A Clinical Study on Islanders to Determine if THC, Nicotine, and Varying Music Types Affect Arithmetic Performance

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Abstract

Studies have shown that listening to music has led to both improvement in cognitive function in areas such as reading comprehension as well as lower stress levels. There are also indications that different types of music have varying effects, such as upbeat music increasing alertness and concentration and slower tempo music providing feelings of calm and relaxation. In recent years, there has been a spike in both cannabis and nicotine use among college-aged adults. Specifically in California, marijuana was legalized for recreational use in 2016, making it more accessible for college-aged adults who often use it for its stress relieving and euphoric properties. Thus, our study aims to determine which type of drugs and which type of music effect arithmetic ability. To study this we designed our experiment as a two factor balanced 3x4 factorial design with a block. We sampled 240 individuals age 18 to 30 from the virtual Island and randomly placed 10 participants in each our 24 treatment groups. Analysis of the data indicated that there was a significant difference in arithmetic score for those who listened to heavy metal music compared to all other types of music. There was no significant difference in mean arithmetic scores between drug types (nicotine, THC, control) nor was their a significant difference in arithmetic scores for the interaction between drug type and music type.

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1 Introduction

According to a study done by *The Cumhuriyet University Faculty of Science*, listening to music just prior to attempting a reading comprehension exam helps raise one's score by not only improving skill level, but also by simultaneously lowering stress level [2]. Along with this, a recent poll suggests that 58% of college-age adults aged 18 to 25 listen to music while studying in order to increase focus and productivity [3]. A poll done at CSU Global states that, 58% of college-age adults aged 18 to 25 regularly listen to music while studying [4].

There's also been a rapid increase in college students vaping. In the United States from 2017 to 2019 the percentage of college-age adults aged 19 to 22 who vaped nicotine rose dramatically from 6.1% to 22%. The percentage of college-aged adults that smoked marijuana also increased from 5.1% to 14% according to a study by the *National Institute on Drug Abuse*. Both nicotine and marijuana use are at a historic highs amongst college students [1].

With the greater part of college students listening to music while studying, and the use of marijuana and nicotine growing at rapid rates, we as fellow college students want to see if these habits students regularly partake in affect one's test-taking ability. We're also interested if the interaction of the two habits show any significant change in students arithmetic skills.

Given that nicotine is known to improve attention and concentration we hypothesize that those given nicotine will have increased arithmetic performance compared to those given THC and no drug.

2 Methods and Procedures

2.1 Participants

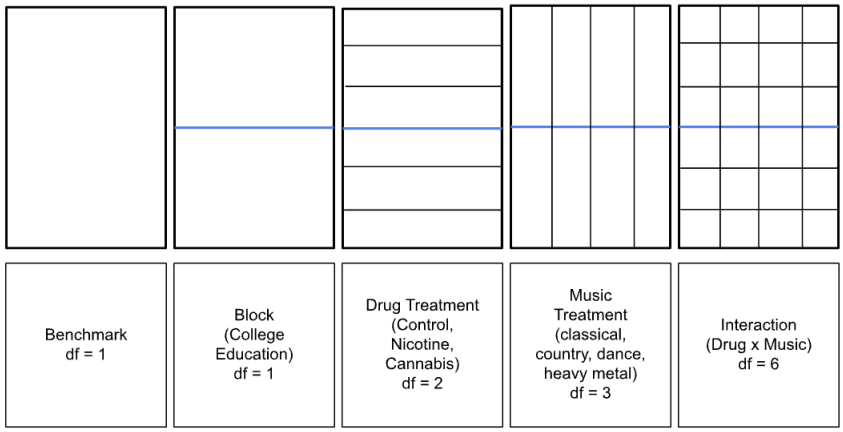
Two hundred and forty virtual participants were recruited from an online resource called the Island. To obtain the sample population, a comprehensive list of individuals on the island between the age of 18 and 30 was collected. Each participant was then assigned a number. Splitting the pool of participants into two groups, college-educated and not college-educated individuals, 120 participants were randomly selected from each group by using R to generate 120 random numbers for each group. Participants from the college-educated and non-college- educated groups were then each randomly assigned to one of our 12 treatment groups, thus there were 24 treatment groups in total, each containing 10 individuals.

2.2 Design

The study was conducted as a Two Factor balanced 3 x 4 factorial design with a block for college-educated and not college-educated. There are an equal number of participants for each of the possible factor combinations in our study, thus making it a balanced design. The factors and blocks are detailed in the table below:

Variable of Interest	Arithmetic Score			
Treatment 1 (Drug type)	Control	THC	Nicotine	
Treatment 2 (Music type)	Classical	Country	Dance	Heavy Metal
Block	College Education	No College Education		

This is the factor diagram for the experiment:



We chose to use college education as our block because higher education level often translates to higher arithmetic scores and would thus increase the variability observed in arithmetic scores between individuals. We chose THC and nicotine specifically because of its usage on college campuses for its stress relieving and instant "feel-good" effects. Music, another vital part of the college scene, was also another factor of interest due to its stress relieving properties. As varying genres of music can improve mood, induce feelings of relaxation, or even be used as outlets of anger we wanted to investigate how varying types of music could potentially interact with psychoactive drugs to impact arithmetic performance.

2.3 Materials

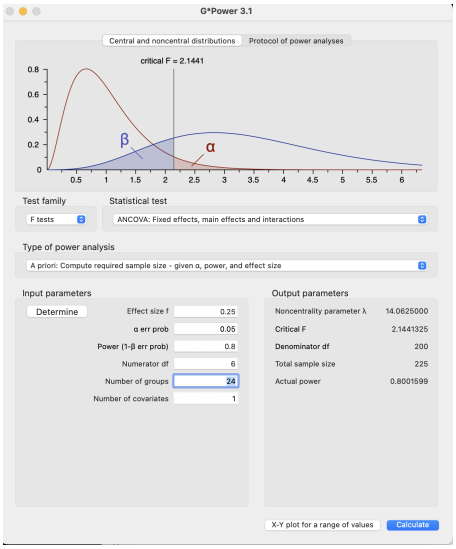
Using the functionality of a virtual resource called the Island (https://islands.smp.uq.edu.au/index.php), our measurements were administered to the participants virtually via the task functionality of the website. The two drugs of interest, THC and nicotine, will be administered through inhalation using the available Island tasks "Reefer" and "Nicotine Inhaler 2 mg" respectively. The amount of drug will be held constant between groups, with each participant in the drug treatment groups receiving two inhalations of their respective drugs. Our response variable, arithmetic capability, will be measured by recording pre-test and post-test scores of the administered "difficult mental arithmetic 4 mins" task which administers 40 difficult arithmetic questions in 4 minutes.

2.4 Instruments

To determine sample size, we used G*Power. This helped us achieve a power of 0.8 along with a balanced design. We took the population of all the consenting individuals on the island, blocked them by college education, and randomly selected participants using R to randomly assign treatments. We stored the results in an Excel sheet, which we converted into a csv file to import into R. Then, all the visualizations and analysis was run in R.

2.5 Calculating Sample Size

When determining the sample size for this experiment, we stuck with $\alpha = 0.05$, meaning the probability of us falsely accepting the alternate hypothesis when in fact null hypothesis is true is 5%. We decided on using a power of .8 allowing us to have an 80% or greater chance of finding a statistically significant difference if there is one. Using G*Power we determined that the appropriate sample size for our experiment would be 225. However, in our study we decided to use a sample size of 240 to create a balanced design with 10 participants in each of our 24 treatment groups.



2.6 Procedures

Firstly, we had to recruit participants for our experiment. As our demographic of interest was 18-30 year olds, we compiled a comprehensive list of islanders who fit into this age range. From this subject pool, we then divided the pool into two groups: college educated and non-college educated individuals. Each subject was then assigned a number and to randomly select participants we used R to generate 120 random participants from each group. Thus, we had a

total sample size of 240 participants, with 120 participants in both the college educated and non-college educated groups.

After generating our sample population, we randomly assigned participants to one of our twenty-four treatment groups. Once participants were randomly assigned their respective treatment groups, we started data collection. Each participant was first administered 40 difficult arithmetic questions and given 4 minutes to complete the task. This served as their pre-treatment score so that we have a baseline for each individual's arithmetic ability. Then each participant is given their respective drug treatments, either no drug, 2 inhalations of nicotine, or 2 inhalations of reefer. We decided to use inhalation to administer the drugs as this provided a quicker and more potent drug effect for participants. For each drug treatment group, the participants are given a 5 minute wait time to allow their respective drugs to reach peak effectiveness. After the 5 minute wait, participants were asked to listen to 10 minutes of either classical, country, dance, or heavy metal music. Finally, the participants were each given another 40 difficult arithmetic questions and 4 minutes to complete the task. Their post-treatment scores were recorded and were used to gauge how the respective treatments affected the participants' arithmetic ability.

3 Analysis

3.1 ANOVA

We used a step-wise regression using the forward selection method to find which factors are significant in affecting arithmetic score given that the other factors are present in the model.

```
## Analysis of Variance Table
##
## Response: Score_After
##                    Df Sum Sq Mean Sq F value Pr(>F)
## College_Education   1   1021  1020.9  1.8025 0.1807
## Residuals         238 134804   566.4
```

From the ANOVA we can see that our block, College Education, has a p-value of 0.1807 which is larger than $\alpha = 0.05$ indicating that it is not statistically significant. This indicates that college education and non college education groups do not have a significant difference in average arithmetic scores. This is alright, since it is just a block. We do not expect college type itself to predict Arithmetic score, but rather be a helpful part of the design to get more significant factors.

```
## Analysis of Variance Table
##
## Response: Score_After
##                    Df Sum Sq Mean Sq F value Pr(>F)
```

```
## College_Education   1   1021 1020.94  1.7942 0.1817
## Drug_Type           2    516  257.99  0.4534 0.6360
## Residuals         236 134288  569.02
```

Since the P-Value of 0.6360 is greater than $\alpha = 0.05$ we fail to reject the null hypothesis. Drug Type by itself does not significantly predict Arithmetic Score. Neither of these factors are significant in predicting the Arithmetic score of an individual after the treatments. Yet we see that the P-Value of College Education decreases, making it more significant. It is not significant enough, but it is helpful in blocking when trying to predict Arithmetic Score.

```
## Analysis of Variance Table
##
## Response: Score_After
##                         Df Sum Sq Mean Sq F value    Pr(>F)
## College_Education        1   1021  1020.9  2.4370    0.1199
## Drug_Type                2    516   258.0  0.6158    0.5411
## Music_Type               3  37686 12561.8 29.9851 2.282e-16 ***
## Drug_Type:Music_Type     6   1504   250.7  0.5983    0.7315
## Residuals              227  95098   418.9
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

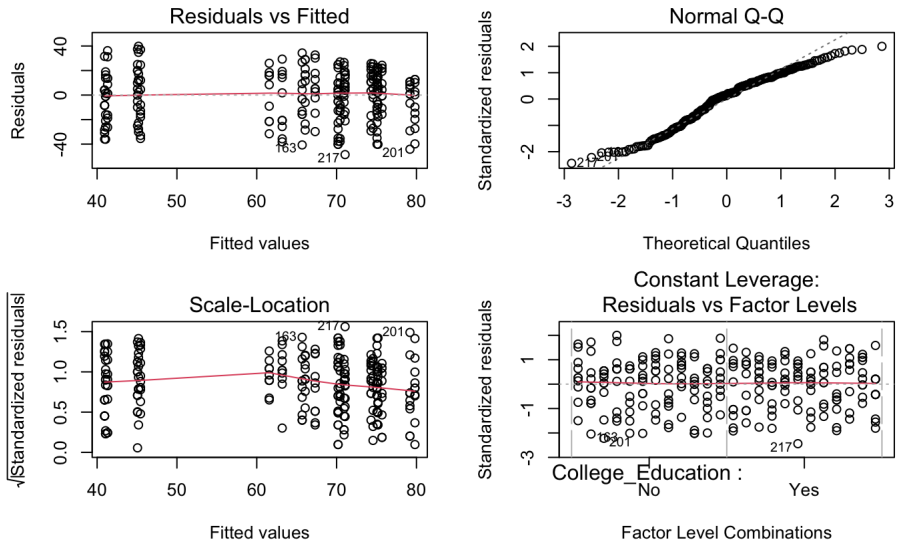
Since the P-Value of 2.282e-16 is less than $\alpha = 0.05$ we reject the null hypothesis and can conclude that Music Type has a significant effect on Arithmetic Score.

Since the P-Value of 0.7315 is greater than $\alpha = 0.05$ we fail to reject the null hypothesis and cannot conclude the interaction between Drug Type and Music Type has a significant effect on Arithmetic Score.

For the purposes of Post-Hoc diagnostics, we will still use all the factors, as some levels may be significant. Thus, our final model becomes Arithmetic Score is predicted by the interaction between Drug Type and Music Type blocked by College Education.

3.2 Model Diagnostics

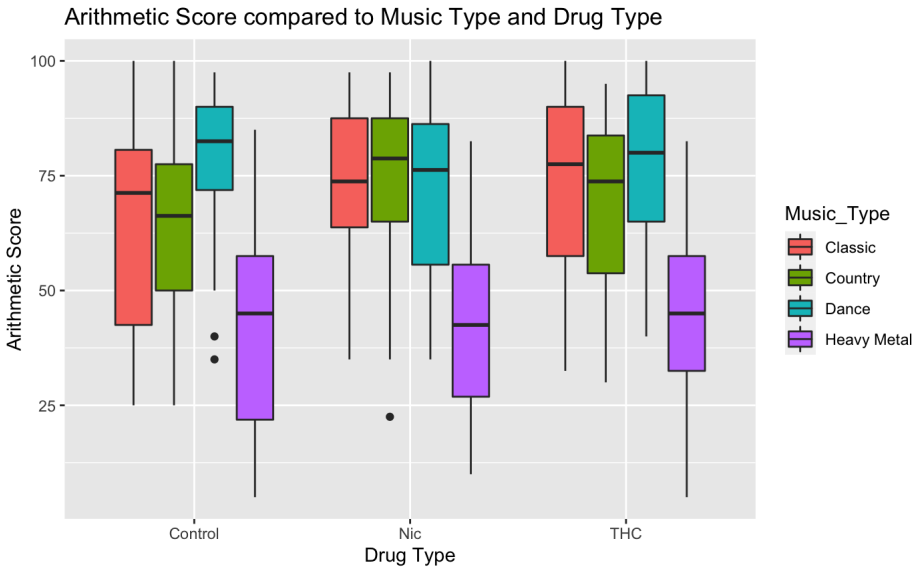
To ensure that our model is valid, we assessed the diagnostic plots, specifically the residual plot, the Normal QQ plot, the Scale-Location plot, and the leverage plot. The goals is to ensure that the errors are independent and normally distributed.



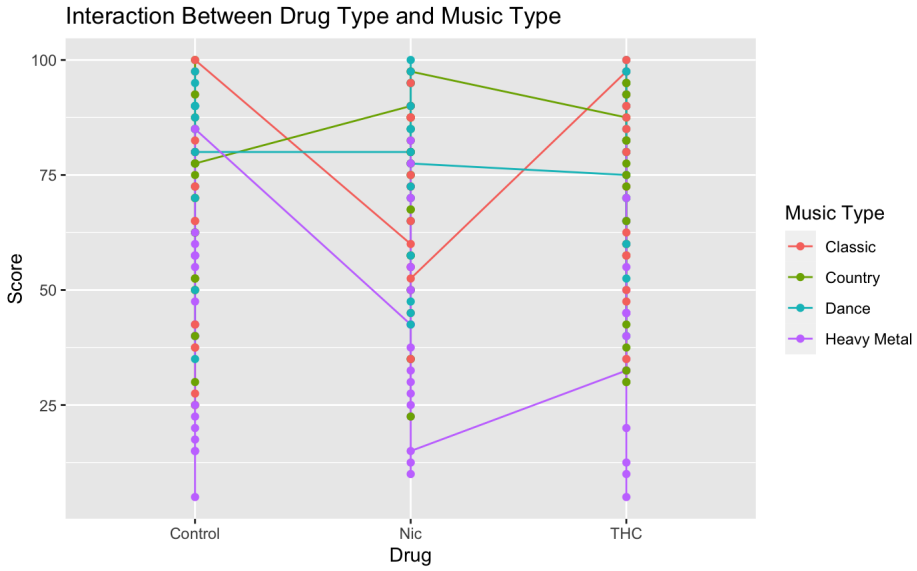
Looking at the residual plot, we can see that for each of the levels of our factors the points are randomly and evenly distributed linearly and there is no visible pattern. This indicates that the normality and linearity assumption holds for our model. Thus we can conclude that that the residuals are independently distributed. Looking at the Normal QQ Plot we can see that the points adhere to the diagonal line indicating that the errors are normally distributed and the normality assumption holds. The scale location plot has a slight decreasing trend, however it does not seem to be problematic and the plot indicates that the constant variance assumption holds for our model. The leverage plot indicates that there are no high leverage points that could potentially affect our data. Ultimately, the diagnostic plots indicates that all assumptions for model validity are met.

3.3 Post Hoc Analysis

3.3.1 Plots

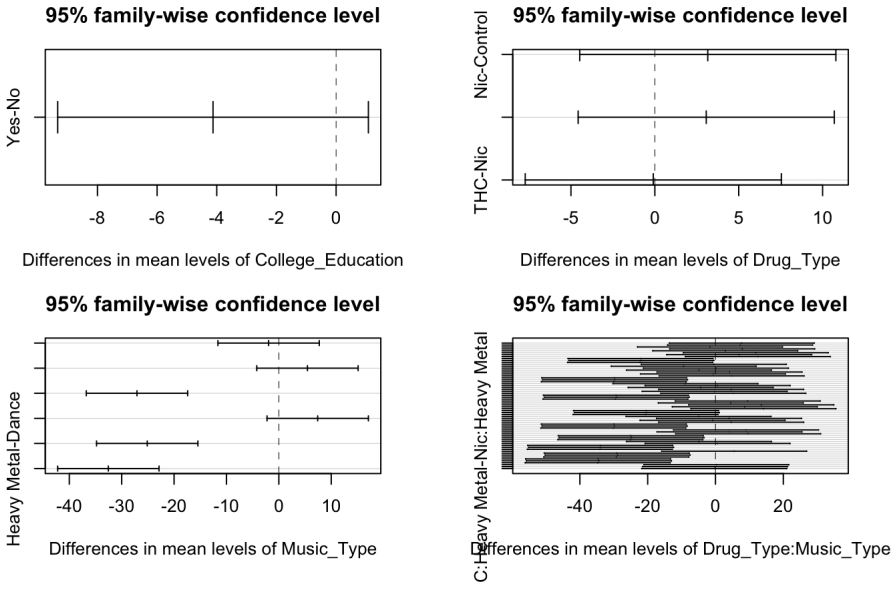


Using a box plot to do an initial visual analysis of the data, there look to be differences in average arithmetic scores between music type as we see that the average arithmetic scores for heavy metal music seems to be consistently lower than all other music types. Between the drug types there does not seem to be a lot of variation in average arithmetic score. From the box plot we are unable to determine significance, however with further post-hoc analyses we can determine which specific levels show significant differences in average arithmetic scores.



This plot shows that there is a bigger difference in score when looking at Music Type, but not so much when looking at Drug type. Also, the interaction is significant for a couple of Drug/Music combinations but not for the most part.

3.3.2 Tukey Analysis



This plot shows all the possible combinations for the levels of each factor to show which differences are significant.

Running a full Tukey analysis indicates that many of the combinations of levels are insignificantly different. Extracting the significant combinations results in:

Music Type:

```
##                           diff       lwr       upr        p adj
## Heavy Metal-Classic -27.08333 -36.75507 -17.41159 3.950140e-11
## Heavy Metal-Country -25.12500 -34.79674 -15.45326 8.517785e-10
## Heavy Metal-Dance   -32.54167 -42.21341 -22.86993 1.554312e-14
```

We are 95% confident that the true difference in arithmetic score for these two levels lies within the interval listen above. Since none of them contain zero, we can say with 95% confidence that the levels above have a significant difference in arithmetic score. There is a significant difference in score with heavy metal compared to classic, heavy metal compared to country and heavy metal compared to dance. Since all of these intervals are negative, and all of them have Heavy Metal on the left, we can say with 95% confidence that any other type of music produces better arithmetic scores than Heavy Metal music.

Interaction:

```
##                                         diff       lwr         upr        p adj
## Control:Heavy Metal-Control:Classic -22.125 -43.50086  -0.7491376 3.520433e-02
## Nic:Heavy Metal-Control:Classic     -21.875 -43.25086  -0.4991376 3.964945e-02
## THC:Heavy Metal-Control:Classic     -22.250 -43.62586  -0.8741376 3.314995e-02
## Control:Heavy Metal-Nic:Classic     -29.875 -51.25086  -8.4991376 4.012158e-04
## Nic:Heavy Metal-Nic:Classic         -29.625 -51.00086  -8.2491376 4.734139e-04
## THC:Heavy Metal-Nic:Classic         -30.000 -51.37586  -8.6241376 3.691832e-04
## Control:Heavy Metal-THC:Classic     -29.375 -50.75086  -7.9991376 5.578970e-04
## Nic:Heavy Metal-THC:Classic         -29.125 -50.50086  -7.7491376 6.566164e-04
## THC:Heavy Metal-THC:Classic         -29.500 -50.87586  -8.1241376 5.140041e-04
## Control:Heavy Metal-Nic:Country     -30.000 -51.37586  -8.6241376 3.691832e-04
## Nic:Heavy Metal-Nic:Country         -29.750 -51.12586  -8.3741376 4.358910e-04
## THC:Heavy Metal-Nic:Country         -30.125 -51.50086  -8.7491376 3.396022e-04
## Control:Heavy Metal-THC:Country     -25.000 -46.37586  -3.6241376 7.928838e-03
## Nic:Heavy Metal-THC:Country         -24.750 -46.12586  -3.3741376 9.103865e-03
## THC:Heavy Metal-THC:Country         -25.125 -46.50086  -3.7491376 7.395178e-03
## Control:Heavy Metal-Control:Dance   -34.000 -55.37586 -12.6241376 2.201312e-05
## Nic:Heavy Metal-Control:Dance       -33.750 -55.12586 -12.3741376 2.647986e-05
## THC:Heavy Metal-Control:Dance       -34.125 -55.50086 -12.7491376 2.006265e-05
## Control:Heavy Metal-Nic:Dance       -29.125 -50.50086  -7.7491376 6.566164e-04
## Nic:Heavy Metal-Nic:Dance           -28.875 -50.25086  -7.4991376 7.718064e-04
## THC:Heavy Metal-Nic:Dance           -29.250 -50.62586  -7.8741376 6.053446e-04
## Control:Heavy Metal-THC:Dance       -34.625 -56.00086 -13.2491376 1.380548e-05
## Nic:Heavy Metal-THC:Dance           -34.375 -55.75086 -12.9991376 1.665144e-05
## THC:Heavy Metal-THC:Dance           -34.750 -56.12586 -13.3741376 1.256547e-05
```

Since all these differences are negative, this means that all the levels on the 'right side' of the equation are higher. For example: Control:Heavy Metal-Control:Classic has a 95% confidence interval between -43.50086 and -0.7491376. This means that the arithmetic score difference between these two levels is between -43.50086 and -0.7491376 with 95% confidence. Since it is all negative, we can say with 95% confidence that Control:Classic produces a higher arithmetic score than Control:Heavy Metal. Similar conclusions can be drawn for all of these intervals.

Heavy metal is always on the left of the equations in these intervals. **Thus, we can say with 95% confidence that any drug (THC, nicotine or nothing) / music (Dance, Country or Classic) combo will produce a higher arithmetic score than any drug (including no drug) and heavy metal music.** This means, taking THC and listening to dance music and would probably produce a better arithmetic score than if you had not taken any drug and listened to heavy metal music.

4 Results

4.1 Conclusions

Originally we were interested if either drug type or music type significantly affected the student's arithmetic score. When using the full model, with College education acting as our block, the resulting ANOVA table gave us conclusive evidence suggesting music type significantly affected the student's arithmetic score while drug type and the interaction between drug and music type didn't significantly affect the student's arithmetic score. After running the Tukey Analysis to help us determine which of all the possible combinations of music types is statistically significant we were able to determine that Heavy Metal music produces worse arithmetic scores compared to all the other types. So if a student listened to Heavy Metal music, regardless of whether or not the student took any drug, they would on average do worse then if they listened to any other type of music (Dance, Country or Classic).

4.2 Discussion

Our study sought to determine the effect of psychoactive drugs (nicotine and THC) and different music genres (classical, country, dance, heavy metal) on arithmetic ability. Our results attempt to support or refute the idea that using THC or nicotine recreationally can impact one's arithmetic performance. We were also interested in whether the interaction between drug usage and music type would impact arithmetic scores as both are thought to have impacts on cognitive function and performance.

Using a sample size of 240 in order to achieve a balance design with 10 participants in each treatment group, we were able to achieve a power of 0.83 which was greater than the initial power value of 0.8 that we wanted to achieve.

Our results indicate that different genres of music affect arithmetic performance, specifically heavy metal seems to be detrimental to arithmetic ability. Ultimately, use of nicotine and THC does not significantly impact arithmetic ability, which goes against the stigma that drugs are detrimental to arithmetic ability. With the significant effect of music of arithmetic ability we can also conclude that listening to specific types of music, namely heavy metal, can be detrimental to arithmetic ability. Thus the results of our study indicates that arithmetic ability is not worsened or improved by drugs but the type of music can change our arithmetic performance.

4.3 Limitations

We acknowledge that within our experiment lies limitations. One limitation of this study is that while each random sample within each condition contained a portion of the sample that were control, each participant did not take part in both the control and the treatment conditions. Because we did not control within individual participants, we cannot say if their score would improve more without any music or drug consumption. In order to establish this, each participant would have to take part in a control trial and then a trial with respective treatment type administered. This could be done in the future to improve upon this experiment. Another limitation lies in the factors we either controlled or failed to control within our experiment. While focusing on participants aged 18-30, we failed to consider if age plays a role in whether the drug and music interactions would differ between age groups. Along with this, we did not control drug tolerance for the individuals chosen, which could impact amount needed to experience an effect. Finally, we did not control for time of day the tests were administered, which also could have potentially impacted participants' ability to improve score. To account for these limitations, a future experiment could also block for age group, focus on participants who are smokers, and administer tests in the morning only. Considering our results, it could also be informative to explore further music genres and their effects on arithmetic performance.

Links

1. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.882.737&rep=rep1&type=pdf
2. https://www.goodnewsnetwork.org/listening-to-music-while-studying-is-more-likely-to-have-higher-gpa/
3. https://nida.nih.gov/news-events/news-releases/2021/09/marijuana-use-at-historic-high-among-college-aged-adults-in-2020
4. https://www.nih.gov/news-events/news-releases/vaping-marijuana-use-2019-rose-college-age-adults#:~:text=In%202017%2C%206.1%25%20of%20college,in%20its%2045%2Dyear%20history
5. https://nypost.com/2022/08/18/students-who-listen-to-music-while-studying-have-a-higher-gpa-poll/

References

[1] Marijuana use at historic high among college-aged adults in 2020, Jan 2022.

[2] Mojtaba Mahdevi. The effects of listening to music just before reading test on students' test score. *Cumhuriyet University Faculty of Science Science Journal (CSJ)*, 36(3), May 2015.

[3] Good News Network. People who play music while studying more likely to have higher gpa, says new poll, Aug 2022.

[4] Brooke Steinberg. Students who listen to music while studying have a higher gpa: Poll, Aug 2022.