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Introduction to Statistics
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Recreational Marijuana and Its Impact on the Developing Mind

Introduction

The debate over policy surrounding marijuana has been a controversial issue for quite some time. In determining marijuana policy, having an understanding of how recreational marijuana affects the development of youth is crucial. The use of marijuana among people over the age of 12 has gone up 0.9% since 2002, bringing it up to 9.4% of the population in 2013. Another 2013 study found that the majority of marijuana users started at age 18 or younger, and we do not have sufficient knowledge about how marijuana affects youth ("DrugFacts: Marijuana."). This is why it is crucial to understand the effects marijuana usage has on youth.

Gaining a better understanding of how recreational marijuana affects developing youth was a common goal among our group. We asked the question “Will using marijuana lower one’s intelligence over time, and will daily marijuana use cause a greater decrease?” Prior to our study, we expected that marijuana use would cause a decrease in intelligence and that daily marijuana use would cause an even greater drop. Our expectations for what we thought the data would show were partially correct. Our analysis suggested that using marijuana does cause a decrease in intelligence; however, there was a negligible difference between an occasional user and a daily user.

Methods

Due to the scope of the data necessary for our project, we were not in a position to collect it ourselves. We obtained a data set from the journal article “Impact of adolescent marijuana use on intelligence: Results from two longitudinal twin studies”. We accessed it by contacting the researchers who performed the study and wrote the article (Jackson et al.). The study has also

been cited in other reputable articles (Grabus). This study was approved by the University of Minnesota and University of Southern California Institutional Review boards at each wave of the study.

We utilized data gathered from the Minnesota Twin Family Study (MFTS). In this study subjects were recruited when they were about 11 or 12 years of age and had a follow-up test between the ages of 17 and 19. The initial assessments of the first group (1,527 people) were taken between 1990 and 1996. The more recent group (1,000 people) was tested between 1999 and 2006. Half of the twins selected had "disruptive behavior problems and academic disengagement." The other half were selected at random from twins born between 1988 and 1994. Participants from the original sample were not selected "on the basis of manifesting behavioral problems" (Jackson et al. 2). Both tests were conducted under the same conditions. A survey was used to collect the subject's age and whether they had used marijuana, used marijuana daily, or used marijuana over 30 times in their lives. The results of these tests were recorded as categorical variables. Additional information was also recorded, however, these additional factors will not be used in our analysis.

In the Minnesota Twin Family Study, researchers used several subtests from the Wechsler Intelligence Scale for Children-Revised to measure an individual's intelligence including an information test on "general knowledge that is culturally valued, such as geographic information and historical events," and a test of participants' knowledge of vocabulary words.Vocabulary scores and information scores are considered to be measures of crystallized intelligence, "measuring knowledge acquired through experience or learning" (Jackson et al. 2). The goal of these tests was to chart intellectual growth through changes in scores over the course of the testing (Jackson et al. 2). The results of these tests were recorded as quantitative variables, which were converted into a common metric with a mean of 100.

To find out whether each wave of the study found similar differences in intelligence between the baseline and follow up scores, 1,000 bootstrap estimates of the "interaction coefficients from each study were compared using a bias-corrected percentile bootstrap method" (Jackson et al. 3). While some measures like this were taken to prevent bias, there was still some bias in the study. Sampling bias occurred because half of the twins in the Enrichment Study (ES)

were selected based on lack of academic engagement and behavioral problems, which may have further biased the study in the baseline daily use group because the lower IQ may have been caused by other factors like a learning disability. Non-response bias may have affected the results as some subjects did not respond to some survey questions. Additionally, response bias may have been at play as many results were garnered from an unsupervised survey vulnerable to dishonesty.

For our analysis, we used version 1.0.136 of RStudio. The main R functions we used were *boxplot* to build the boxplots, *lm* to construct our models, *summary* to determine the multiple r-squared value, and anova to determine the p-values from each of the models. The significance level we chose was $\alpha = 0.05$. We chose this significance level because we did not want to have a greater chance of committing one type of error over another, as we wanted our results to be as accurate as possible.

Results -

The Box Plots

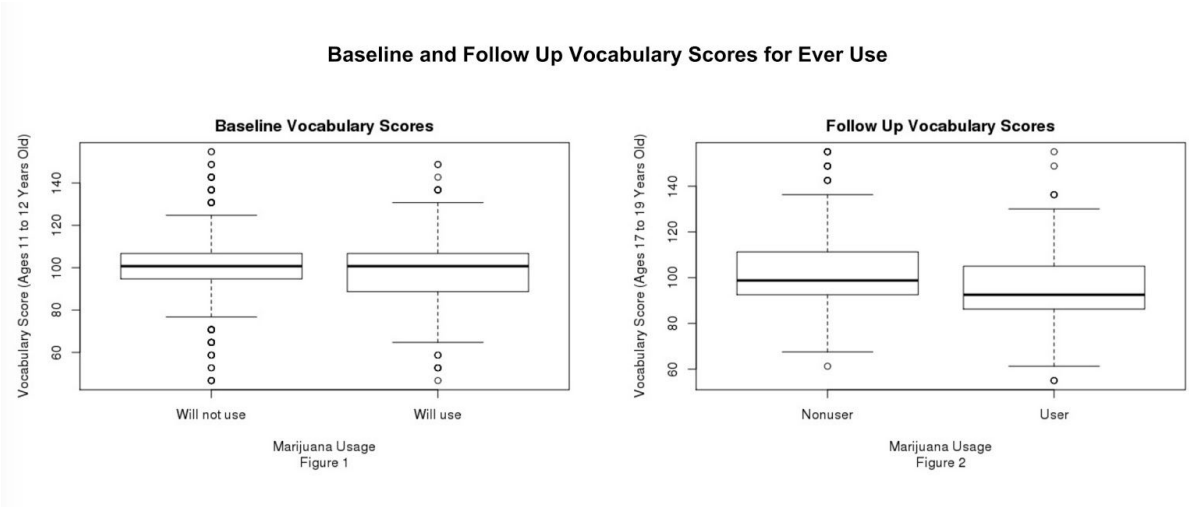


Figure 1 shows the baseline vocabulary scores of 11 and 12 year olds and uses side-by-side boxplots to visualize the differences in the baseline vocabulary scores among the individuals who will use marijuana and those who will not use marijuana. The vocabulary scores of those who have never used marijuana have a very standard distribution. Because of how the data was processed, the mean was adjusted to exactly 100. Interestingly, the median vocabulary score for

those who have used marijuana is nearly the same as for those who have never used marijuana. The minimum score for those who have used marijuana, not including outliers, is noticeably and significantly lower. Interestingly, however, the maximum vocabulary score is also slightly higher than that for those who haven't used marijuana.

Figure 2 shows the follow-up vocabulary scores of 17 to 19 year olds and uses side-by-side boxplots to visualize the differences in the follow-up vocabulary scores among the individuals who have used marijuana and those who have not. The distribution of the vocabulary scores for those who have not used marijuana has become moderately less standard, but is still very standard. Continuing to support our predictions, the boxplot for those who have used marijuana has compressed and shifted lower. The median vocabulary score is slightly lower than in the baseline data set and still significantly lower for those who have not used marijuana. The maximum vocabulary score for those who have used marijuana is no longer higher than for those who have not used marijuana.

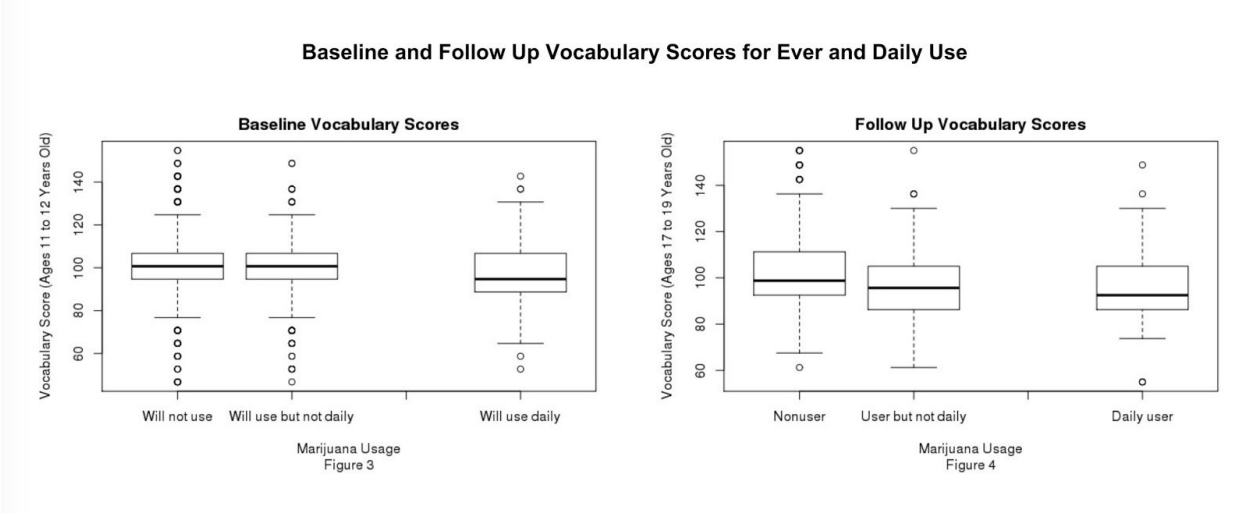


Figure 3 shows the baseline vocabulary scores of 11 and 12 year olds and uses side-by-side boxplots to visualize the differences in the baseline vocabulary scores among the individuals who will not use marijuana, will use marijuana but not daily, and will use marijuana daily. There is a gap in the plot because it would not make sense for a person to use marijuana daily but never

have used marijuana to begin with. It appears that the medians of 'will not use' and 'will use but not daily' are about the same. The median baseline vocabulary score for 'will use daily' is about ten points less. The 'will use daily' boxplot is slightly more skewed to the right than the other two relatively symmetrical boxplots. The 'will not use' and the 'will use but not daily' boxplots also have more outliers on each side than the 'will use daily' boxplot.

Figure 4 displays the follow up vocabulary scores of 17 to 19 year olds and uses side-by-side boxplots to visualize the differences in the follow up vocabulary scores among those individuals. For the same reason as *Figure 3,* there is a gap with a missing plot. The medians of the three plots are slightly different. The median for 'non user' is greater than 'user but not daily', which is slightly greater than the median for 'daily user.' While the median for 'daily use' may be less than 'user but not daily', both of the groups share the same 50% coverage interval. The boxplots for 'non user' and 'user but not daily' have practically doubled in size, increasing their interquartile ranges, causing the data points to be more spread out. Now, each of the three boxplots appear to have very similar interquartile ranges. Each group had fewer outliers in the follow up vocabulary scores, which may indicate less variability in scores.

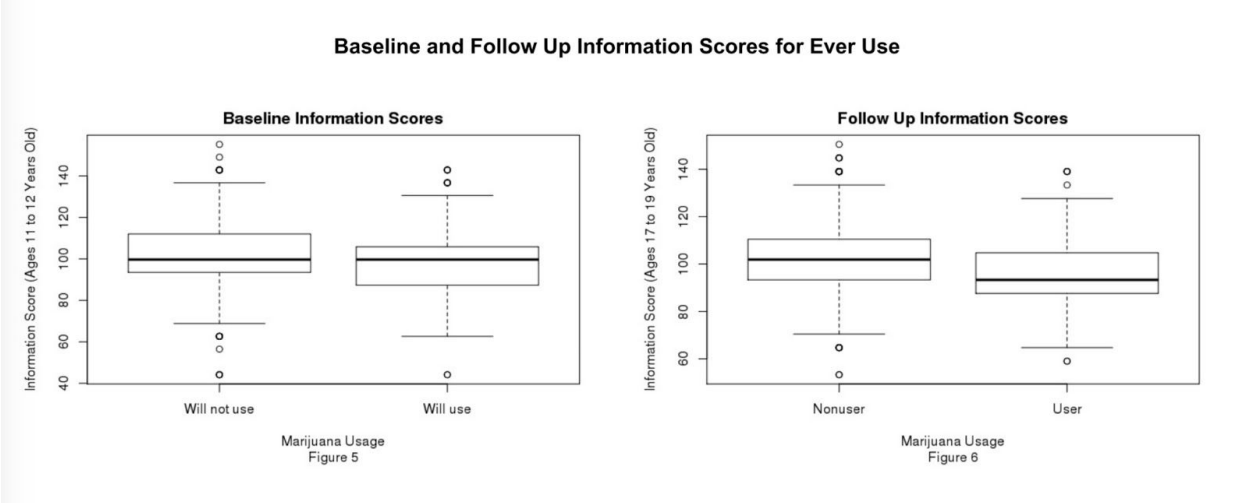


Figure 5 compares the baseline information scores of those who will and will not use. Again, the plot for those who have not used marijuana has a very standard distribution. The median score for those who have used marijuana is slightly higher than the median for those who have not

used marijuana. The first quartile and third quartile baseline scores of those who will not use are higher than for those who will use, which is problematic as it may have had the effect of biasing the results. As predicted, the minimum and maximum scores for those who have used marijuana are lower than the scores for those who have not used marijuana.

Figure 6 shows the differences in the follow up information test scores based on whether or not the subject used marijuana. Unlike the baseline data set, the results now match our predictions, as the median score for those who have used marijuana is significantly lower than those who have not used marijuana. The entire plot has shifted down, as the maximum, minimum, and interquartile range is lower than for those who have not used marijuana.

Baseline and Follow Up Information Scores for Ever and Daily Use

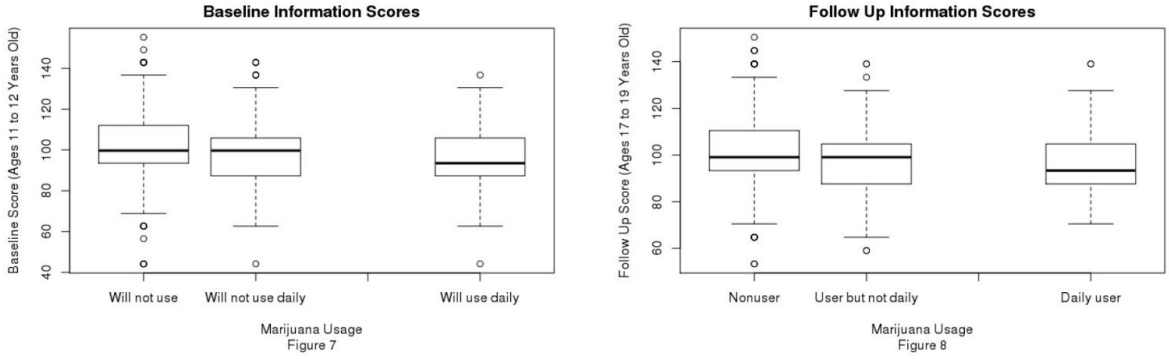


Figure 7 Figure 8

In *figure 7*, the three boxplots represent the baseline information scores of individuals assessed at 11 to 12 years of age. The medians of the 'non user' and 'user but not daily' baseline information scores are about the same with a score of about 100, while the 'daily user' baseline median information score is about 95. This is problematic because the lower median may have altered the follow up results. The groups for "will not use" and "will use daily" appear to be more right skewed while the group for "will use but not daily" appears to be more left skewed.

In *figure 8*, the three plots representing the follow up information scores of 17 to 19 year olds have the same medians and interquartile ranges as the three plots in *figure 7*. 'Non user' only has two instead of three outliers below the first quartile. The 'user but not daily user'' group had a decrease in its minimum information score. For "daily use" there is no longer an outlier below

the first quartile, indicating a large increase in the minimum information score of daily users. The outlier above the third quartile increased, indicating an increase in the maximum information score daily users of marijuana had received.

Models

For the purpose of our statistical analysis, each model analyzes the possible relationship between a quantitative variable and one or two categorical variables. In this case our quantitative variable will either be the vocabulary score or the information score. In each model there will be either one or two categorical predictors because the variable corresponding with ever using marijuana can be the sole categorical predictor and the categorical variable for daily use of marijuana can be combined with having ever used of marijuana.

Vocabulary Ever Use Baseline Model

$$\widehat{VocabBaseline} = 100.689 - 1.909 \quad I(YMarEverUseBaseline)$$

$$I(YMarEverUseBaseline) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

This groupwise mean model predicts that the average vocabulary score from the baseline round of testing for a subject who does not use marijuana is 100.689 points. If the subject will use marijuana, the model predicts that their vocabulary test score will be 1.909 points lower. Our multiple R-squared is .0037, so this model explains 0.37% of the variability between the vocabulary baseline score and whether or not someone will ever use marijuana.

Vocabulary Ever Use Follow Up Model

$$\widehat{VocabFollowUp} = 102.02 - 5.68 \quad I(YMarEverUseFollowUp)$$

$$I(YMarEverUseFollowUp) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

This groupwise mean model predicts that the average vocabulary score from the follow up round of testing for a subject who did not use marijuana is 102.02 points. The indicator function

predicts that for subjects who have used marijuana, the average vocabulary test score will decrease by 5.68 points. Our multiple R-squared is 0.0329, so this model predicts 3.29% of the variability. Though the multiple R-squared value is low, other factors could be at play, reducing the accuracy of this model.

Vocabulary Ever Use and Daily Use Baseline Model

$$\widehat{VocabBaseline} = 100.755 - \ 1.546 \ \ I(YMarEverUseBaseline) \ -1.678 \ \ I(YMarDailyBaseline)$$

$$I(YMarEverUseBaseline) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

$$I(YMarDailyBaseline) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

This model predicts that the average vocabulary test score from the baseline round of testing is 100.755 for a subject who does not use marijuana. The first indicator function predicts that for subjects who have ever used marijuana, the average vocabulary test score is 1.546 points lower. The second indicator function predicts that for subjects who use marijuana daily, the average vocabulary test score is 1.678 points lower. Our multiple R-squared is .00454, so this model predicts .454% of the variability. Because the multiple R-squared is quite low, it is likely that a relationship exists between daily use and lowered vocabulary test scores.

Vocabulary Ever Use and Daily Use Follow Up Model

$$\widehat{VocabFollowUp} = 101.990 - 4.949 I(YMarEverUseFollowUp) - 2.887 I(YMarDailyFollowUp)$$

$$I(YMarEverUseFollowUp) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

$$I(YMarDailyFollowUp) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

This model predicts that the average vocabulary test score from the follow up round of testing is 101.990 for a subject who does not use marijuana. The first indicator function predicts that for subjects who have ever used marijuana, the average vocabulary test score is 4.949 points lower. The second indicator function predicts that for subjects who use marijuana daily, the average vocabulary test score is 2.887 points lower. Our multiple R-squared is .0344, so this model

predicts 3.44% of the variability. While our multiple R-squared is still relatively low, suggesting a relationship between daily marijuana use and lowered vocabulary test scores, it is strange that R-squared for the baseline test is significantly lower. This could indicate bias in the data collection.

Information Ever Use Baseline Model

$$\widehat{InfoBaseline} = 101.202 - 3.328 \quad I(YMarEverUseBaseline)$$

$$I(YMarEverUseBaseline) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

This model predicts that the average information test score from the baseline round of testing for a subject who does not use marijuana is 101.202 points. The indicator function predicts that for subjects who have used marijuana, the average vocabulary test score will decrease by 3.328 points. Our multiple R-squared is .0114, so this model predicts 1.14% of the variability. Because our multiple R-squared is relatively low, this suggests that there is a relationship between lower information test scores and marijuana usage.

Information Ever Use Follow Up Model

$$\widehat{InfoFollowUp} = 102.309 - 5.949 \quad I(YMarEverUseFollowUp)$$

$$I(YMarEverUseFollowUp) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

This model predicts that the average information test score from the follow up round of testing for a subject who does not use marijuana is 102.309 points. The indicator function predicts that for subjects who have used marijuana, the average vocabulary test score will decrease by 5.94 points. Our multiple R-squared is .0374, so this model predicts 3.74% of the variability. This multiple R-squared is relatively low, indicating that there is likely a relationship between follow up information test scores and marijuana use.

Information Ever Use and Daily Use Baseline Model

$$\widehat{InfoBaseline} = 101.2586 - 3.0884 I(YMarEverUseBaseline) - 0.4986 I(YMarDailyBaseline)$$

$$I(YMarEverUseBaseline) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

$$I(YMarDailyBaseline) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

This model predicts that the average information test score from the baseline round of testing is 101.259 for a subject who does not use marijuana. The first indicator function predicts that for subjects who have ever used marijuana, the average vocabulary test score is 3.088 points lower. The second indicator function predicts that for subjects who use marijuana daily, the average vocabulary test score is 0.499 points lower. Our multiple R-squared is 0.01052, so this model predicts 1.052% of the variability. Because the multiple R-squared value is relatively low, this suggests there is a relationship between daily marijuana usage and lower information test scores.

Information Ever Use and Daily Use Follow Up Model

$$\widehat{InfoFollowUp} = 102.259 \ \ -5.574 \ \ \ I(YMarEverUseFollowUp) \ \ -1.22 \ \ \ I(YMarDailyFollowUp)$$

$$I(YMarEverUseFollowUp) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

$$I(YMarDailyFollowUp) = \{1 \ \ if \ \ yes, 0 \ \ if \ \ no\}$$

This model predicts that the average information test score from the baseline round of testing is 102.259 for a subject who does not use marijuana. The first indicator function predicts that for subjects who have ever used marijuana, the average vocabulary test score is 5.574 points lower. The second indicator function predicts that for subjects who use marijuana daily, the average vocabulary test score is 1.22 points lower. Our multiple R-squared is .0367, so this model predicts 3.67% of the variability. This multiple R-squared value is relatively low, suggesting a relationship between daily marijuana use and lowered information test scores.

Hypothesis Testing

Hypothesis Test 1 - Vocabulary Ever Use

The query of investigation:

Is there a relationship between a decrease in one's vocabulary score and whether or not an individual has ever used marijuana?

Determining the null and alternative hypothesis:

H_0: There is NOT a relationship between a decrease in one's vocabulary score and whether or not they have ever used marijuana.

H_a: There is a relationship between a decrease in one's vocabulary score and whether or not they have ever used marijuana.

Choosing the significance level:

The significance level that we selected is $\alpha = 0.05$. We selected this value for its intermediate position that favors neither Type I nor Type II errors. As this is only an observational study, we wanted a significance level that would give us the most accurate results.

Performing the test and calculating the p-value:

Next, we created a linear model comparing the variable "Vocab"—indicating vocabulary scores on a quantitative scale—and the "YMarEverUse" variable—indicating whether the subject has ever used marijuana, denoted by a categorical answer of "yes" or "no". We obtained the p-value of **2.2E-16** by calling the anova command on our Vocabulary Ever Use Follow Up Model.

Comparing, deciding (either rejecting or failing to reject the null hypothesis), and interpreting:

Because the p-value of **2.2E-16** is smaller than 0.05, we reject the null hypothesis in favor of the alternative hypothesis that there is a relationship between a decrease in one's vocabulary score and whether or not a subject has ever used marijuana. This means that it is likely that on average a subject who smokes marijuana will have a lower follow up vocabulary score than a subject that

does not smoke marijuana.

Hypothesis Test 2 - Vocabulary Ever Use And Daily Use

The query of investigation:

Will using marijuana daily cause a greater decrease in one's vocabulary score than having ever used it?

Determining the null and alternative hypothesis:

H_0: Using marijuana daily will NOT cause a greater decrease in one's vocabulary score than ever having used marijuana.

H_a: Using marijuana daily will cause a greater decrease in one's vocabulary score than ever having used marijuana.

Choosing the significance level:

The significance level that we selected is $\alpha = 0.05$. We selected this value for its intermediate position that does not favor either Type I or Type II errors. (*See "Significance level" under the heading "Vocab" for a more detailed explanation.)*

Performing the test and calculating the p-value:

Next, we created a linear model comparing the variable "YMarEverUse"—if a subject has ever used marijuana—and the "YMarDaily" variable—indicating whether the subject uses marijuana daily—both denoted by a categorical answer of "yes" or "no". These two variables were then compared to the response variable "Vocab"—the subject's quantitative vocabulary test score. We obtained the p-value of **0.09307** by calling the anova command on our Information Ever Use Follow Up Model.

Comparing, deciding (either rejecting or failing to reject the null hypothesis), and interpreting:

Because the p-value of **0.09307** is larger than 0.05, we fail to reject the null hypothesis, indicating that using marijuana daily is not likely to cause a greater decrease in one's vocabulary

score than ever having used marijuana.

Hypothesis Test 3 - Information Ever Use

The query of investigation:

Is there a relationship between a decrease in one's information test score and whether or not they have ever used marijuana?

Choosing the null and alternative hypothesis:

H_0*:* There is NOT a relationship between a decrease in one's information test score and whether or not they have ever used marijuana.

H_a*:* There is a relationship between a decrease in one's information test score and whether or not they have ever used marijuana.

Choosing the significance level:

The significance level that we selected is $\alpha = 0.05$. We selected this value for its intermediate position that favors neither Type I nor Type II errors. (*See "Significance level" under the heading "Vocab" for a more detailed explanation).*

Performing the test and calculating the p-value:

Next, we created a linear model comparing the variable "info"—indicating vocab scores on a quantitative scale—and the "ymareveruse" variable—indicating whether the subject has ever used marijuana—denoted by a categorical answer of "yes" or "no". We obtained the p-value of **5.185E-12** by calling the anova command on our Information Ever Use Follow Up Model.

Comparing, deciding (either rejecting or failing to reject the null hypothesis), and interpreting:

Because the p-value of **5.185E-12** is smaller than 0.05, we reject the null hypothesis in favor of the alternative hypothesis that there is a relationship between whether or not a subject has ever used marijuana and their information test score. This means that it is likely that on average a subject who smokes marijuana will have a lower follow up information score than a subject that

does not smoke marijuana.

Hypothesis Test 4 - Information Ever Use And Daily Use

The query of investigation:

Will using marijuana daily cause a greater decrease in one's information test score than having ever used it?

Determining the null and alternative hypothesis:

H_0: Using marijuana daily will NOT cause a greater decrease in one's info score than having ever used marijuana.

H_a: Using marijuana daily will cause a greater decrease in one's info score than having ever used marijuana.

Choosing the significance level:

The significance level that we selected is $\alpha = 0.05$. We selected this value for its intermediate position that does not favor either Type I or Type II errors. (*See "Significance level" under the heading "Vocab" for a more detailed explanation.)*

Performing the test and calculating the p-value:

Next, we created a linear model comparing "info", "ymareveruse", and "ymardaily", which indicates whether or not the subject uses marijuana on a daily basis. We obtained the p-value of **0.7428** by calling the anova command on our Information Ever Use And Daily Use Follow Up Model.

Comparing, deciding (either rejecting or failing to reject the null hypothesis), and interpreting:

Because the p-value of **0.7428** is larger than 0.05, we fail to reject the null hypothesis indicating that using marijuana daily is not likely to cause a greater decrease in one's information score than ever having used marijuana.

Discussion

All data in our models was drawn from a single data set entitled Minnesota Long. Minnesota indicates that this set of data was taken from the University of Minnesota; "long" indicates the method with which the data was formatted. This data set includes entries from both an initial baseline set of data collection and a follow up set of data collected from the same subjects several years later. To best interpret the data, we decided to split the data set into two separate datasets: one including only the baseline data and one containing only the follow up data.

We concluded that there is a relationship between lower intelligence scores and the consumption of marijuana. However, this result did not reflect our initial expectation that daily users of marijuana would have a greater decrease in both vocabulary and information scores. This conclusion most accurately illustrates the effects of marijuana usage on youths aged 12-18. While we do believe that the findings in this study can be applied to a more general population, it is important to note that the sample was a relatively non-diverse group of youths only from Minnesota.

There were instances in our data that seemed contrary to this conclusion. For example, the median baseline vocabulary test scores were higher for participants who would go on to use marijuana than those who would not. However, there could be multiple sources of bias at play. This could be because this was a baseline test; follow-up test results argued the opposite. In addition, most participants said that they had never used marijuana, leading to a possible sampling bias that could affect the accuracy of our results. For example, it could be that the sample used, due to its proportionally smaller size, may just have abnormally low scores on the tests their IQs were based on, and the marijuana may have had no effect. However, due to the fact that the sample as a whole was still quite large, this is unlikely.

Despite these few inconsistencies, these data provide evidence that marijuana does affect intelligence among youth. Due to the lack of diversity in the sample, more testing should be done before conclusions are drawn. However, the tests used to collect the data were relatively robust,

and as such, could be applied to a more varied group of children across the United States in order to draw broader and more definitive conclusions.

Studies in the past on the effects of marijuana on youth have generally been biased, and with more states legalizing marijuana every year, it is imperative that its effects are understood. In conclusion, we believe that our study shows that marijuana usage does affect intelligence among youth but that more studies should be performed to better understand the extent of its effects.

Appendix

All annotated R code used in the paper:

We started out by attaching the data into our file.

```{r}
attach(MinnesotaBaselineDataset)
attach(MinnesotaFollowupDataSet)
attach(MinnLongWholeDataSet)
attach(VocabDataForHypothesisTest) #*#
attach(InfoDataForHypothesisTest) #*#
```

* Same dataset but without NA values filled in missing cells. The “anova” command would output an error when models from the dataset with NA in the cells were passed in. The hypothesis testing for the information scores and test scores were separated into two different files to two different files to make the data easier to work with.

We then created the appropriate models for our statistical analysis.

````{r}
````

```
VocabEverUseBaselineModel <- lm(VocabBaseline~YMarEverUseBaseline, data =
BaselineMNDatasetMods)
```

The above model compares the baseline vocab scores of those who will and will not use marijuana.

```{r}
VocabEverUseFollowUpModel <- lm(VocabFollowUp~YMarEverUseFollowUp, data =
FollowupMNDatasetMods)
```

The above model compares the follow-up vocab scores of those who had or hadn't used marijuana (the same participants who said they would or wouldn't use marijuana).

```{r}
VocabEverUseAndDailyBaselineModel <-
lm(VocabBaseline~YMarEverUseBaseline+YMarDailyBaseline, data =
BaselineMNDatasetMods)
```

The above model compares the baseline vocab scores of those who will not use marijuana, those who will use marijuana but not daily, and those who will use it daily.

```{r}
VocabEverUseAndDailyFollowUpModel <-
lm(VocabFollowUp~YMarEverUseFollowUp+YMarDailyFollowUp, data =
FollowupMNDatasetMods)
```

The above model compares the follow-up vocab scores of those did not use marijuana, those who used it but not daily, and those who used marijuana daily.

```{r}
InfoEverUseBaselineModel <- lm(InfoBaseline~YMarEverUseBaseline, data = FollowupMNDatasetMods)
```

The above model compares the baseline info scores of those who will and will not use marijuana.

```{r}
InfoEverUseFollowUpModel <- lm(InfoFollowUp~YMarEverUseFollowUp, data = FollowupMNDatasetMods)
```

The above model compares the follow-up info scores of those who had and had not used marijuana.

```{r}
InfoEverUseAndDailyBaselineModel <- lm(InfoBaseline~YMarEverUseBaseline+YMarDailyBaseline, data = BaselineMNDatasetMods)
```

The above model compares the baseline info scores of those who will use marijuana daily, those who will use but not daily, and non-users.

```{r}
```

```
InfoEverUseAndDailyFollowUpModel <-
lm(InfoFollowUp~YMarEverUseFollowUp+YMarDailyFollowUp, data =
FollowupMNDatasetMods)
```

The above model compares the follow up info scores of those did use marijuana daily, those who used but not daily, and non users.

We used the "summary" command to get the coefficients and multiple r-squared from each model.

```{r}
summary(VocabGrandMeanBaselineModel)
```

```
##
 Call:
lm(formula = VocabBaseline ~ 1, data = BaselineMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-53.274  -5.267   0.734   6.735  54.742

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 100.0000     0.3146   317.8   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Residual standard error: 15 on 2272 degrees of freedom

(4 observations deleted due to missingness)

##

The above R code and output show the summary of our model of the grand mean of all participants' baseline vocab test scores.

```{r}
summary(VocabGrandMeanFollowUpModel)
```

```
##
Call:
lm(formula = VocabFollowUp ~ 1, data = BaselineMNDatasetMods)

Residuals:
   Min     1Q  Median     3Q    Max
-44.997  -7.486  -1.234  11.269  55.032

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 100.0000     0.3324   300.8   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 15 on 2035 degrees of freedom
  (241 observations deleted due to missingness)
##
```

The above R code and output show the summary of our model of the grand mean of all participants' follow-up vocab test scores.

```{r}
summary(VocabEverUseBaselineModel)
```

```
##
Call:
lm(formula = VocabBaseline ~ YMarEverUseBaseline, data = BaselineMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-53.962  -5.955   0.045   7.955  54.053

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)           100.6885     0.3929 256.294  < 2e-16 ***
YMarEverUseBaselineYes  -1.9085     0.6541  -2.918  0.00356 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 14.98 on 2271 degrees of freedom
  (4 observations deleted due to missingness)
Multiple R-squared:  0.003735,         Adjusted R-squared:  0.003296
F-statistic: 8.514 on 1 and 2271 DF,  p-value: 0.003559
##
```

The above R code and output show the summary of our first model comparing the baseline vocab scores of those who will and will not use marijuana.

```{r}
summary(VocabEverUseFollowUpModel)
```

```
##
Call:
lm(formula = VocabFollowUp ~ YMarEverUseFollowUp, data = FollowupMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-41.340  -9.509  -3.257   9.247  58.690

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)          102.0227     0.4075 250.359   <2e-16 ***
YMarEverUseFollowUpYes  -5.6802     0.6829  -8.318   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 14.75 on 2034 degrees of freedom
  (241 observations deleted due to missingness)
Multiple R-squared:  0.0329,  Adjusted R-squared:  0.03242
F-statistic: 69.19 on 1 and 2034 DF,  p-value: < 2.2e-16
##
```

The above R code and output show the summary of our first model comparing the follow-up vocab scores of those who did and did not use marijuana.

```{r}
summary(VocabEverUseAndDailyBaselineModel)
```

```
##
Call:
lm(formula = VocabBaseline ~ YMarEverUseBaseline + YMarDailyBaseline,
    data = BaselineMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-54.029  -6.022  -0.021   7.526  53.986

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)             100.7551     0.3991 252.458   <2e-16 ***
YMarEverUseBaselineYes  -1.5462     0.7290  -2.121    0.034 *
YMarDailyBaselineYes    -1.6777     1.2803  -1.310    0.190
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 15.02 on 2197 degrees of freedom
  (77 observations deleted due to missingness)
Multiple R-squared:  0.004543,          Adjusted R-squared:  0.003637
F-statistic: 5.013 on 2 and 2197 DF,  p-value: 0.006728
```

##

The above R code and output show the summary of our model comparing the baseline vocab scores of those who will not use marijuana, those who will use marijuana but not daily, and those who will use it daily.

```{r}
summary(VocabEverUseAndDailyFollowUpModel)
```

```
##
Call:
lm(formula = VocabFollowUp ~ YMarEverUseFollowUp + YMarDailyFollowUp,
    data = FollowupMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-40.735  -9.476  -3.224   9.280  57.992

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)
(Intercept)          101.9896     0.4079 250.063  < 2e-16 ***
YMarEverUseFollowUpYes  -4.9494     0.7456  -6.638 4.08e-11 ***
YMarDailyFollowUpYes    -2.8872     1.3097  -2.204   0.0276 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 14.75 on 2026 degrees of freedom
  (248 observations deleted due to missingness)
```

Multiple R-squared: 0.03435, Adjusted R-squared: 0.0334

F-statistic: 36.03 on 2 and 2026 DF, p-value: 4.191e-16

##

The above R code and output show the summary of our model comparing the follow-up vocab scores of those did not use marijuana, those who used it but not daily, and those who used marijuana daily.

```{r}
summary(InfoGrandMeanBaselineModel)
```

```
##
Call:
lm(formula = InfoBaseline ~ 1, data = BaselineMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-55.870 -12.662  -0.317  12.028  55.235

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 100.0000     0.3143   318.1   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 15 on 2276 degrees of freedom
##
```

The above R code and output show the summary of our model of the grand mean of all participants' baseline info test scores.

```{r}
summary(InfoEverUseBaselineModel)
```

```
##
Call:
lm(formula = InfoBaseline ~ YMarEverUseBaseline, data = FollowupMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-57.071 -10.535  -1.519  10.826  54.034

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)           101.2016     0.3911 258.770  < 2e-16 ***
YMarEverUseBaselineYes  -3.3284     0.6509  -5.114 3.43e-07 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 14.92 on 2275 degrees of freedom
Multiple R-squared:  0.01136,           Adjusted R-squared:  0.01093
F-statistic: 26.15 on 1 and 2275 DF,  p-value: 3.426e-07
##
```

The above R code and output show the summary of our model comparing the baseline info scores of those who will and will not use marijuana.

```{r}
summary(InfoGrandMeanFollowUpModel)
```

```
##
Call:
lm(formula = InfoFollowUp ~ 1, data = BaselineMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-46.682 -12.389  -0.959  10.472  50.480

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 100.0000     0.4239   235.9   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 15 on 1251 degrees of freedom
  (1025 observations deleted due to missingness)
##
```

The above R code and output show the summary of our model of the grand mean of all participants' follow-up info test scores.

```{r}
```

summary(InfoEverUseFollowUpModel)

```
##
Call:
lm(formula = InfoFollowUp ~ YMarEverUseFollowUp, data = FollowupMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-48.991  -8.983  -3.034   8.397  48.171

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)           102.3094     0.5320 192.327  < 2e-16 ***
YMarEverUseFollowUpYes  -5.9494     0.8538  -6.968 5.19e-12 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 14.72 on 1250 degrees of freedom
  (1025 observations deleted due to missingness)
Multiple R-squared:  0.03739,           Adjusted R-squared:  0.03662
F-statistic: 48.55 on 1 and 1250 DF,  p-value: 5.185e-12
##
```

The above R code and output show the summary of our model comparing the follow-up info scores of those who did and didn't use marijuana.

```{r}
summary(InfoEverUseFollowUpModel)
```

```
##
Call:
lm(formula = InfoFollowUp ~ YMarEverUseFollowUp, data = FollowupMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-48.991  -8.983  -3.034   8.397  48.171

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)             102.3094     0.5320 192.327  < 2e-16 ***
YMarEverUseFollowUpYes  -5.9494     0.8538  -6.968 5.19e-12 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 14.72 on 1250 degrees of freedom
  (1025 observations deleted due to missingness)
Multiple R-squared:  0.03739,           Adjusted R-squared:  0.03662
F-statistic: 48.55 on 1 and 1250 DF,  p-value: 5.185e-12
##
```

The above R code and output show the summary of our model of the grand mean of all participants' follow-up info test scores.

```{r}
summary(InfoEverUseAndDailyBaselineModel)
```

```
##
Call:
lm(formula = InfoBaseline ~ YMarEverUseBaseline + YMarDailyBaseline,
    data = BaselineMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-57.128 -10.334  -1.576  10.769  53.977

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)             101.2586     0.3965 255.373  < 2e-16 ***
YMarEverUseBaselineYes  -3.0884     0.7238  -4.267 2.07e-05 ***
YMarDailyBaselineYes    -0.4986     1.2725  -0.392    0.695
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 14.93 on 2201 degrees of freedom
  (73 observations deleted due to missingness)
Multiple R-squared:  0.01052,           Adjusted R-squared:  0.009621
F-statistic:  11.7 on 2 and 2201 DF,  p-value: 8.82e-06
##
```

The above R code and output show the summary of our model comparing the baseline info scores of those who will use marijuana daily, those who will use but not daily, and non-users.

```{r}
summary(InfoEverUseAndDailyFollowUpModel)
```

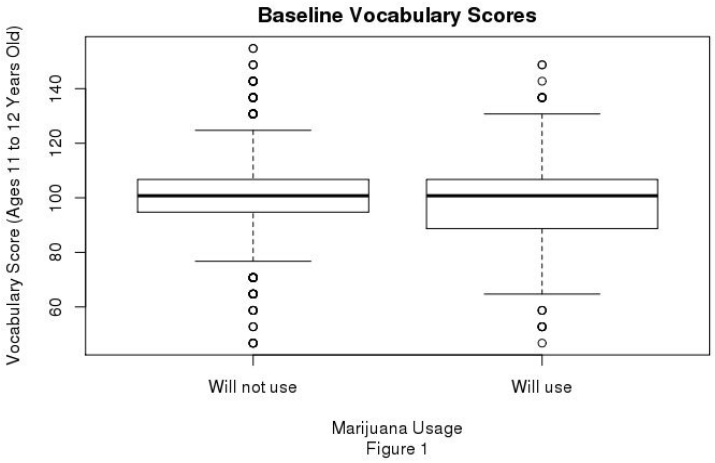
```
##
Call:
lm(formula = InfoFollowUp ~ YMarEverUseFollowUp + YMarDailyFollowUp,
    data = FollowupMNDatasetMods)

Residuals:
    Min      1Q  Median      3Q     Max
-48.941  -9.075  -2.137   8.213  48.221

Coefficients:
                          Estimate Std. Error t value Pr(>|t|)
(Intercept)              102.2591     0.5328 191.938  < 2e-16 ***
YMarEverUseFollowUpYes  -5.5738     0.9269  -6.014 2.38e-09 ***
YMarDailyFollowUpYes    -1.2227     1.6114  -0.759    0.448
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 14.71 on 1242 degrees of freedom
  (1032 observations deleted due to missingness)
Multiple R-squared:  0.03666,           Adjusted R-squared:  0.03511
F-statistic: 23.63 on 2 and 1242 DF,  p-value: 8.452e-11
##
```

The above R code and output show the summary of our model comparing the follow up info scores of those did use marijuana daily, those who used it but not daily, and non users.

We made a separate boxplot for each linear model.

```{r}
boxplot(VocabBaseline~YMarEverUseBaseline, data =BaselineMNDataset, xlab = "Marijuana Usage", names= c("Will not use", "Will use"), ylab = "Vocabulary Score (Ages 11 to 12 Years Old)", main = "Baseline Vocabulary Scores", sub = "Figure 1")
```

##



##

The following R code creates a boxplot comparing baseline vocab scores with whether participants will or will not use marijuana.

```{r}
boxplot(VocabFollowUp~YMarEverUseFollowUp, data =FollowupMNDataset, xlab = "Marijuana Usage",names= c("Nonuser", "User"), ylab = "Vocabulary Score (Ages 17 to 19 Years Old)", main = "Follow Up Vocabulary Scores", sub="Figure 2" )
```

##

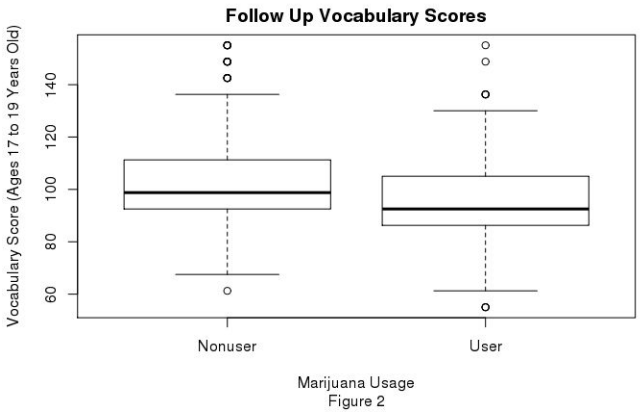


Figure 2

##

The above R code creates a boxplot comparing follow-up vocab scores with whether participants did or didn't use marijuana.

```{r}
boxplot(VocabBaseline~YMarEverUseBaseline+YMarDailyBaseline, data =BaselineMNDataset, xlab = "Marijuana Usage", names= c("Will not use", "Will not use daily", " ", "Will use daily"), ylab = "Vocabulary Score (Ages 11 to 12 Years Old)", main = "Baseline Vocabulary Scores", sub = "Figure 3")
```

##

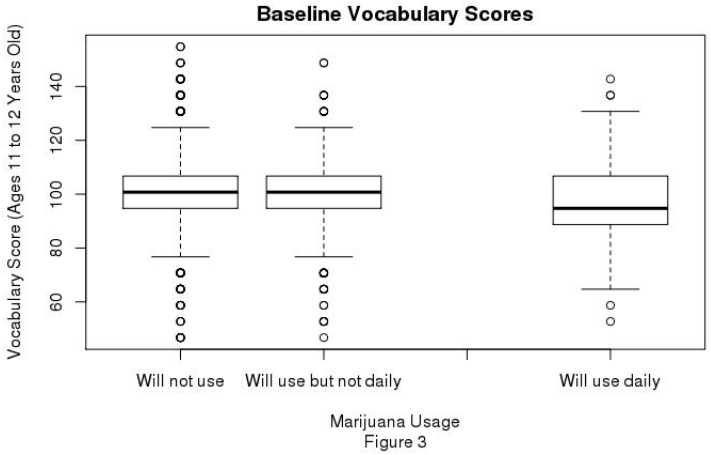


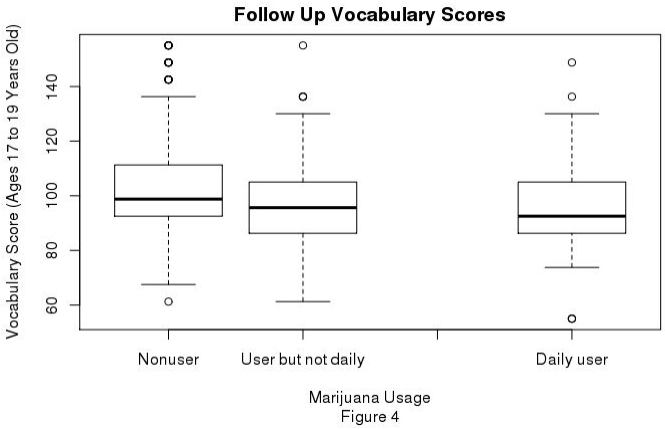
Figure 3

##

The above R code creates a boxplot comparing baseline vocab scores with whether participants will or will not use marijuana and with whether participants do or don't use marijuana daily.

```{r}
boxplot(VocabFollowUp~YMarEverUseFollowUp+YMarDailyFollowUp, data = FollowupMNDataset, xlab = "Marijuana Usage", names= c("Nonuser", "Nondaily user", " ", "Daily user" ), ylab = "Vocabulary Score (Ages 17 to 19 Years Old)", main = "Follow Up Vocabulary Scores", sub = "Figure 4")
```

##



##

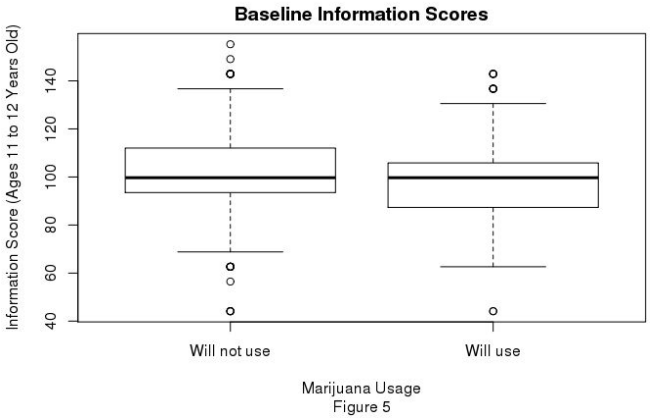
The above R code creates a boxplot comparing follow-up vocab scores with whether participants did or did not use marijuana in the past and with whether participants do or don't use marijuana daily.

```{r}
```

boxplot(InfoBaseline~YMarEverUseBaseline, data =BaselineMNDataset, xlab = "Marijuana Usage", names= c("Will not use", "Will use"), ylab = "Information Score (Ages 11 to 12 Years Old)", main = "Baseline Information Scores", sub = "Figure 5")

```

##




##

The above R code creates a boxplot comparing baseline info scores with whether participants will or will not use marijuana.

```{r}
boxplot(InfoFollowUp~YMarEverUseFollowUp, data =FollowupMNDataset, xlab = "Marijuana Usage", ylab = "Information Score (Ages 17 to 19 Years Old)", names= c("Nonuser", "User"), main = "Follow Up Information Scores", sub = "Figure 6")
```

##
```

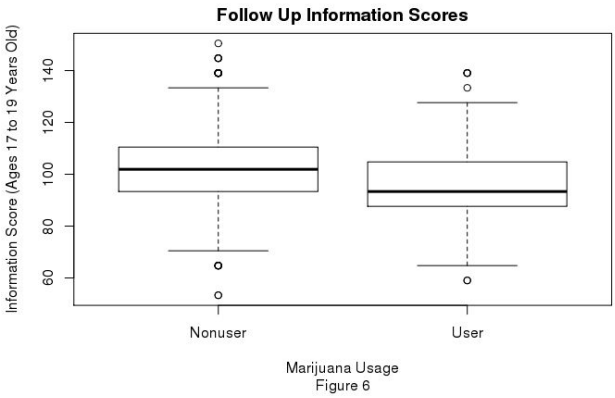


Figure 6

##

The above R code creates a boxplot comparing follow-up info scores with whether participants did or did not use marijuana.

```{r}
boxplot(InfoBaseline~YMarEverUseBaseline+YMarDailyBaseline, data =BaselineMNDataset, xlab = "Marijuana Usage", names= c("Will not use", "Will not use daily", " ", "Will use daily" ), ylab = "Baseline Score (Ages 11 to 12 Years Old)", main = "Baseline Information Scores", sub = "Figure 7")
```

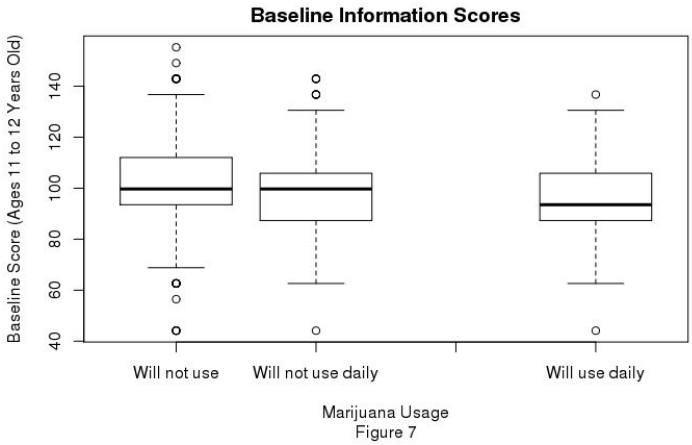


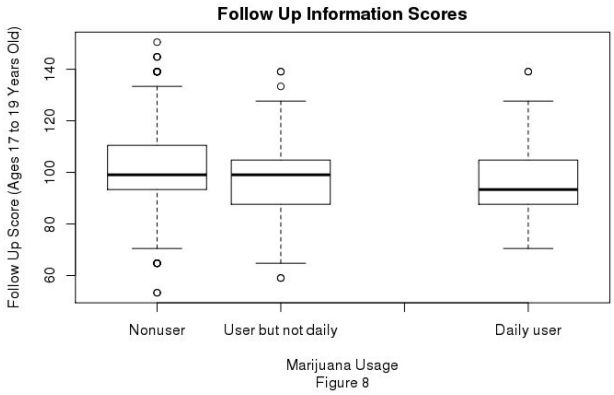
Figure 7

##

The above R code creates a boxplot comparing baseline info scores with whether participants will or will not use marijuana and with whether participants do or don't use marijuana daily.

```{r}
boxplot(InfoFollowUp~YMarEverUseFollowUp+YMarDailyFollowUp, data = FollowupMNDataset, xlab = "Marijuana Usage", names= c("Nonuser", "Nondaily user", " ", "Daily user" ), ylab = "Follow Up Score (Ages 17 to 19 Years Old)", main = "Follow Up Information Scores", sub = "Figure 8")
```

##



##

The above R code creates a boxplot comparing follow-up info scores with whether participants did or did not use marijuana and with whether participants do or don't use marijuana daily.

```{r}
VocabGrandMeanFollowUpModelHT <- lm(VocabFollowUp~1, data=VocabDataForHypothesisTest)
```

```
VocabEverUseFollowUpModelHT <- lm(VocabFollowUp~YMarEverUseFollowUp,
data=VocabDataForHypothesisTest)

VocabEverUseAndDailyUseFollowUpModelHT <-
lm(VocabFollowUp~YMarEverUseFollowUp+YMarDailyFollowUp, data =
VocabDataForHypothesisTest)

InfoGrandMeanFollowUpModelHT <- lm(InfoFollowUp~1, data=InfoDataForHypothesisTest)

InfoEverUseFollowUpModelHT <- lm(InfoFollowUp~YMarEverUseFollowUp,
data=InfoDataForHypothesisTest)

InfoEverUseAndDailyUseFollowUpModelHT <-
lm(InfoFollowUp~YMarEverUseFollowUp+YMarDailyFollowUp, data
=InfoDataForHypothesisTest)
```

Above are the models we generated through hypothesis testing.

We used the command “anova” for hypothesis testing.

```{r}
anova(VocabEverUseFollowUpModel,VocabGrandMeanFollowUpModel, data =
VocabDataForHypothesisTest)
```

##
models with response ‘"NULL"’ removed because response differs from model 1Analysis of Variance Table

Model 1: VocabFollowUp ~ YMarEverUseFollowUp

Model 2: VocabFollowUp ~ 1

  Res.Df   RSS Df Sum of Sq   F   Pr(>F)

1   2034 442813

2   2035 457875 -1   -15062 69.187 < 2.2e-16 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

##

The above R code shows the analysis of variables for the model comparing the follow up vocab scores of those who had or hadn’t used marijuana (the same participants who said they would or wouldn’t use marijuana) and the model showing the grand mean of follow-up vocab scores. Because the p-value was smaller than the significance level of .05, we reject the null hypothesis.

```{r}

anova(VocabEverUseAndDailyUseFollowUpModel, VocabEverUseFollowUpModel, data = VocabDataForHypothesisTest)

```

##

models with response ‘"NULL"’ removed because response differs from model 1Analysis of Variance Table

Model 1: VocabFollowUp ~ YMarEverUseFollowUp + YMarDailyFollowUp

Model 2: VocabFollowUp ~ YMarEverUseFollowUp

  Res.Df   RSS Df Sum of Sq   F Pr(>F)

1   2032 441779

2   2034 442813 -2   -1033.7 2.3772 0.09307 .

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

##

The above R code shows the analysis of variables for the model comparing the follow up vocab scores with whether participants did or didn’t use marijuana and with whether they currently use it daily or not and for the model comparing follow-up vocab scores with whether participants had ever used marijuana or not. Because the p-value was greater than .05, we do not reject the null hypothesis.

##

```{r}
anova(InfoEverUseFollowUpModelHT,InfoGrandMeanFollowUpModelHT, data = InfoDataForHypothesisTest)
```

##

models with response ‘"NULL"’ removed because response differs from model 1Analysis of Variance Table

Model 1: InfoFollowUp ~ YMarEverUseFollowUp

Model 2: InfoFollowUp ~ 1

  Res.Df   RSS Df Sum of Sq   F   Pr(>F)

1   1250 270951

2   1251 281475 -1   -10525 48.554 5.185e-12 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

##

The above R code shows the analysis of variables for the model comparing follow-up info scores with whether participants have ever used marijuana or not and for the model showing the grand mean of follow-up info scores. Because the p-value of 0.09307 is bigger than 0.05, we fail to reject the null hypothesis.

```{r}
anova(InfoEverUseAndDailyUseFollowUpModelHT, InfoEverUseFollowUpModelHT)
```

##
models with response ‘"NULL"’ removed because response differs from model 1Analysis of Variance Table

Model 1: InfoFollowUp ~ YMarEverUseFollowUp + YMarDailyFollowUp
Model 2: InfoFollowUp ~ YMarEverUseFollowUp
  Res.Df   RSS Df Sum of Sq   F Pr(>F)
1   1248 270821
2   1250 270951 -2   -129.07 0.2974 0.7428
##
The above R code shows the analysis of variables for the model comparing follow-up info scores with whether participants have ever used marijuana or not and with whether they currently use it daily and for the model comparing follow-up info scores with whether participants have ever used marijuana.Because the p-value of 5.185e-12 is less than 0.05, we reject the null hypothesis.

Works Cited

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