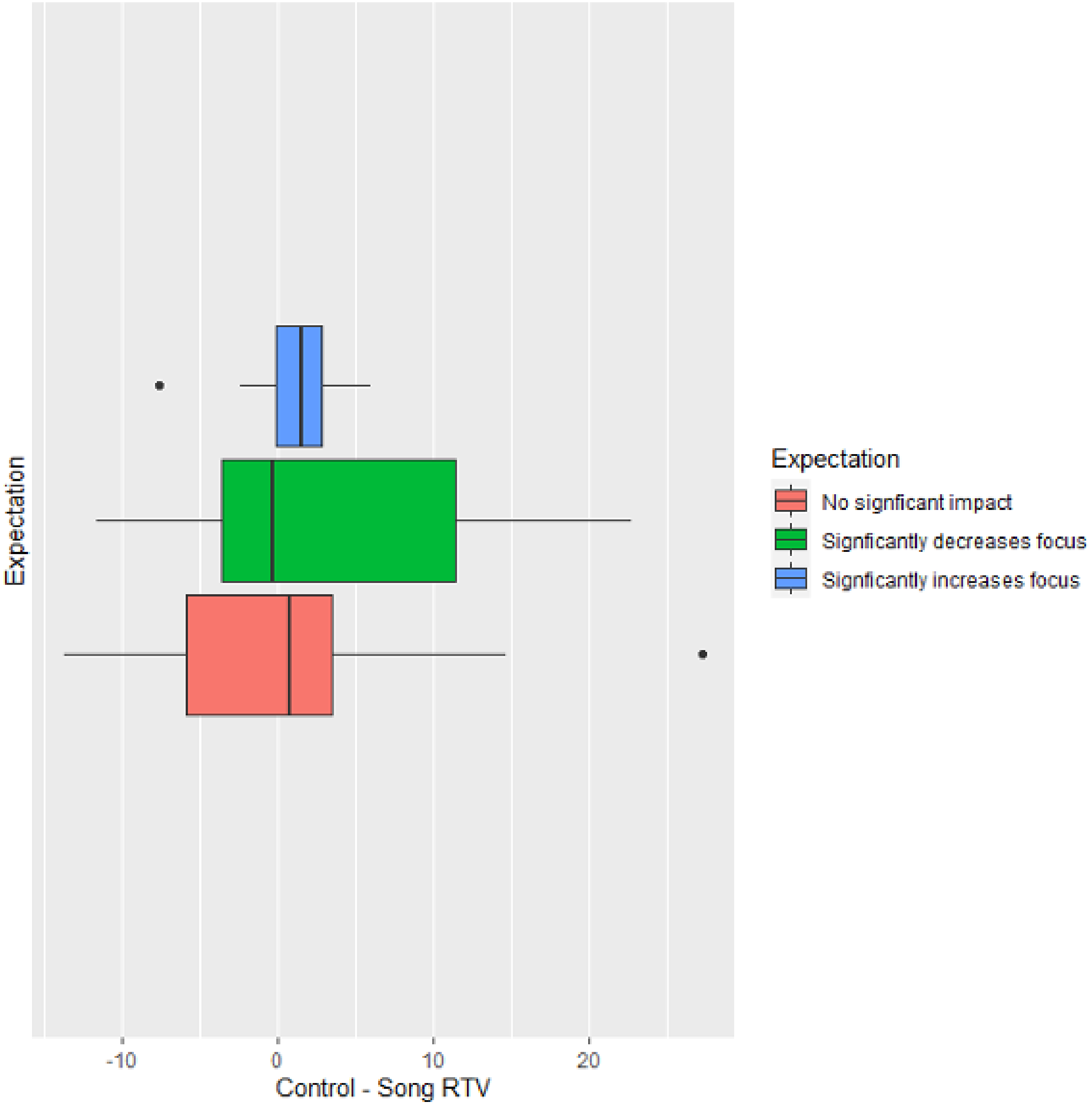

Figure 10. *Box Plot of Song Reaction Time Variability Difference from Control, Broken Down by Expectation*

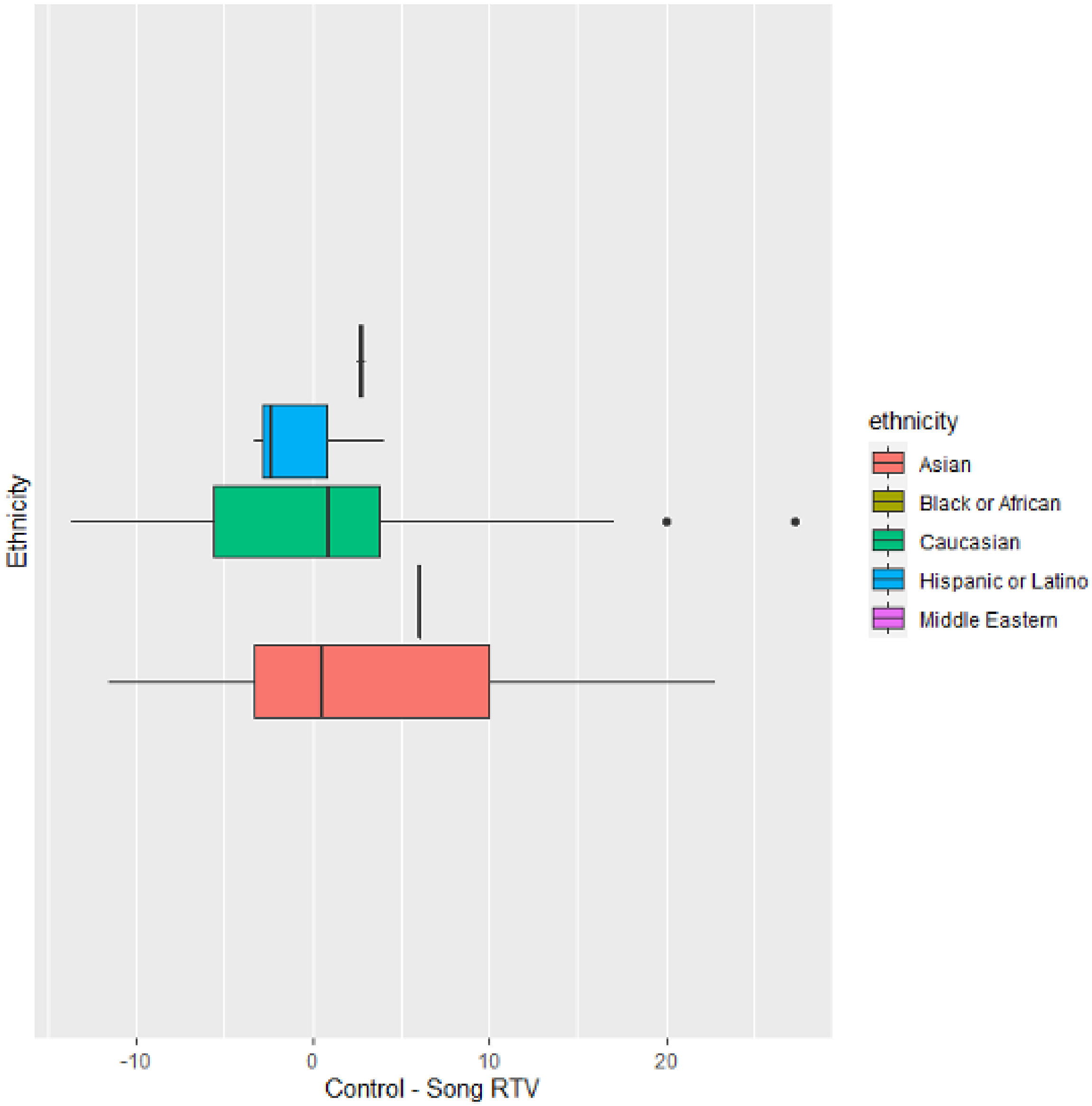

Figure 11. *Box Plot of Song Reaction Time Variability Difference from Baseline, Broken down by Ethnicity*

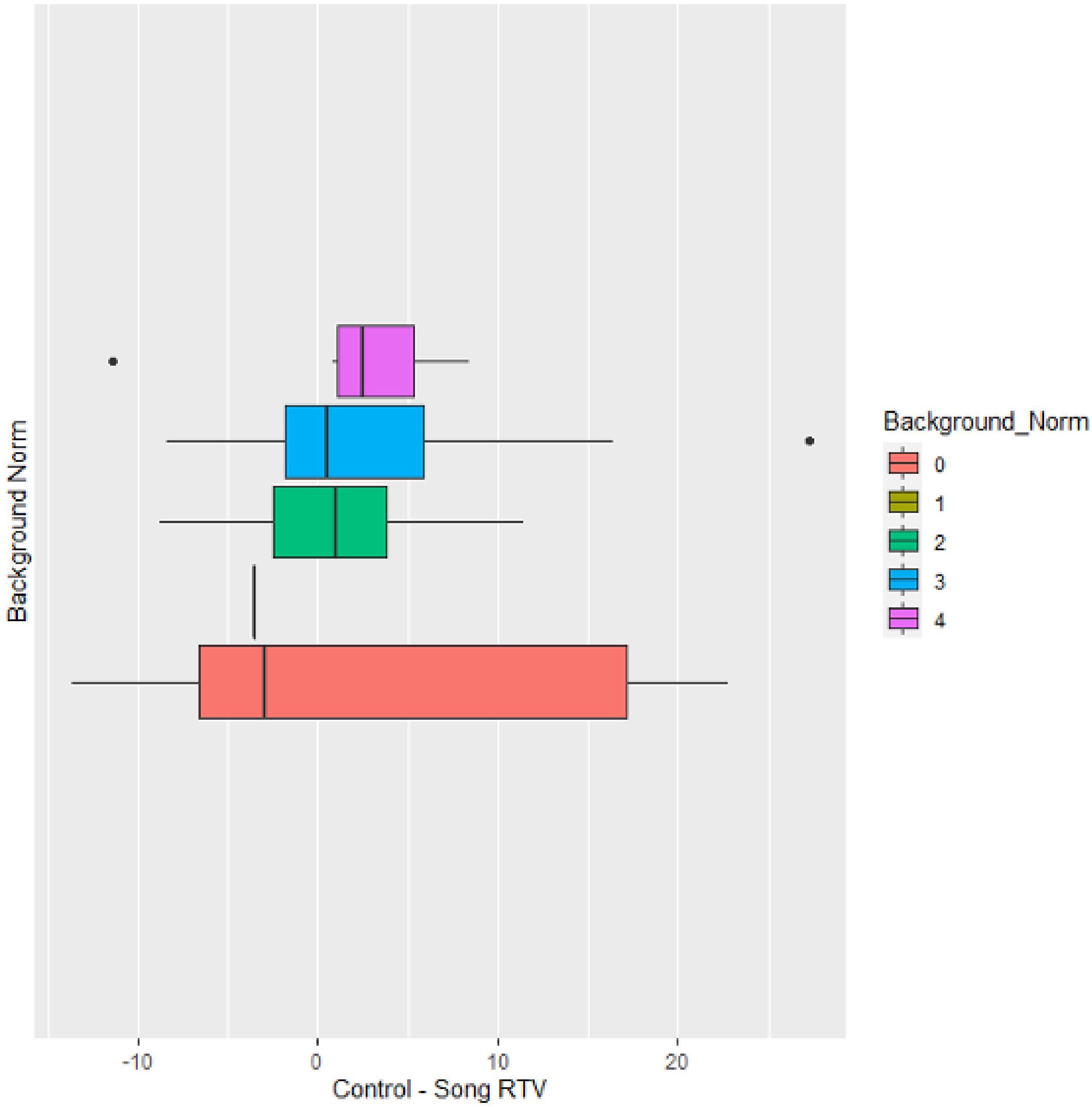

Figure 12. *Box Plot of Song RTV Difference from Control, Broken Down by Background Norm* 0- No sound1-wordless/musicless white noise2- music without words3- music with words4- speaking/conversational noise (i.e. podcast)

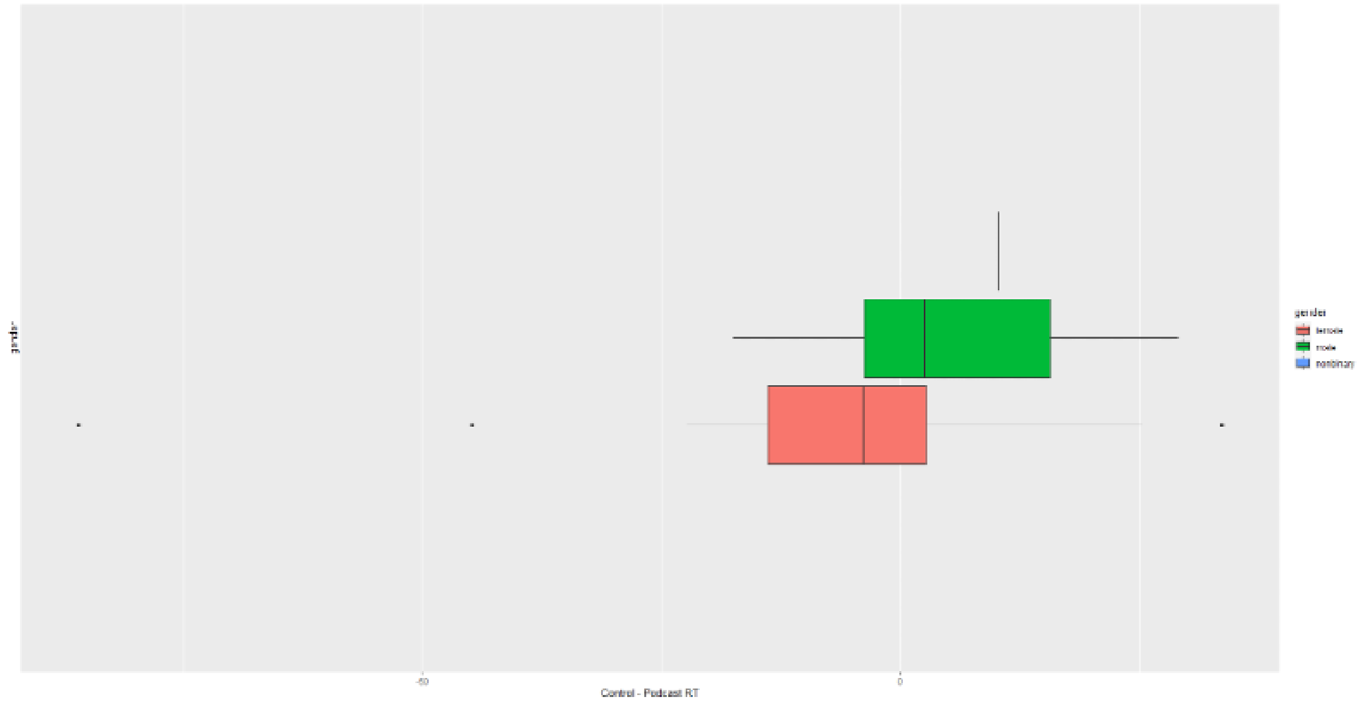

Figure 13. *Box Plot of Podcast RT Difference from Control, Broken Down by Gender*

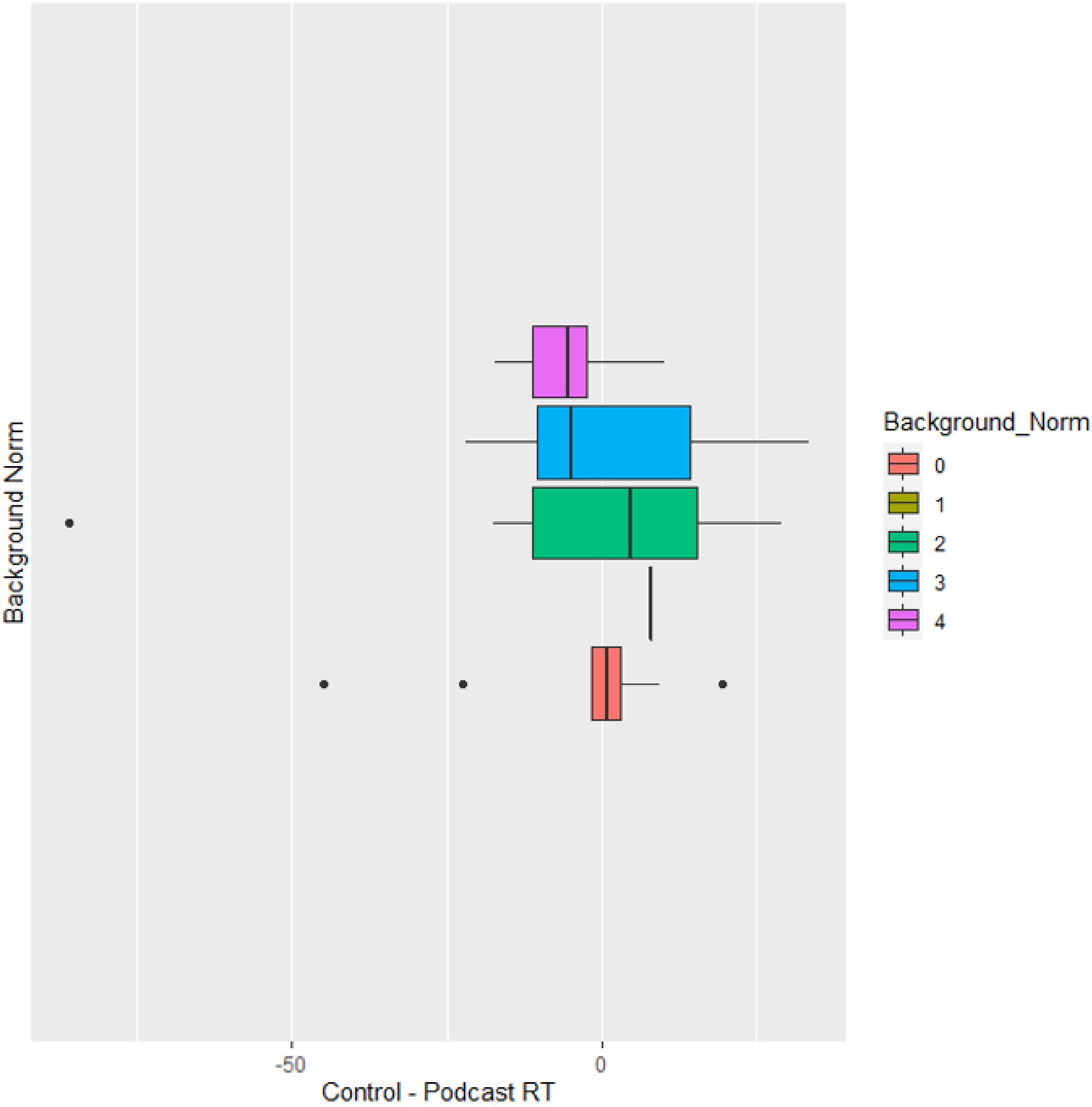

Figure 14. *Box Plot of Podcast RT Difference from Control, Broken Down by Background Norm*

Discussion

As music and podcasts are commonly a part of daily routine, it is vital to understand their impact on focus in everyday tasks. Moreover, it is also essential to realize people's perceptions of the influence which background noises have in how efficient they are at doing certain tasks. By better understanding these perceptions we can learn how to become more efficient and productive workers by increasing focus. Through this study, we predicted that participants would expect there to be a difference in reaction time variability between reaction time tests done with background noise compared to those done without background noise, but that the true reaction time variance data would not be significantly different between the two conditions.

In our study, it was found that there is a statistically significant difference between the control RT and song RT, control RTV vs song RT, and control RTV vs song RTV (Figure 3). This indicates that songs do impact reaction time and reaction time variability, aligning with previous studies. Similarly, we found statistical significance between control RT vs podcast RT, control RTV vs podcast RT, control RT vs podcast RTV, and control RTV vs podcast RTV (Figure 3). Moreover, podcasts seem to increase reaction time and reaction time variability, while music seems to decrease these variables (Figure 4a/b). It is important to note that the usage of songs and podcasts doesn't necessarily increase focus, but it can improve sustainability of motivation over time. This explains why people polled that they don't see any positive effects on improving their focus but still choose to listen to something There was also statistical significance between song RTV and ethnicity compared to the control, however no valid conclusions can be made from this due to the small sample sizes of the entire group, and having unequal numbers of participants from each ethnicity categories (Figure 11).

Furthermore, there was a significant finding between the difference of control and song RTV with expectation. It was found that individuals who expect to do better with the presence of their preferred background sound actually have increased focus in the presence of music in comparison to the control. This is evident in Figure 10 which illustrates a much tighter spread among this group, indicating that there is less variability and a clear consensus among these individuals. It is interesting to note that from the pre-survey, all participants who think there is a positive impact of listening to some form of sound actually do while studying. Thereby, our study illustrated that participants who believe that music will help them actually see improvements. This mindset could possibly be serving as a placebo effect, leading to participants doing better than other groups.

Looking closely at the impact which normal background sound has on reaction time and reaction time variability, it was found that there is a significant interaction between RT difference from control and podcast, broken down by normal background (Figure 14). Similarly, there was a significant interaction between podcast reaction time and gender as male identifying students had a higher reaction time than female identifying students (Figure 13). Normal background sound was categorized by maximum mentioned distractibility from 0-4 (0- No sound, 1-wordless/musicless white noise, 2-music without words, 3- music with words, 4- speaking/conversational noise). It is important to note that this data is skewed as the majority of participants normally listened to no background noise and there was only 1 participant that listened to white noise, therefore the significance cannot be generalized. Also, there was a significant interaction between song RTV difference from control, broken down by normal background sound (Figure 12).

Overall, our hypothesis was partially successful as it was found that in the podcast experimental group the participants would expect there to be a difference between RT and RTV in the presence of a podcast vs control, and there indeed was no significant difference between the two conditions as stated in our hypothesis. However, our hypothesis was disproved in the music experimental group as it was found that participants who expected there to be a difference in RT and RTV actually did have a difference between the two conditions. Moreover, it was shown that music leads to a decrease in RTV, indicating its possible benefits in daily cognitive tasks.

Author Contributions

HM, MM, AP, CS, and MZ designed the experiment. HM wrote the abstract. CS wrote the introduction. HM, AP and MZ wrote the methods section. CS and MZ made the google form survey. AP and MZ generated the data and results. HM, CS, and MZ wrote the discussion.

Supplementary Figures

Scatterplots

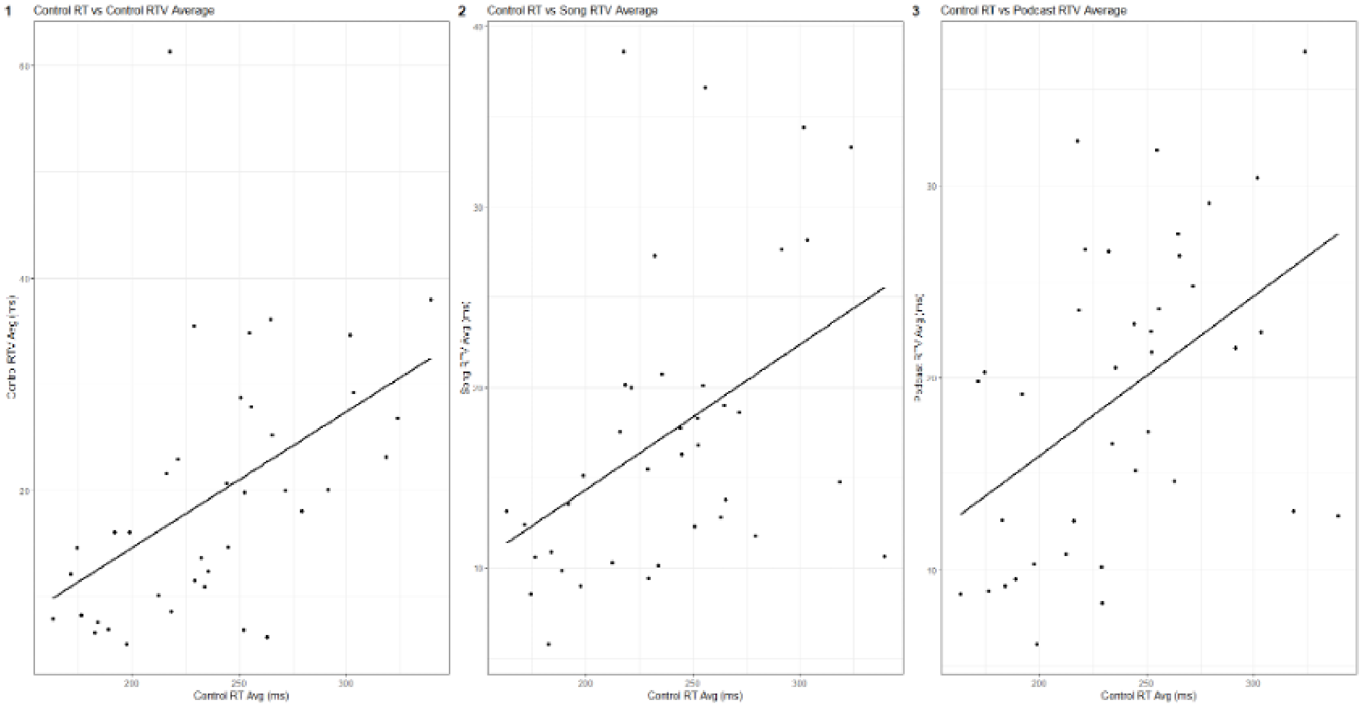

Figure 15. *Scatterplot of RT vs RTV for each condition*

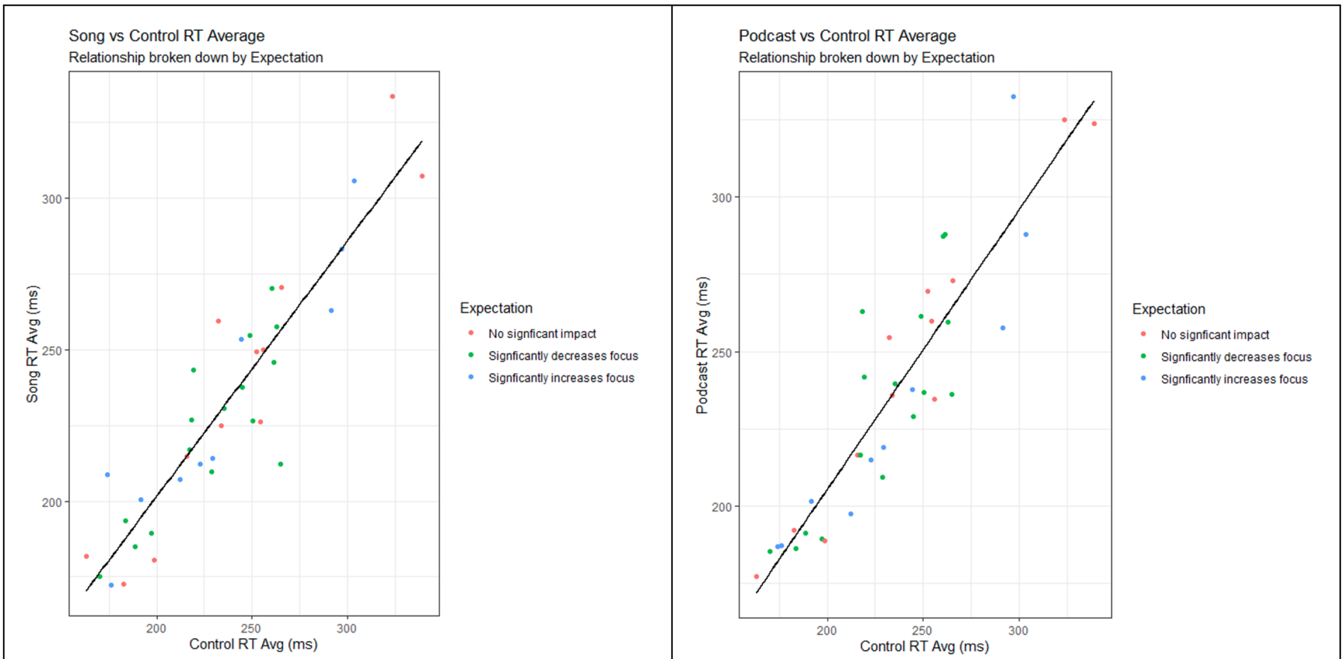

Figure B. Relationship between Song and Control Reaction Time by Expectation

Figure C. Relationship between Podcast and Control Reaction Time by Expectation

Figure 16.

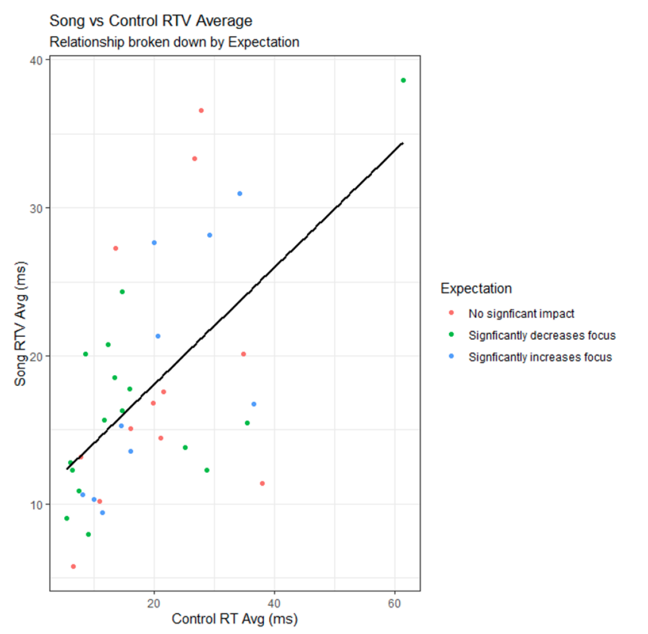

Figure D. Relationship between Song Reaction Time Variance and Control Reaction Time Variance by Expectation

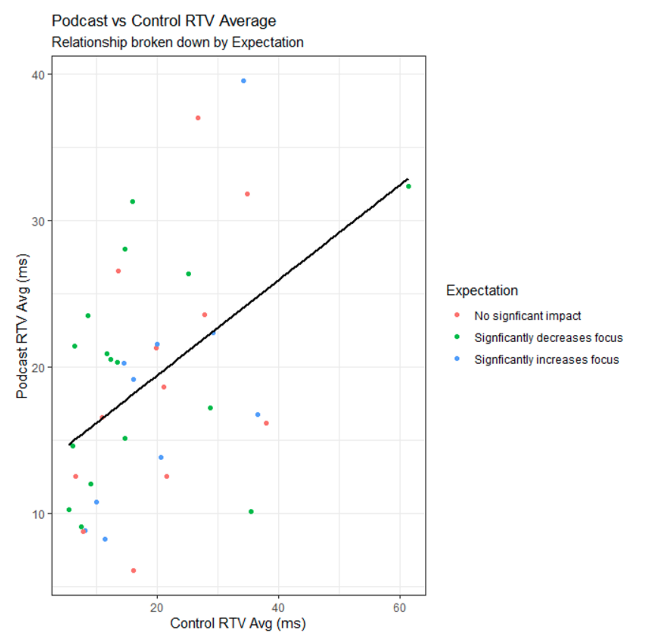

Figure E. Relationship between Podcast Reaction Time Variance and Control Reaction Time Variance by Expectation

Figure 17.

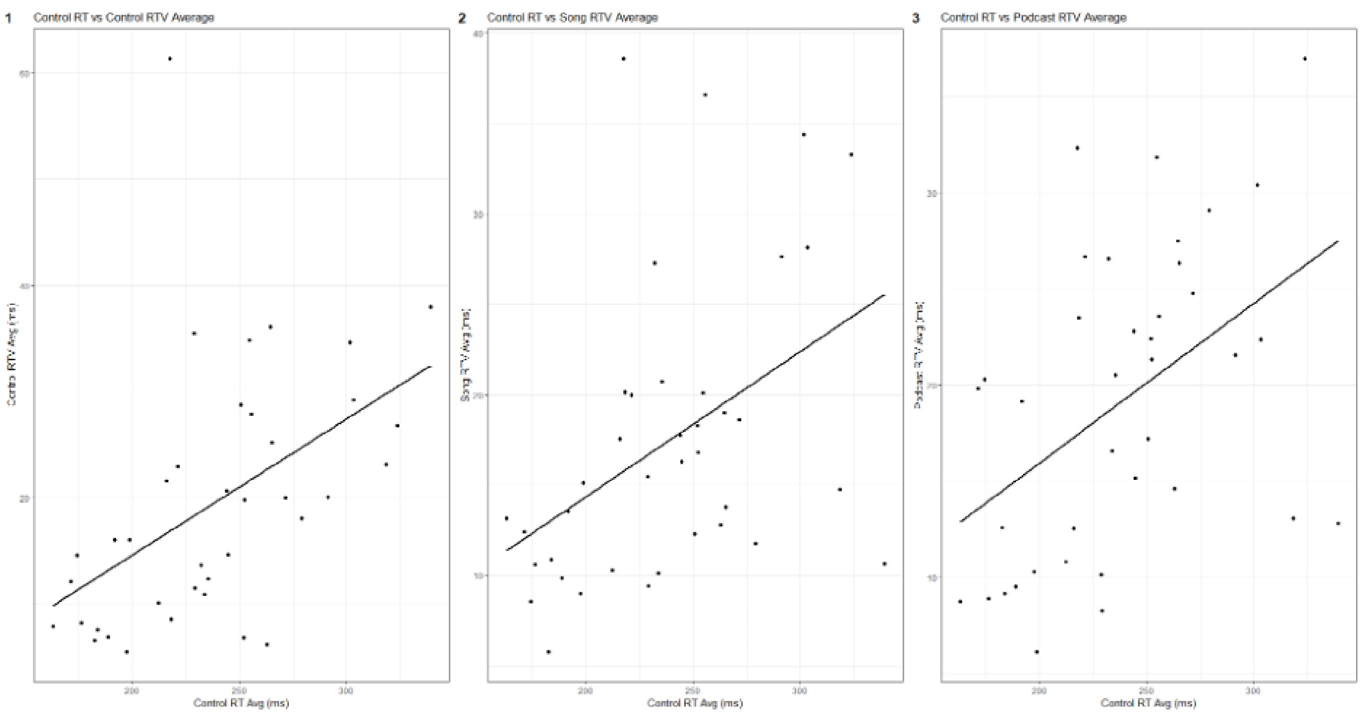

Figure 18.

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