

The Effects of Music on Performance in Human Hand-Eye Coordination

By Ethan Zhou

AUTHOR BIO

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ABSTRACT

In this paper, the effect of music on hand-eye coordination is studied. The intricacies of the complex system that enables hand-eye coordination is discussed, the possible effects of music analyzed, and an original experiment was conducted. In the experiment, participants listened to multiple genres of music while completing a task requiring hand-eye coordination and recording four statistics per trial per task. There were limitations to the experimentation that may have resulted in inconclusive data, but the available data was still analyzed for any possible results. After processing the data, the results indicated that music did not have a significant impact on the participant's hand-eye coordination for the overall group, but individually, certain participants did significantly perform better with select genres.

Keywords: Accuracy, Hand-Eye Coordination, Music, Oculomotor, Reaction Time, Saccades

INTRODUCTION

As humans, we often overlook many things that are common to our everyday lives. Two of those things, music and our hand-eye coordination, are both so prevalent that we sometimes forget they are even there. Seemingly unrelated, the frequency with which we execute hand-eye coordination is quite high, which led to the research question of this paper: Which genres of music, if any, are most beneficial to the performance of tasks requiring hand-eye coordination? To answer this question, the functions that constitute hand-eye coordination were first researched, the possible effects of music were analyzed, and an original experiment gathered data for a conclusion. Through the completion of an experiment that observes music and its impact on hand-eye coordination, we can see that music did not result in a significant increase in efficiency while executing hand-eye coordination-related tasks, which is important because it indicates that while music is not beneficial to our performance as a whole, personal enjoyment of music while doing these tasks may be a way to enhance our everyday lives.

Hand-Eye Coordination

As humans, we have a multitude of crucial features built into our anatomy that aid in everyday tasks and activities. Perhaps one of the most important features is hand-eye coordination, since without it, many of our daily actions would be made impossible. As Pelz et al. (2001) describe it, “in natural circumstances, the eye, head, and hand are in continual motion in the context of ongoing behavior. This requires the coordination of these movements in both time and space” (p. 266). Hand-eye coordination can be used for something as simple as opening a door, or for an action that is extremely demanding, such as juggling or gymnastics. This begs the question: how does hand-eye coordination work?

Hand-eye coordination involves multiple steps, with each step influencing the others. The first step of hand-eye coordination is using the eyes to identify the target, as “each

targeted movement requires a shift of attention to the target location” (Pelz et al, 2001, p. 266). This process of focusing on a target is executed by various parts of the brain. First, the eye muscles receive their motor function from three nuclei located in the brain stem (Land & Tatler, 2009, p. 16). These three nuclei are the *oculomotor* nucleus, which controls the superior, inferior, and medial rectus and inferior oblique via the cranial nerve III, the *trochlear* nucleus responsible for the lateral rectus via nerve VI, and the *abducens* nucleus, which controls the superior oblique via nerve VI (Land & Tatler, 2009, p. 16). On top of these motor nuclei, there are also pre-motor nuclei that construct specific patterns of neural activity for certain eye movements (Land and Tatler, 2009, p. 16). One of the most crucial of these pre-motor nuclei is the *paramedian pontine reticular formation*, which is responsible for the generation of saccades.

Saccades are the rapid movement of gaze using short bursts of impulses between two locations, and, as Sailer et al. (2000) put it, they can be either “reflexive (reactive) and intentional (voluntary) responses” (p. 164), with reflexive saccades being due to outside stimuli, and intentional saccades being triggered by internal stimuli relating to visual cues. Although the maximum frequency of saccades can reach up to 4 per second, it usually only occurs that rapidly when reading or scanning over an area (Land & Tatler, 2009, p. 17). Assuming a typical saccade takes around 30 ms and the corresponding fixation of gaze takes 300 ms, Land & Tatler (2009) estimate that about one tenth of the day is spent making saccades, revealing just how crucial they are to our daily lives. This finding is further backed by Sailer et al. (2000) when they cite the work of Burman and Segraves (1994), who write that saccades performed while scanning are an “automated process of breaking fixation and redirecting sight toward a feature of the visual scene that has captured the viewer's attention” (p. 164), meaning that saccades are essential for the visualization of images or scenery taken in through the eyes. Another pre-motor nucleus, the *nucleus reticularis tegmenti pontis*, is

responsible for smooth tracking movements (Land & Tatler, 2009, p. 16).

In conjunction with the movement of the eyes is the movement of the head. *Vestibular nuclei* of the pre-motor brain stem provide signals for head movement after the eyes track the target (Land & Tatler, 2009, p. 17). Humans have an oculomotor range of around $\pm 55^\circ$ (Guitton & Volle, 1987, p. 427), but in practice, the eyes hardly ever rotate beyond $\pm 30^\circ$ (Land & Tatler, 2009, p. 19). Finally, after the target has been identified and tracked, the hand executes the last part of hand-eye coordination. In an experiment conducted by Sailer et al. (2000), the eyes arrived at the target an average of 386 ms (with a 106 ms standard deviation) before the hand, which, according to Jeannerod (1988) and Elliott & Allard (1985), is enough time to allow the limb to correct its movement and position in response to the visual information received.

The Effects of Music

Music has long been an important art with its various genres and multitude of applications. In our everyday lives, we experience music in multiple ways, whether it be the calming jazz in a hotel lobby, the radio playing on the commute to work, or the blaring speakers at concerts. As previously discussed, hand-eye coordination is prevalent at all times, and encompasses many of the tasks we execute on a day-to-day basis. Thus, if music and hand-eye coordination are both so common, how may one affect the other? This question resulted in the ultimate goal of this study, which was to find out if music had an impact on the performance of hand-eye coordination.

Concentration is a major factor in how we may perform on a task, especially with hand-eye coordination. By definition, we are learning and adapting while we use our hand-eye coordination, since the use of saccades and head movements are meant to gather information to better enable the limbs to move with precision. When we are highly concentrated, we can understand and memorize many complex ideas in short amounts of time, while learning is

significantly hindered if distracted (Mori et al., 2014, p. 34). Many variables may affect concentration, and one prevalent example is music. In their study, Mori et al. analyzed the effect of music on concentration, and found that the participants performed best while listening to music they liked, second best when listening to unfamiliar music, and the least when in silence (Mori et al., 2014, p. 37). From these results, it can be concluded that music did significantly benefit concentration, specifically when the participant enjoyed the music. Another point that Mori et al. (2014) made clear was that regardless of musical preferences, when one was in a work environment, only music without lyrics is beneficial, while music with lyrics actually reduces concentration and performance (p. 40).

Now that enjoyment of music has been established as beneficial for concentration, it is imperative that we figure out why that is. In a paper by Salimpoor et al., the authors discuss how music can arouse feelings of pleasure (p. 257). Upon further research, it was discovered that we release dopamine from the striatal system when experiencing intense pleasure from music (Salimpoor et al., 2011, p. 257). Dopamine, which is a chemical released by the brain, has been identified as a chemical that contributes to learning (Harley, 2004, p. 191). Therefore, if music can result in dopamine release when experiencing pleasure, and dopamine is an indication of learning occurring, then the likelihood of music benefitting the performance of hand-eye coordination in humans is greater.

Experiment Inspiration

In order to see if music did significantly benefit hand-eye coordination, a new experiment needed to be conducted. Inspiration for experiment ideas came from Donovan et al. (2022) where they used an application called AimLabs™ (2.2. Apparatus). AimLabs™, and more specifically Gridshot (Donovan et al., 2022, 2.3.1. Gridshot), was the ideal program to use, as it could best measure hand-eye coordination as a skill, similar to how Smith et al. (2000) used digital targets and various input devices (p. 118).

THE EXPERIMENT

Participants

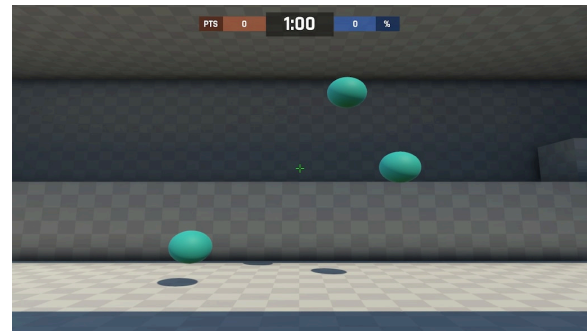
There were 7 volunteers in the experiment. All participants had normal vision (glasses and contacts accounted for) and were right-handed. There were 3 biological males and 4 biological females. The range of ages for the participants spanned from 12 to 48. The majority of the participants were teenagers ages 15-16. All participants will remain anonymous.

Experiment Design

The experiment revolved around a program called AimLabs™. Within AimLabs™, there is a task named “Gridshot”. Gridshot is a task that requires a high level of concentration, hand-eye coordination, and reaction time to perform well in, which is why it was the task chosen for the experiment. In Gridshot, users are presented with a 3-D grid space, with the walls to this virtual space being a dark gray checkerboard. At the beginning of each round, there is a message on the screen that reads “Click to Begin”. Upon clicking, a countdown from three will appear on the screen, and once that countdown reaches zero, the task officially begins.

The user’s cursor, along with three bright-cyan colored targets (meant to contrast with the dark gray background), will appear as soon as the countdown ends, and a one minute timer will begin. The targets randomly spawn within a given area in front of the user’s POV, and, in order to register a hit on a target, the user must place their cursor on the target’s hitbox and left click. When a target is hit, it will make a distinct noise and disappear, which then prompts the program to randomly spawn in another target somewhere else within the grid. This way, Gridshot ensures that at any given point in time there will always be three targets present for the user to track.

Figure 1.
Example of the Gridshot test



At the end of the minute, Gridshot will automatically send the user to a ‘results’ screen, where different statistics such as Overall Score, Accuracy, Average Reaction Time per Target, and Total Targets Hit will be shown. Gridshot was especially helpful with measuring Reaction Time, as the randomization of target locations prevented muscle memory from taking effect, as “presenting a target at the same position on every trial results in most responses’ being anticipatory” (Kingstone & Klein, 1993, p. 264).

In order to answer the research question, the participants were asked to listen to a variety of genres of music as they completed their trials in Gridshot. There were a total of six categories (5 musical genres), with those categories being None (no music), Rap, Pop, Classical, Rock, and Country. There was not a specific song or album assigned to each participant; instead, each participant was instructed to find a playlist of the top songs in a genre and put it on shuffle to avoid bias or blurring genres. If an advertisement happened to start in the middle of a trial (for example, Spotify has advertisements if the premium version is not purchased), the user was told to stop and retry that trial. In order to minimize the effect of human error, participants were asked to complete three trials in each category and to re-do any extreme outliers due to outside factors, such as cramps, dizziness, etc, within that respective category. Following each trial, the user would record the four aforementioned statistics, and an average of the three trials for each category was calculated to get the overall results.

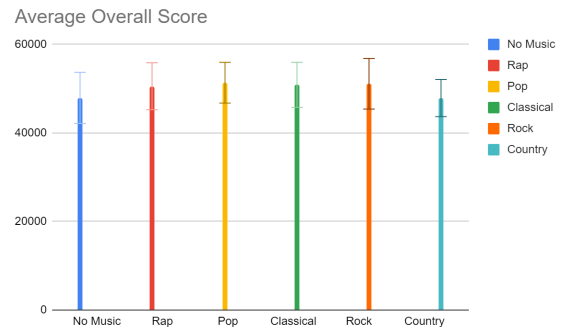
The goal for the user is to track down one of the three targets with their eyes, move their mouse using their hand, wrist, and/or arm,

and click on the target to make it disappear. With each registered hit, the user's number of targets hit and accuracy rating will go up, while every missed attempt (clicking when the mouse cursor is NOT on the hitbox of a target) will not add to the number of total targets hit and will decrease the accuracy rating. Users were asked to give their best attempt to score as high as possible on each trial. To maximize consistency, all users were required to keep the same environmental conditions when doing the experiment. This included, but was not limited to, the following variables: room temperature, clothing worn, light levels (including screen brightness), music volume, any performance-affecting drugs or substances (e.g. caffeine), and background noise and distractions. Additionally, before beginning the experiment, all users were allowed to find preferred peripherals and given ample time to accustom themselves to the intricacies of Gridshot. After ensuring all conditions were met, the user could begin the experiment.

Results

As there were multiple variables in consideration when the data was analyzed, there were varied results depending on the factors that were in play. First, the data was analyzed to see if having any genre of music was more beneficial in comparison to no music. For the Overall Score statistic, all genres except for Country produced scores at least 2000 points higher than the scores with no music. However, upon calculating the standard error of each category, error bars overlap as shown in Figure 2, suggesting that although there is a slight benefit in Overall Score for the four genres of Rap, Pop, Classical, and Rock, it is not significantly more beneficial than having no music, thus implying that music does not contribute to the performance of hand-eye coordinated tasks.

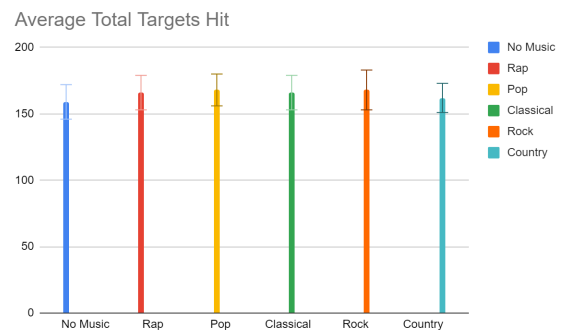
Figure 2.
Average Overall Score for All Participants



Note. The Overall Scores for all participants for each category were averaged with standard error applied.

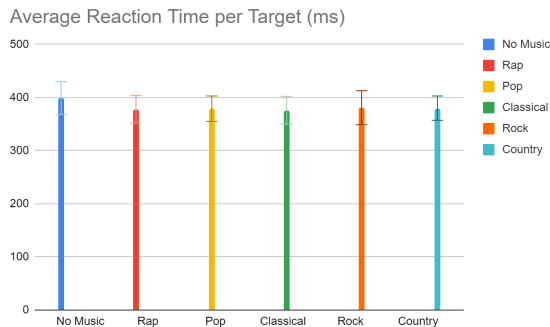
To acquire more specific results, the statistics for each sub-category were analyzed. For both the Reaction Time and Total Targets Hit statistics, depicted in Figures 3 and 4, No Music held the lowest score with 399 ms and 159 targets hit, respectively, but once again, all error bars overlapped. This indicates that while No Music was the worst category for Reaction Time and Total Targets Hit, no genres provided enough of an increase in performance to be considered significant improvement.

Figure 3.
Average Total Targets Hit for All Participants



Note. The Total Targets Hit for all participants for each category were averaged with standard error applied.

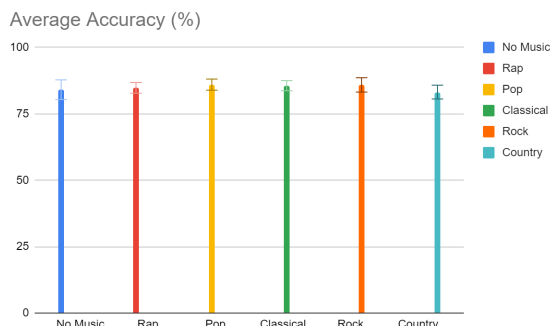
Figure 4.
Average Reaction Time in Milliseconds for All Participants



Note. The Reaction Time per Target in milliseconds for all participants for each category was averaged with standard error applied.

Finally, as seen in Figure 5, the range of the scores for the Accuracy statistic was around 3%, with Country at the lowest with 83.2% and Rock at the highest with 86%. No Music scored an average of 84.1%. Considering that accuracy had the smallest range of data and the least amount of standard error, these results reveal that Accuracy remained relatively stable across all categories. This indicates that music has little to no effect on the accuracy of an individual when performing tasks requiring hand-eye coordination.

Figure 5.
Average Accuracy in Percentage for All Participants

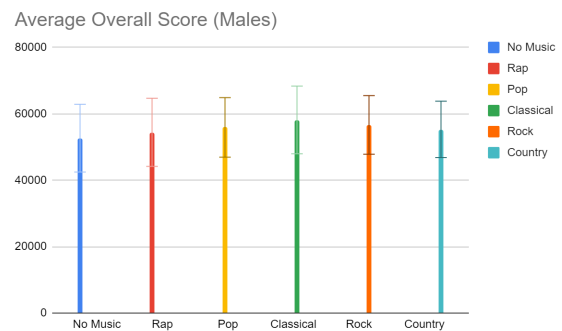


Note. The Accuracy in percentage for all participants for each category was averaged with standard error applied.

Next, each biological gender was separately analyzed to see if the participants of a certain gender experienced more influence than the overall population. Firstly, the Overall Score

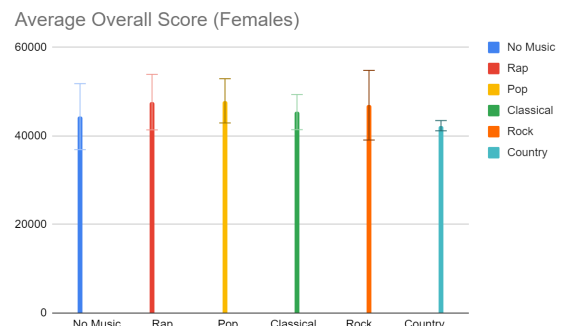
statistic was calculated and standard error was applied. For both genders, all genres and no music showed no significant difference, supporting the trend from analyzing the overall group of participants (refer to Figures 6 and 7). Accuracy yielded the same results for both genders, as did Reaction Time and Total Targets Hit. Because both genders follow the same pattern observed in the overall group, it is accepted that music does not significantly impact the hand-eye coordination of either gender in comparison to the general population.

Figure 6.
Average Overall Score for Males



Note. The Overall Scores for the male participants were averaged and standard error was applied.

Figure 7.
Average Overall Score for Females

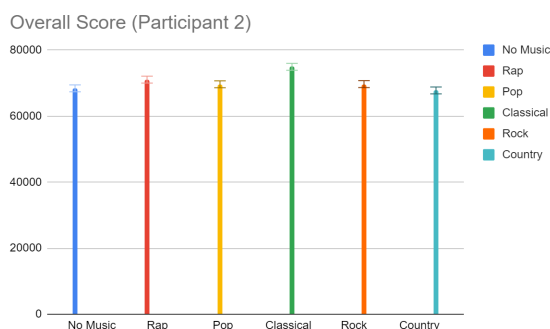


Note. The Overall Scores for the female participants were averaged and standard error was applied.

Finally, individual performance was analyzed. On an individual level, 4 of the 7 participants produced their high score in 3 or more of the statistics while listening to Rock

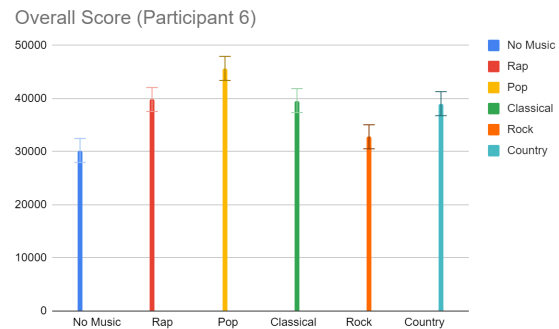
music. Given that there are 4 total statistics, this means that a majority of participants recorded their highest score for a majority of the statistics while listening to Rock, thus supporting the notion that Rock is the most beneficial genre on a personal level. By analyzing each participant individually, the most significant results were produced, as the numbers were only reflective of the individual in question. Surprisingly, of the four participants that recorded their high scores in three or more statistics while listening to Rock, none of them showed a significant preference for Rock. The closest to showing a favorable outcome for Rock was Participant 1, who recorded an average Overall Score of 60462, with an error of 751 points. The next closest genre, Classical, corresponded to a score of 59794, but due to the error value, there was no significant difference. However, two of the other three participants did see some genres outperform others by considerable margins. In Figure 8, Participant 2 recorded three high scores while listening to Classical, which was further backed by their personal graph for Overall Score, as Classical is significantly above the next genre. Similarly, in Figure 9, Participant 6 performed best in all four statistics listening to Pop, which was supported by the significant gap between Pop and their next best genre. So, even though Rock was the most promising in yielding high scores, it was not statistically significant, despite the participants seeming to prefer it. A few other genres were the clear favorite for certain participants, but since they did not make a majority, their individual performances cannot be applied to the group as a whole.

Figure 8.
Overall Score for Participant 2



Note. Classical is significantly higher than the next highest genre, Rap.

Figure 9.
Overall Score for Participant 6



Note. The range for Pop is significantly higher than the closest genres of Rap, Classical, and Country.

Experiment Limitations

While this experiment was conducted to the highest standards possible, the natural limitations of doing the experiment without assistance from an institution or research group did lead to desired variables being excluded. If this experiment were to be conducted again, a few changes would be made to enhance the accuracy, reliability, and consistency of the study. If possible, all trials would be completed at a host location (instead of completing the experiment at home and sending results in), with a larger sample size that enables the representation of all age groups. Additionally, more genres would be considered in the experiment, although the additional genres may extend the time required to complete the experiment significantly. With respect to each individual genre, however, a standardized playlist should be created, rather than letting participants find playlists on their respective music listening platforms (this was the case for the experiment in this paper). Finally, more aspects of the music would be considered; for example, the tempo or bass of any given song may vary.

DISCUSSION AND CONCLUSION

In contrast to what was originally hypothesized to be the likely outcome, this study resulted in a null result. As can be concluded from the data, music did not significantly impact performance in the general group or by gender, although having no music did result in the lowest scores of the categories. However, when looking back at the literature review completed prior to the experiment, these results are not entirely unexpected. Mentioned by Mori et al. (2014) in their research, music with lyrics has a negative impact on concentration and performance in a work environment (p. 40). Granted that all participants were asked to avoid work-like environments, the idea that lyrics provide a distraction is still very much plausible, and, based on the results, most likely did play a role in music's insignificant benefit.

The effects of music were not felt when analyzed in the group or by gender, but when narrowed down to each individual, music can be seen having a significant effect. This result is strongly supported by Salimpoor et al. (2011), who stated that when listening to music one enjoys, there is an increased pleasure and dopamine release (p. 257). Nonetheless, just because listening to pleasurable music leads to a likely improvement in performance does not mean that all participants will show a preference. A multitude of factors may have resulted in this outcome, but some of the more reasonable ones would be that the participant either has little to no preference for multiple genres of music in comparison to having no music, or the participant's favorite genre was more niche and therefore not included in the variable genres.

Finally, an important factor that was not discussed was each participant's prior experience with regards to hand-eye coordination tasks on a computer, or just exposure to any hand-eye coordination-related tasks in general. For example, a tennis player may possess a superior skill set than someone who does not play sports. Similarly, someone who devotes time to playing video games, especially on the computer, may bolster their hand-eye coordination skills in comparison to someone who does not play video games. And,

while these differences in backgrounds are crucial and do provide further insight on the possible implications of this experiment, no form of prior experience caused a significant difference in trend; the only indicator of this would be the overall score being higher due to a better performance on the task.

Following the conclusion of this experiment, many other points and questions were raised, and it is likely that a more in-depth, technologically advanced, and professionally structured version of this experiment (refer to the Experimentation Limitations section for specifics) could result in a different outcome. The full effects of music on hand-eye coordination may yet to be found.

REFERENCE

- Donovan, I., Saul, M. A., DeSimone, K., Listman, J. B., Mackey, W. E., & Heeger, D. J. (2022). Assessments of human expertise and movement kinematics in first-person shooter games. *Front. Hum. Neurosci.*, 16, 979293.
- Guitton, D., & Volle, M. (1987). Gaze Control in Humans: Eye-Head Coordination During Orienting Movements to Targets Within and Beyond the Oculomotor Range. *Journal of Neurophysiology*, 58(3), pp. 427-459.
- Harley, C. W. (2004). Norepinephrine and Dopamine as Learning Signals. *Neural Plasticity*, 11(3-4), pp. 191-204.
- Kingstone, A., & Klein, R.M. (1993) What are human express saccades?. *Perception and Psychophysics*, 54(2), pp. 260-273.
- Land, M. F., & Tatler, B. W. (2009). *Looking and Acting: Vision and Eye Movements in Your Natural Behavior*. Oxford University Press.
- Mori, F., Naghsh, F. A., & Tezuka, T. (2014). The Effect of Music on the Level of Mental Concentration and its Temporal Change. *Proceedings of the 6th International Conference on Computer Supported Education*, pp. 34-42.

Pelz, J., Hayhoe, M., & Loeber, R. (2001). The coordination of eye, head, and hand movements in a natural task. *Exp Brain Res*, pp. 266-277.

Sailer, U., Eggert, T., Ditterich, J., & Straube, A. (2000). Spatial and temporal aspects of eye-hand coordination across different tasks. *Exp Brain Res*, pp. 165-173.

Salimpoor, V. N., Benovoy, M., Larcher, K., Dagher, A., & Zatorre, R. J. (2011). Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nature Neuroscience*, 14(2), pp. 257-264.