STA303: M1 tutorial activity

Recap and ANOVA

Instructions

To participate in this activity you will need have to two windows readily available to you:

1) Your Zoom window

2) The Team Up! activity linked from Quercus in a browser window for voting.

I would recommend that one member of the team shares their screen with the rest of the team and shows this activity where you can see the question and options.

Note 1: In the Team Up! activity you will just see the letters for the questions, not the options themselves.

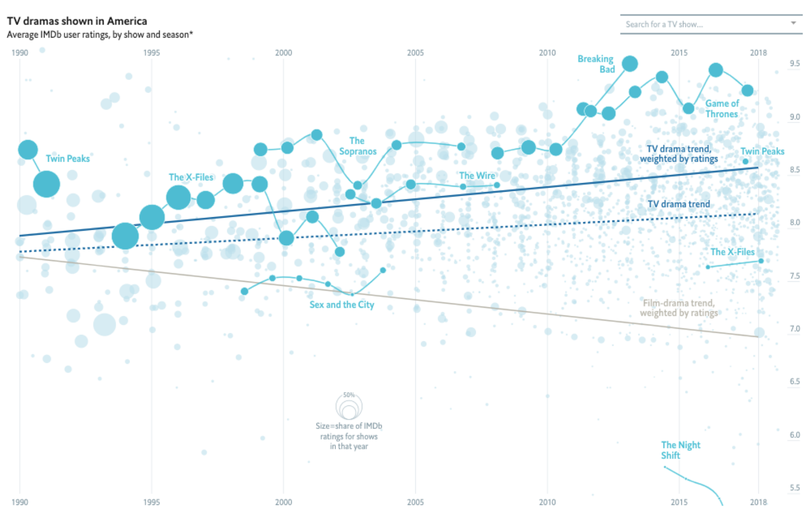
Note 2: There are hints for some questions, but if you get really stuck, please use the 'Ask for Help' option in Zoom.

Question 1 to 6 refer to the TV show data discussed in the next tab. Question 7, 8 and 9 are self-contained.

The data

Golden age of TV?

Let's look at some data from a 2018 article in the Economist. This is the direct link to the CSV (but you shouldn't need it).



```r
# Libraries
library(tidyverse)
library(modelr)
library(lubridate) # to make it easy to work with dates

url <- "https://raw.githubusercontent.com/TheEconomist/graphic-detail-data/master/data/2018-11-24_tv-ra

tv_data <- read_csv(url)
```

```r
head(tv_data, n = 10)
```

```
## # A tibble: 10 x 7
##    titleId   seasonNumber title          date       av_rating share genres
##    <chr>            <dbl> <chr>          <date>         <dbl> <dbl> <chr>
##  1 tt2879552            1 11.22.63       2016-03-10      8.49  0.51 Drama,Myste~
##  2 tt3148266            1 12 Monkeys     2015-02-27      8.34  0.46 Adventure,D~
##  3 tt3148266            2 12 Monkeys     2016-05-30      8.82  0.25 Adventure,D~
##  4 tt3148266            3 12 Monkeys     2017-05-19      9.04  0.19 Adventure,D~
##  5 tt3148266            4 12 Monkeys     2018-06-26      9.14  0.38 Adventure,D~
##  6 tt1837492            1 13 Reasons Why 2017-03-31      8.44  2.38 Drama,Myste~
##  7 tt1837492            2 13 Reasons Why 2018-05-18      7.51  2.19 Drama,Myste~
##  8 tt0285331            1 24             2002-02-16      8.56  6.67 Action,Crim~
##  9 tt0285331            2 24             2003-02-09      8.70  7.13 Action,Crim~
## 10 tt0285331            3 24             2004-02-09      8.72  5.88 Action,Crim~
```

```r
glimpse(tv_data)
```

```
## Rows: 2,266
## Columns: 7
## $ titleId      <chr> "tt2879552", "tt3148266", "tt3148266", "tt3148266", "tt31~
## $ seasonNumber <dbl> 1, 1, 2, 3, 4, 1, 2, 1, 2, 3, 4, 5, 6, 7, 8, 1, 1, 1, 1, ~
## $ title        <chr> "11.22.63", "12 Monkeys", "12 Monkeys", "12 Monkeys", "12~
## $ date         <date> 2016-03-10, 2015-02-27, 2016-05-30, 2017-05-19, 2018-06-~
## $ av_rating    <dbl> 8.4890, 8.3407, 8.8196, 9.0369, 9.1363, 8.4370, 7.5089, 8~
## $ share        <dbl> 0.51, 0.46, 0.25, 0.19, 0.38, 2.38, 2.19, 6.67, 7.13, 5.8~
## $ genres       <chr> "Drama,Mystery,Sci-Fi", "Adventure,Drama,Mystery", "Adven~
```

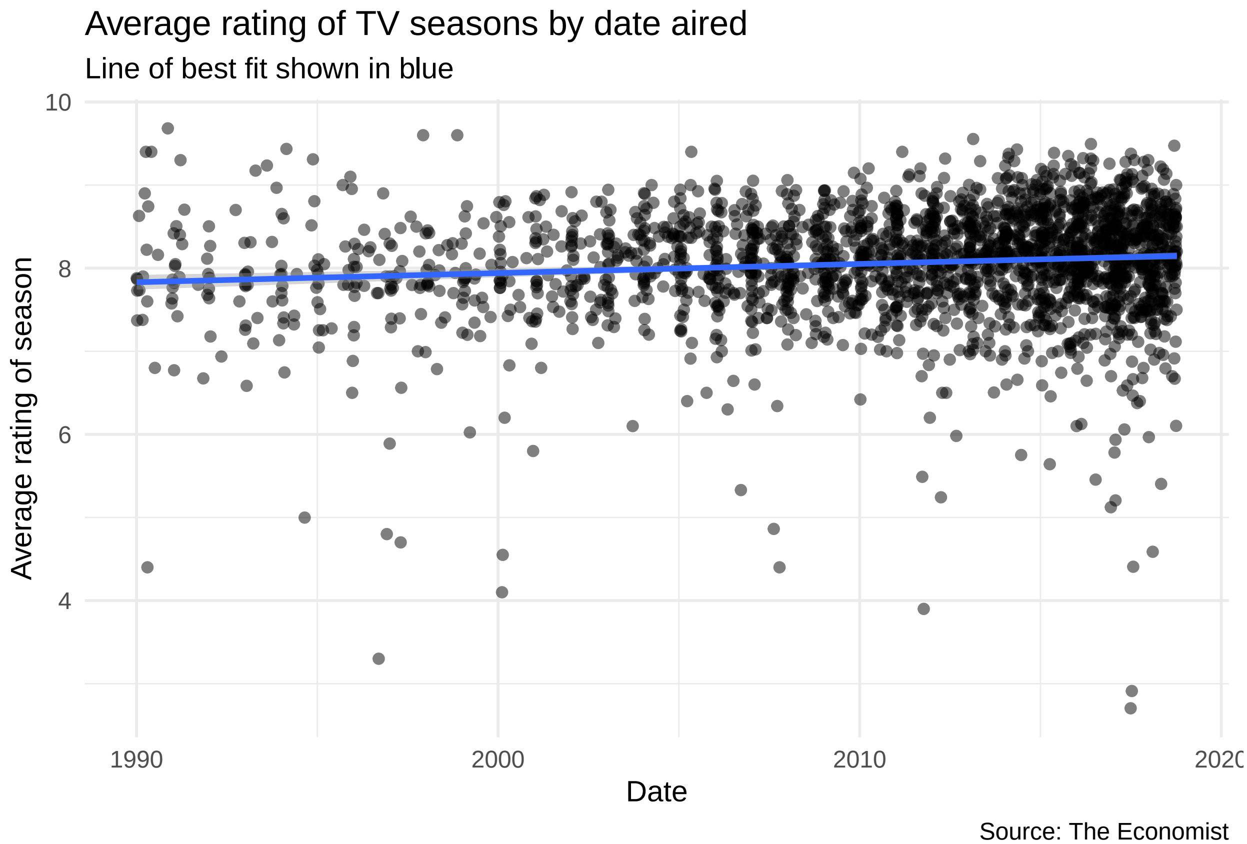
Each row (i.e., observation) is a season of TV show.

Suppose we are interested in investigating the association between when an season was released (`decade`, the decade that the TV show was released, or `date`, the actual date) and `av_rating` (average rating per season).

Question 1

Assumptions

Carefully consider the `head` and `glimpse` of the data provided in the data section and the plot below.



Suppose you wish to use fit a model to predict average season rating (`av_rating`) from `date` alone. Using just the information you have so far, which ONE of the following comments is most appropriate?

A. Linear regression seems appropriate.
B. Linear regression does not seem appropriate due to the equality of variance assumption being violated.
C. Linear regression does not seem appropriate due to the linearity assumption being violated.
D. Linear regression does not seem appropriate due to the independence assumption being violated.

Note: In the following questions we will assume we can proceed with linear regression. This may or may not be *correct*. I.e., it is not a hint to the answer to this question.

Question 2

t-test

Suppose you talk to a TV critic and they suggest that in industry there is a common belief that the average 'average' rating for TV shows in the 2010s was 8.1. (Note the careful language, we are working with data aggregated at the season level.)

Restrict the data to just the seasons from 2010. (If you don't know how to do this, there is a hint). Run a one sample t-test (with `var.equal = TRUE` to test the claim from the TV critic.

(There are two hints in the interative version.)

Which of the following is the best conclusion based on the result of your t-test?

A. We have no evidence against the claim that the average, average rating is 8.1.
B. We have some evidence against the claim that that the average, average rating is 8.1.
C. We have very strong evidence against the claim that the average, average rating is 8.1.
D. The `t.test` function produces an error due to a violation of Normality assumption.

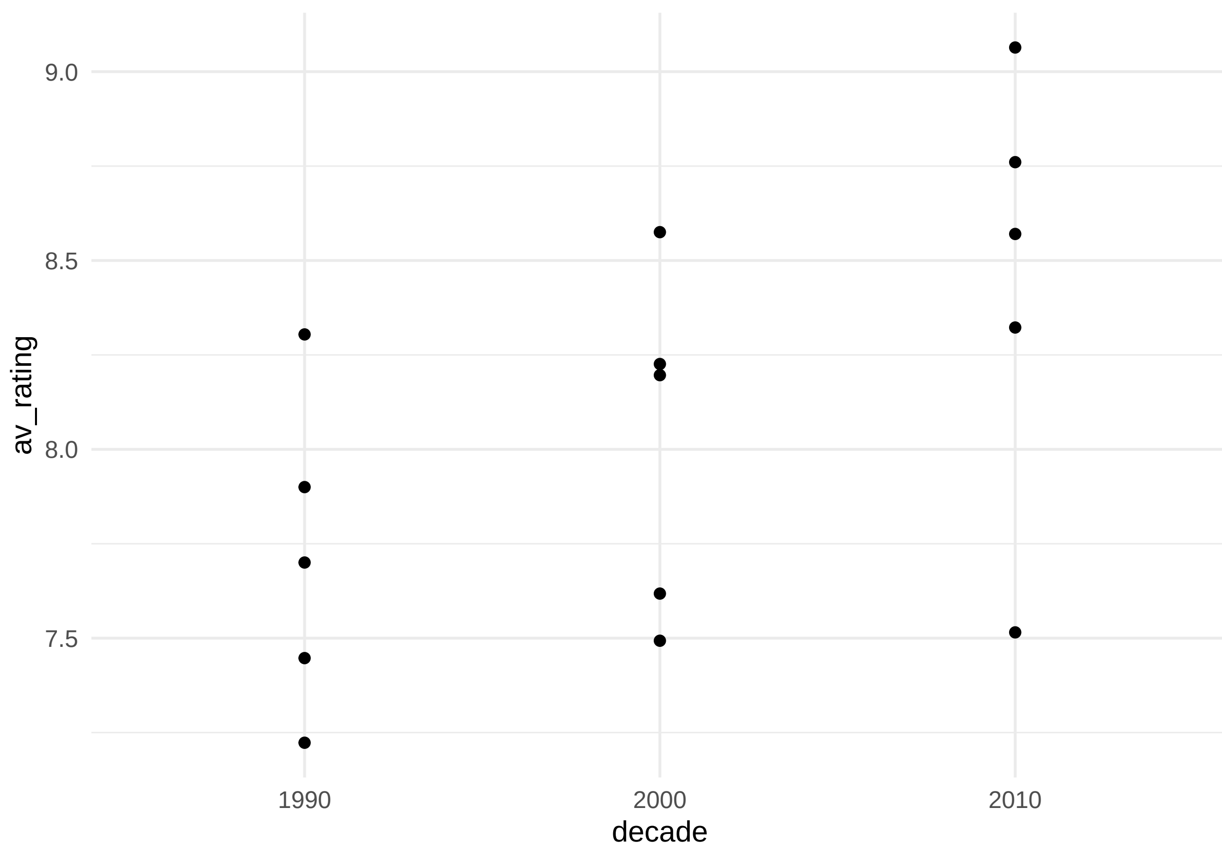
If you get an error saying your data is missing, add the following code to the beginning of the code chunk to call it again.

```
url <- "https://raw.githubusercontent.com/TheEconomist/graphic-detail-data/master/data/2018-11-24_tv-ra

tv_data <- read_csv(url)

tv_data_edit <- tv_data %>%
  mutate(decade = lubridate::floor_date(ymd(date), years(10))) %>%
  mutate(decade = as.character(format(decade,"%Y"))) %>%
  mutate(scifi = ifelse(grepl("Sci-Fi", genres), "scifi", "no")) %>%
  group_by(decade) %>%
  mutate(mean = mean(av_rating))
```

Question 3

Toy data

Let's take a moment to do something very simple. I have pulled five observations from each decade to plot.



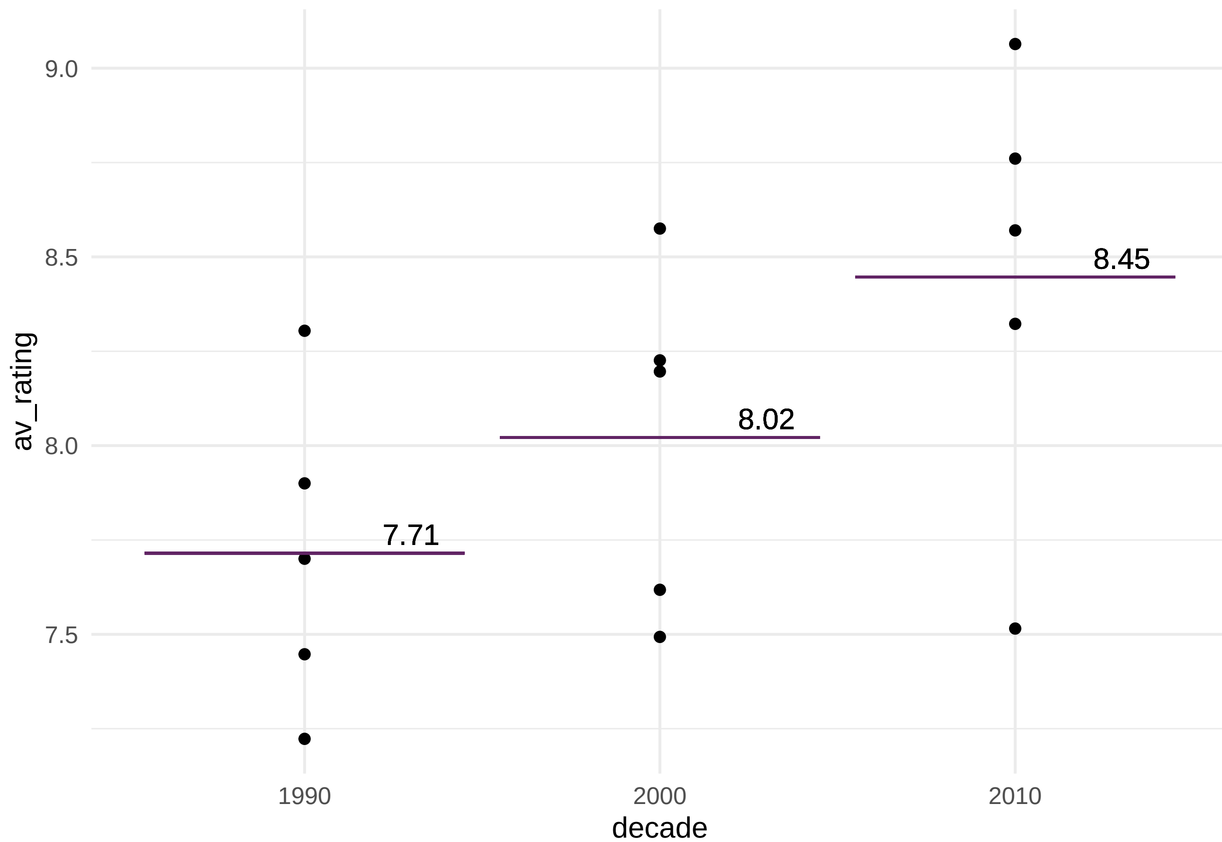
How do we make sense of this with linear regression?

Let's start by fitting a line to each group separately. (Aside: if you interpreted each of these as a one sample t-test, you'd be testing $H_0 : \mu$

```
sep_mod <- c(
  lm(av_rating~1, filter(simple, decade == 1990))$coef,
  lm(av_rating~1, filter(simple, decade == 2000))$coef,
  lm(av_rating~1, filter(simple, decade == 2010))$coef
  )

names(sep_mod) <- c("xbar1990", "xbar2000", "xbar2010")

sep_mod
```

```
## xbar1990 xbar2000 xbar2010
##  7.71498  8.02172  8.44652
```

Hopefully you agree that the intercept of each of these 'intercept only' models are the means of each group.



Now suppose I claim that we can describe all 15 points with this equation:

$$y_i = d_1\bar{x}_{1990} + d_2\bar{x}_{2000} + d_3\bar{x}_{2010} + \epsilon_i$$

Where $\epsilon_i \sim \mathrm{N}(0, \sigma)$.

Which ONE of the following would have to be true for this to be true?

A. d_1 **would be a column of FIFTEEN 1s and then** d_2 **and** d_3 **would be columns of 0s and 1s, and take the value 1 when the observation is from 2000 and 2010 respectively.**
B. There are infinite possible combinations of three d **vectors for which this would be true, so as long as it is any one of those, this will be true.**
C. Each d **would have to be a vector of FIVE 0s and 1s, and take the value 1 when the observation is the decade indicated by the** μ_{year} **it is multiplied by.**
D. Each d **would have to be a vector of FIFTEEN 0s and 1s, and take the value 1 when the observation is that decade.**

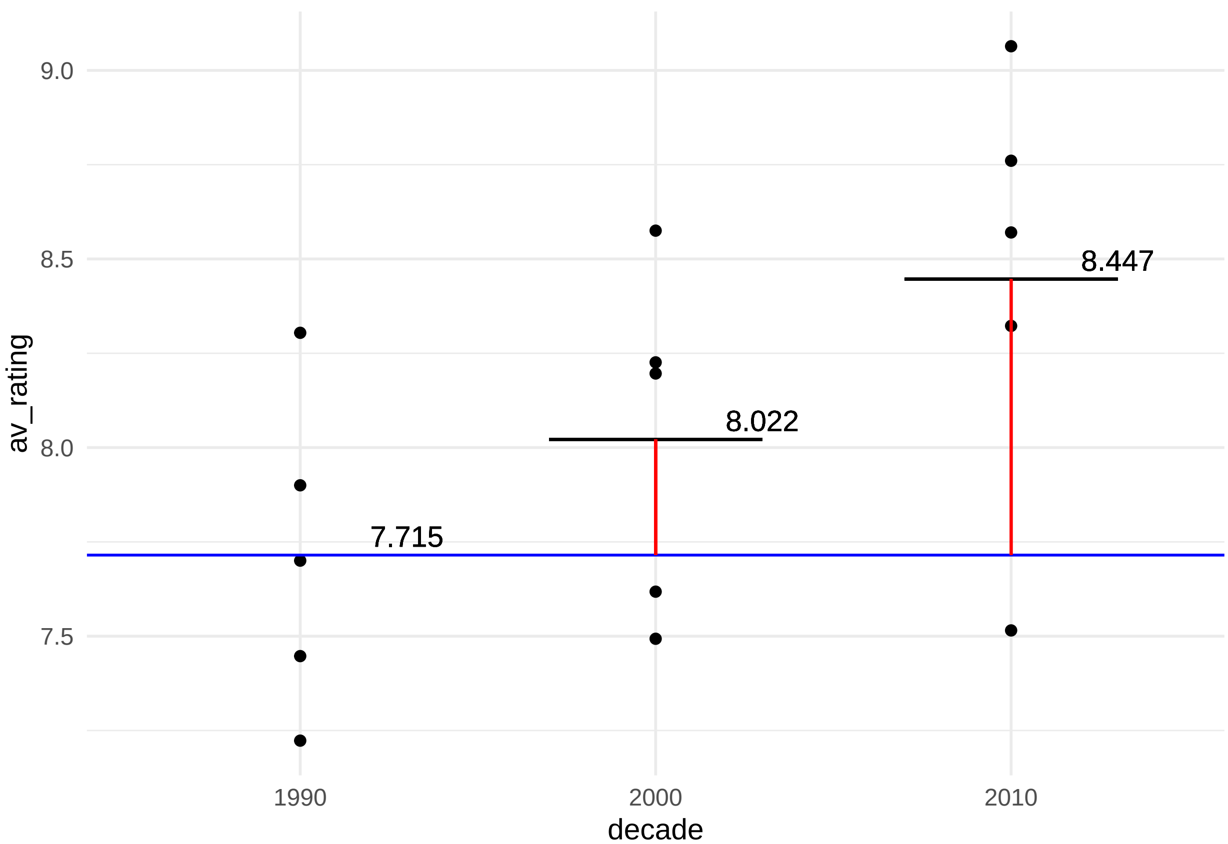
Question 4

Equations

Which ONE of these equations is equivalent to $y_i = d_1\bar{x}_{1990} + d_2\bar{x}_{2000} + d_3\bar{x}_{2010} + \epsilon_i$?

A. $y_i = \bar{x}_{1990} + d_2(\bar{x}_{2000} - \bar{x}_{1990}) + d_3(\ \bar{x}_{2010} - \bar{x}_{1990}) + \epsilon_i$
B. $y_i = \bar{x}_{1990} + d_2(\bar{x}_{2000} - \bar{x}_{1990} - \bar{x}_{2010}) + d_3(\bar{x}_{2010} - \bar{x}_{1990} - \bar{x}_{2000}) + \epsilon_i$
C. $y_i = (\bar{x}_{1990} + \bar{x}_{2000} + \bar{x}_{2010}) * (-d_1 - d_2 - d_3)$
D. $y_i = d_1(\bar{x}_{1990} - \bar{x}_{2010}) + d_2(\bar{x}_{2000} - \bar{x}_{1990}) + d_3(\bar{x}_{2010} - \bar{x}_{1990}) + \epsilon_i$

You may (or may not) find this visualization helpful to your thinking.



Question 5

ANOVA assumption rule of thumb

Note: there are specific tests for equality of variances, but for the purposes of this course we will just consider a rule of thumb from Dean and Voss (*Design and Analysis of Experiments*, 1999, page 112): if the ratio of the largest within-in group variance estimate to the smallest within-group variance estimate does not exceed 3, $s^2_{max}/s^2_{min} < 3$, the assumption is probably satisfied.

The below code produces a summary of the `tv_data_edit` tibble. You can ignore the '.groups = "keep"' part. Even if you are unfamiliar with the over syntax, you should be able to figure out what a, b, c, d and e are from your previous knowledge of R.

```
tv_data_edit %>%
  group_by(decade) %>%
  summarise(a = mean(av_rating), b = var(av_rating), c = sd(av_rating),
            d = var(av_rating)^2, e = max(av_rating), .groups = "keep")
```

```
## # A tibble: 3 x 6
## # Groups:   decade [3]
##   decade     a     b     c     d     e
##   <chr>  <dbl> <dbl> <dbl> <dbl> <dbl>
## 1 1990    7.83 0.686 0.829 0.471  9.68
## 2 2000    8.02 0.361 0.600 0.130  9.4
## 3 2010    8.11 0.444 0.666 0.197  9.55
```

Which of the following is true based on this table?

A. The equality of variances assumption appears to be satisfied, therefore ANOVA is definitely appropriate.
B. The equality of variances assumption appears to be satisfied, but we can't proceed with ANOVA without checking the other assumptions.
C. The equality of variances assumption appears to be seriously violated, therefore ANOVA is not appropriate.
D. Not enough information to make a claim about the equality of variances assumption.

Question 6

One-way ANOVA as regression

```
summary(lm(av_rating ~ decade, data = tv_data_edit))
```

```
##
## Call:
## lm(formula = av_rating ~ decade, data = tv_data_edit)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.4043 -0.3159  0.0541  0.4194  1.8491
##
## Coefficients:
```

```
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  7.83327    0.04634 169.055  < 2e-16 ***
## decade2000   0.18845    0.05384   3.500 0.000474 ***
## decade2010   0.27497    0.04949   5.555 3.09e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6667 on 2263 degrees of freedom
## Multiple R-squared:  0.01462,    Adjusted R-squared:  0.01375
## F-statistic: 16.79 on 2 and 2263 DF,  p-value: 5.788e-08
```

```
summary(aov(av_rating ~ decade, data = tv_data_edit))
```

```
##               Df Sum Sq Mean Sq F value   Pr(>F)
## decade         2   14.9   7.461   16.79 5.79e-08 ***
## Residuals   2263 1005.7   0.444
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Assume the assumptions for ANOVA are valid (this may not be true). Which ONE of the following is the best conclusion?

A. We have very strong evidence (p-value < 2e-16) against the hypothesis that the mean season average ratings are the same in each decade.
B. We have very strong evidence (p-value = 5.788e-08) against the hypothesis that the mean season average ratings are the same in each decade.
C. We have very very strong evidence (p-value = 5.788e-08) that at least one of the mean season average ratings is different from the others.
D. We have very strong evidence (p-value < 2e-16) that at least one of the mean season average ratings is different from the others.

Question 7

Linearity

Which ONE of these models is NOT linear?

A. $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_3^2$
B. $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 X_3$
C. $Y = \beta_0 + \beta_1 X_1 + X_3^{\beta_2}$
D. $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 cos(X_3)$

Question 8

LaTeX

LaTeX is a document preparation system that allows us to type set mathematical symbols well. In R Markdown, which we will use for assessments in this course (more on that next week for those who are unfamiliar), we can use LaTeX syntax to write equations and mathematical symbols. Single dollar sign pairs $ create inline expressions and double dollar sign pairs ($$) will show the express in display mode.

Inline: π^2

Display:

$$\pi^2$$

- Greek letters can be displayed with a back slash before their name, e.g., `$\eta$` -> η.
- Superscripts: `$a^b$` -> a^b, or `$a^{2b}$` -> a^{2b}.
- Subscripts: `$a_b$` -> a_b, or `$a_{2b}$` -> a_{2b}.

Note: `$a_bi$` -> a_bi

Which of the following lines of LaTeX would create the equation below (if correctly put in dollar signs $)?

$$y_i = \beta_0 + \beta_1 x_{1i} + \epsilon_i$$

A. `yi = \beta0 + \beta1x{1i} + \epsilon i`
B. `y_i = \beta_0 + \beta_1x_1i + \epsilon_i`
C. `y_i = \b_0 + \b_0\ex_1i + \error_i`
D. `y_i = \beta_0 + \beta_1x_{1i} + \epsilon_i`

Question 9

Test choices

CSC108 has 5 sections this semester (L0101, L0201, L0301, L5101, L5102). Suppose the course coordinator hires you to help them do some statistical analysis on their course. They are interested in knowing whether or not all the sections have the same mean score on the first test. The dataset they give you has three columns: student_id, section, score.

Which of the following analyses could you conduct to answer this question? Tick all that apply.

Test 1: One-way anova

Test 2: Linear regression with `score` as the response and 4 dummy variables indicating sections: L0201, L0301, L5101, L5102.

Test 3: Linear regression with formula `score ~ section`

Test 4: Independent t-test

Test 5: Wilcoxon signed-rank test

A. Tests 1, 2 & 3
B. Tests 2 & 3
C. Tests 4 & 5
D. Tests 1, 3 & 5