Applied Linear Modeling

September 3, 2019

To-do

- With your table:
  - *pick a to-do number*
  - *compare your exercise results with the others at the table*
  - *agree on a set of results and work together to write them on the board*
  - *when finished, put all your names on the to-do number and drop in Done jar*
- Create a week-2 folder on your laptop and put the following files in it (from GitHub):
  - *week-2-workshop.Rmd*
  - *nhanes_2011_2012_ch3.csv*
- Install the following R packages:
  - *tableone*

All the things for today

- Discussion of exercises
- Workshop
  - *Bivariate review flow chart activity*
  - *Data management: selecting cases and variables, adding labels*
  - *Descriptive statistics review & conducting in R*
  - *Null hypothesis significance testing (NHST)*
  - *Chi-squared review & R code*
  - *One-sample t-test review & R code*
  - *One-way ANOVA review & R code*

Import and review the data for today

- Note that the file extension should be **.csv** for this code to work
- The data are from the 2011-2012 National Health and Nutrition Examination Survey (NHANES)

```r
# import the data using read.csv
nhanes.2012 <- read.csv(file = "nhanes_2011_2012_ch3.csv")

# examine the data set
head(x = nhanes.2012)
```

```
##    SEQN     cycle SDDSRVYR RIDSTATR RIAGENDR RIDAGEYR RIDAGEMN RIDRETH1
## 1 62161 2011-2012        7        2        1       22       NA        3
## 2 62162 2011-2012        7        2        2        3       NA        1
## 3 62163 2011-2012        7        2        1       14       NA        5
## 4 62164 2011-2012        7        2        2       44       NA        3
## 5 62165 2011-2012        7        2        2       14       NA        4
## 6 62166 2011-2012        7        2        1        9       NA        3
##   RIDRETH3 RIDEXMON RIDEXAGY RIDEXAGM DMQMILIZ DMQADFC DMDBORN4 DMDCITZN
## 1        3        2       NA       NA        2      NA        1        1
## 2        1        1        3       41       NA      NA        1        1
## 3        6        2       14      177       NA      NA        1        1
## 4        3        1       NA       NA        1       2        1        1
## 5        4        2       14      179       NA      NA        1        1
## 6        3        2       10      120       NA      NA        1        1
##   DMDYRSUS DMDEDUC3 DMDEDUC2 DMDMARTL RIDEXPRG SIALANG SIAPROXY SIAINTRP
## 1       NA       NA        3        5       NA       1        1        2
## 2       NA       NA       NA       NA       NA       1        1        2
## 3       NA        8       NA       NA       NA       1        1        2
## 4       NA       NA        4        1        2       1        2        2
## 5       NA        7       NA       NA       NA       1        1        2
## 6       NA        3       NA       NA       NA       1        1        2
##   FIALANG FIAPROXY FIAINTRP MIALANG MIAPROXY MIAINTRP AIALANGA   WTINT2YR
## 1       1        2        2       1        2        2        1 102641.406
## 2       1        2        2      NA       NA       NA       NA  15457.737
## 3       1        2        2       1        2        2        1   7397.685
## 4       1        2        2      NA       NA       NA       NA 127351.373
## 5       1        2        2       1        2        2        1  12209.745
```

```
## 6        1        2        2        1        2        2       NA  60593.637
##     WTMEC2YR SDMVPSU SDMVSTRA INDHHIN2 INDFMIN2 INDFMPIR DMDHHSIZ DMDFMSIZ
## 1 104236.583       1       91       14       14     3.15        5        5
## 2  16116.354       3       92        4        4     0.60        6        6
## 3   7869.485       3       90       15       15     4.07        5        5
## 4 127965.226       1       94        8        8     1.67        5        5
## 5  13384.042       2       90        4        4     0.57        5        5
## 6  64068.123       1       91       77       77       NA        6        6
##   DMDHHSZA DMDHHSZB DMDHHSZE DMDHRGND DMDHRAGE DMDHRBR4 DMDHREDU DMDHRMAR
## 1        0        1        0        2       50        1        5        1
## 2        2        2        0        2       24        1        3        6
## 3        0        2        1        1       42        1        5        1
## 4        1        2        0        1       52        1        4        1
## 5        1        2        0        2       33        2        2       77
## 6        0        4        0        1       44        1        5        1
##   DMDHSEDU AUQ054 AUQ060 AUQ070 AUQ080 AUQ090 AUQ100 AUQ110 AUQ136 AUQ138
## 1        5      2      1     NA     NA     NA      5      5      1      1
## 2       NA      1     NA     NA     NA     NA     NA     NA     NA     NA
## 3        4      2     NA     NA     NA     NA     NA     NA     NA     NA
## 4        4      1     NA     NA     NA     NA      4      5      2      2
## 5       NA      2     NA     NA     NA     NA     NA     NA     NA     NA
## 6        5      1     NA     NA     NA     NA     NA     NA     NA     NA
##   AUQ144 AUQ146 AUD148 AUQ152 AUQ154 AUQ191 AUQ250 AUQ255 AUQ260 AUQ270
## 1      4      2     NA     NA      2      2     NA     NA     NA     NA
## 2     NA     NA     NA     NA     NA     NA     NA     NA     NA     NA
## 3     NA     NA     NA     NA     NA     NA     NA     NA     NA     NA
## 4      4      2     NA     NA      2      1      5      1      2      1
## 5     NA     NA     NA     NA     NA     NA     NA     NA     NA     NA
## 6     NA     NA     NA     NA     NA     NA     NA     NA     NA     NA
##   AUQ280 AUQ300 AUQ310 AUQ320 AUQ330 AUQ340 AUQ350 AUQ360 AUQ370 AUQ380
## 1     NA      2     NA     NA      2     NA     NA     NA      2      1
## 2     NA     NA     NA     NA     NA     NA     NA     NA     NA     NA
## 3     NA     NA     NA     NA     NA     NA     NA     NA     NA     NA
## 4      1      1      2      1      2     NA     NA     NA      2      6
## 5     NA     NA     NA     NA     NA     NA     NA     NA     NA     NA
## 6     NA     NA     NA     NA     NA     NA     NA     NA     NA     NA
##   file_name begin_year end_year
## 1     AUQ_G       2011     2012
## 2     AUQ_G       2011     2012
## 3     AUQ_G       2011     2012
## 4     AUQ_G       2011     2012
## 5     AUQ_G       2011     2012
## 6     AUQ_G       2011     2012
```


That's a lot of variables and observations

Research questions we can answer with this data

- Are age and sex associated with gun use?
- Are age and sex associated with frequency of gun use among those who have used a gun?
- Is the mean age of a gun user the same as the mean age of all participants?

Data management topic: selecting cases and variables

- Firearm use:
  - *AUQ300: Every used firearms for any reason?*
  - *AUQ310: How many total rounds ever fired?*
- Demographics:
  - *RIAGENDR: Gender of the participant.*
  - *RIDAGEYR: Age in years at screening.*

Let's select the four variables listed and all the cases where AUQ300 (gun use) was answered either Yes or No.

Codebook for AUQ300 and AUQ310

AUQ300 - Ever used firearms for any reason?

Variable Name: AUQ300

SAS Label: Ever used firearms for any reason?

English Text: This next question is about {your/SP's} use of firearms that {you/he/she} may have used for target shooting, hunting, for {your/his/her} job or in military service. {Have you/Has SP} ever used firearms for any reason?

Target: Both males and females 20 YEARS - 69 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
1	Yes	1613	1613	
2	No	3061	4674	AUQ330
7	Refused	1	4675	AUQ330
9	Don't know	0	4675	AUQ330
.	Missing	4689	9364	

AUQ310 - How many total rounds ever fired?

Variable Name: AUQ310

SAS Label: How many total rounds ever fired?

English Text: How many total rounds {have you/has SP} ever fired?

English Instructions: READ CATEGORIES IF NECESSARY INTERVIEWER: ONE ROUND EQUALS ONE SHOT. INCLUDE TARGET SHOOTING, HUNTING, YOUR JOB AND MILITARY SERVICE.

Target: Both males and females 20 YEARS - 69 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
1	1 to less than 100 rounds	701	701	
2	100 to less than 1000 rounds	423	1124	
3	1000 to less than 10,000 rounds	291	1415	
4	10,000 to less than 50,000 rounds	106	1521	
5	50,000 rounds or more	66	1587	
7	Refused	0	1587	
9	Don't know	26	1613	
.	Missing	7751	9364	

Data management topic: selecting cases and variables

```
# open the tidyverse for data management
library(package = "tidyverse")

# make a smaller data frame with four variables
nhanes.2012.cleaned <- nhanes.2012 %>%
    select(AUQ300, AUQ310, RIAGENDR, RIDAGEYR)

# check the new data frame
summary(object = nhanes.2012.cleaned)
```

```
##      AUQ300          AUQ310          RIAGENDR        RIDAGEYR    
##  Min.   :1.000   Min.   :1.000   Min.   :1.000   Min.   : 1.00  
##  1st Qu.:1.000   1st Qu.:1.000   1st Qu.:1.000   1st Qu.:11.00  
##  Median :2.000   Median :2.000   Median :2.000   Median :28.00  
##  Mean   :1.656   Mean   :2.113   Mean   :1.502   Mean   :32.72  
##  3rd Qu.:2.000   3rd Qu.:3.000   3rd Qu.:2.000   3rd Qu.:53.00  
##  Max.   :7.000   Max.   :9.000   Max.   :2.000   Max.   :80.00  
##  NA's   :4689    NA's   :7751
```


Data management topic: selecting cases and variables

```
# add code to keep values of AUQ300 that are Yes and No
nhanes.2012.cleaned <- nhanes.2012 %>%
    select(AUQ300, AUQ310, RIAGENDR, RIDAGEYR) %>%
    filter(AUQ300 <= 2)

# check the new data frame
summary(object = nhanes.2012.cleaned)
```

```
##      AUQ300          AUQ310          RIAGENDR        RIDAGEYR    
##  Min.   :1.000   Min.   :1.000   Min.   :1.000   Min.   :20.00  
##  1st Qu.:1.000   1st Qu.:1.000   1st Qu.:1.000   1st Qu.:31.00  
##  Median :2.000   Median :2.000   Median :2.000   Median :43.00  
##  Mean   :1.655   Mean   :2.113   Mean   :1.506   Mean   :43.74  
##  3rd Qu.:2.000   3rd Qu.:3.000   3rd Qu.:2.000   3rd Qu.:56.00  
##  Max.   :2.000   Max.   :9.000   Max.   :2.000   Max.   :69.00  
##                  NA's   :3061
```


Codebook for RIAGENDR

RIAGENDR - Gender

Variable Name: RIAGENDR

SAS Label: Gender

English Text: Gender of the participant.

Target: Both males and females 0 YEARS - 150 YEARS

Code or Value	Value Description	Count	Cumulative	Skip to Item
1	Male	4856	4856	
2	Female	4900	9756	
.	Missing	0	9756	

Data cleaning: Fix data types and add labels

```
# add to the smaller data frame with four variables
# to keep values of AUQ300 that are Yes and No
nhanes.2012.cleaned <- nhanes.2012 %>%
    select(AUQ300, AUQ310, RIAGENDR, RIDAGEYR) %>%
    filter(AUQ300 <= 2) %>%
    mutate(AUQ300 = recode_factor(.x = AUQ300,
                            `1` = 'Yes',
                            `2` = 'No')) %>%
    mutate(AUQ310 = recode_factor(.x = AUQ310,
                            `1` = "1 to less than 100",
                            `2` = "100 to less than 1000",
                            `3` = "1000 to less than 10k",
                            `4` = "10k to less than 50k",
                            `5` = "50k or more",
                            `7` = "Don't know",
                            `9` = "Refused")) %>%
    mutate(RIAGENDR = recode_factor(.x = RIAGENDR,
                              `1` = 'Male',
                              `2` = 'Female')) %>%
    rename(gun.use = AUQ300) %>%
    rename(rounds.fired = AUQ310) %>%
    rename(sex = RIAGENDR) %>%
    rename(age = RIDAGEYR)


# check the recoding
summary(object = nhanes.2012.cleaned)
```


Data cleaning: Fix data types and add labels

```
##  gun.use                    rounds.fired      sex            age
##  Yes:1613   1 to less than 100    : 701   Male  :2311   Min.   :20.00
##  No :3061   100 to less than 1000: 423   Female:2363   1st Qu.:31.00
##             1000 to less than 10k: 291                 Median :43.00
##             10k to less than 50k : 106                 Mean   :43.74
##             50k or more          :  66                 3rd Qu.:56.00
##             NA's                 :3087                 Max.   :69.00
```

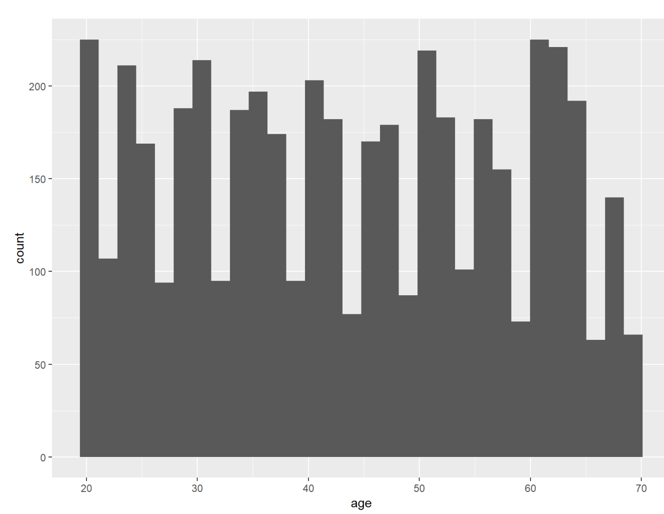

Descriptive statistics review & conducting in R

- Continuous variables
  - *Mean and standard deviation*
  - *Median and interquartile range (IQR)*
- Categorical variables
  - *Frequencies and percentages*

Choosing mean or median

- Means are useful when a variable is normally distributed (or close to normal)
- Medians are useful when a variable is not normally distributed

```
# examine age distribution
nhanes.2012.cleaned %>%
    ggplot(aes(x = age)) +
    geom_histogram()
```



Find the mean, median, std dev, IQR in tidyverse

- The median and IQR would be more appropriate given the distribution
- The `summarize()` function can compute descriptive statistics for continuous variables

```
# descriptive statistics for continuous variables
nhanes.2012.cleaned %>%
    drop_na(age) %>%
    summarize(mean.age = mean(x = age),
              sd.age = sd(x = age),
              med.age = median(x = age),
              iqr.age = IQR(x = age))
```

```
##   mean.age   sd.age med.age iqr.age
## 1 43.74369 14.39535      43      25
```


Interpreting the results

Participants in the 2012 NHANES survey who responded Yes or No to the gun use question had a median age of 43 years old (IQR = 25).

Find frequencies and percentages in base R

- Base R functions can be used to get simple frequencies and percents

```
# descriptive statistics for categorical variables
table(nhanes.2012.cleaned$gun.use)
```

```
##
##  Yes   No
## 1613 3061
```

```
prop.table(x = table(nhanes.2012.cleaned$gun.use))
```

```
##
##       Yes        No
## 0.3451006 0.6548994
```

Find frequencies and percentages in tidyverse

- To stay consistent with tidyverse, use `group_by()`

```
# descriptive stats for categorical in tidyverse
nhanes.2012.cleaned %>%
  group_by(gun.use) %>%
  summarize(freq.gun.use = n()) %>%
  mutate(perc.gun.use = 100*(freq.gun.use / sum(freq.gun.use)))
```

```
## # A tibble: 2 x 3
##   gun.use freq.gun.use perc.gun.use
##   <fct>          <int>        <dbl>
## 1 Yes             1613         34.5
## 2 No              3061         65.5
```


Interpreting the frequencies and percentages

Fewer participants in the NHANES 2012 survey had ever used a gun (n = 1613; 34.5%) compared to not ever used a gun (n = 3061; 65.5%).

Using tableone to get all the descriptive stats

```
# open tableone package
library(package = "tableone")
```

```
# create table of all variables
gun.use.table <- CreateTableOne(data = nhanes.2012.cleaned)

# print the table with all variables
print(x = gun.use.table)
```

```
##
##                               Overall
##    n                           4674
##    gun.use = No (%)            3061 (65.5)
##    rounds.fired (%)
##       1 to less than 100        701 (44.2)
##       100 to less than 1000     423 (26.7)
##       1000 to less than 10k     291 (18.3)
##       10k to less than 50k      106 ( 6.7)
##       50k or more                66 ( 4.2)
##    sex = Female (%)            2363 (50.6)
##    age (mean (SD))            43.74 (14.40)
```


Update the table with median instead of mean

```
# create table of all variables
gun.use.table <- CreateTableOne(data = nhanes.2012.cleaned)

# print showing all levels for categorical
# and stats for non-normal age variable
print(x = gun.use.table,
      showAllLevels = TRUE,
      nonnormal = 'age')
```

```
##
##                       level                 Overall
##    n                                         4674
##    gun.use (%)        Yes                    1613 (34.5)
##                       No                     3061 (65.5)
##    rounds.fired (%)   1 to less than 100      701 (44.2)
##                       100 to less than 1000   423 (26.7)
##                       1000 to less than 10k   291 (18.3)
##                       10k to less than 50k    106 ( 6.7)
##                       50k or more              66 ( 4.2)
##    sex (%)            Male                   2311 (49.4)
##                       Female                 2363 (50.6)
##    age (median [IQR])                       43.00 [31.00, 56.00]
```

Null Hypothesis Significance Testing

- Step 1: Write the null and alternate hypothesis
- Step 2: Calculate the test statistic
- Step 3: Calculate the probability that your test statistic is at least as big as it is if there were no relationship (i.e., if the null hypothesis is true)
- Step 4: If the probability that the null is true is very small (usually less than 5%) reject the null hypothesis
- Step 5: If the probability that the null is true is not small (usually 5% or greater) retain the null hypothesis

Step 1: Chi-squared null and alternate hypotheses

- Chi-squared is usually used to examine associations between *two categorical variables*

Research question: Is sex associated with gun use? Is there a difference between males and females in having used a gun?

- H0: There is no association between sex and gun use
- HA: There is an association between sex and gun use

Step 2: Chi-squared test statistic

```
# does gun use vary by sex
chisq.test(x = nhanes.2012.cleaned$sex,
           y = nhanes.2012.cleaned$gun.use)
```

```
##
##  Pearson's Chi-squared test with Yates' continuity correction
##
## data:  nhanes.2012.cleaned$sex and nhanes.2012.cleaned$gun.use
## X-squared = 532.48, df = 1, p-value < 2.2e-16
```


Step 3: Calculate the probability that your test statistic is at least this big if the null hypothesis were true

- The probability that your chi-squared statistic is 532.48 or bigger under the null hypothesis is shown in the output as p < 2.2e-16
- This is scientific notation for .00000000000000022
- So, there is a tiny probability that you'd have a chi-squared of 532.48 or bigger *if there were no association between sex and gun use*

Step 4 & 5: Reject or retain the null hypothesis

The null hypothesis that there is no association between sex and gun use is rejected (chi-squared = 532.48; p < .001). There is a statistically significant association between sex and gun use.

Ok, but what is the relationship?

- Examine percentages or make a graph to demonstrate

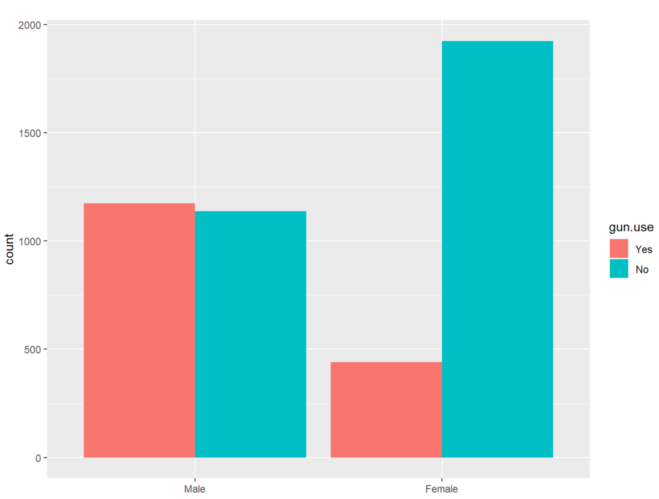
```
# gun use by sex percentages
prop.table(x = table(nhanes.2012.cleaned$sex,
                     nhanes.2012.cleaned$gun.use),
           margin = 1)
```

```
##
##                Yes        No
##   Male   0.5075725 0.4924275
##   Female 0.1862040 0.8137960
```

Among NHANES 2012 participants, a higher percentage of males (50.8%) compared to females (18.6%) had ever used a gun.

Ok, but what is the relationship? (graph)

```
# gun use by sex
nhanes.2012.cleaned %>%
    ggplot(aes(x = sex, fill = gun.use)) +
    geom_bar(position = "dodge")
```



Chi-squared assumptions

- Both variables are categorical (either nominal or ordinal)
  - *If not met, use another statistical test*
- A minimum of 5 observations in at least 80% of groups
  - *If not met, use Fisher's Exact Test (in R: `fisher.test()`)*
- Independent observations
  - *If not met, McNemar's test if the variables are binary and the observations are paired*
  - *If not met, Cochran's Q-test if one variable is binary and the other has 3+ categories and the observations are paired*
  - *If not met, clean up the data and use descriptives if this results from sloppy data collection (e.g., mistakenly surveyed the same person twice)*

One-sample t-test review

- One-sample t-tests are used to compare a mean from a sample to a hypothesized or population mean

Research question: Is the mean age of gun users the same as the mean age of everyone (m_{age} = 43.7)?

Step 1: One-sample t-test null and alternate hypotheses

H0: There is no difference between the mean age of gun users and the mean age of 43.7 years old in the full sample (i.e., gun users have a mean age of 43.7 years old)

HA: There is a difference between the mean age of gun users and the mean age of 43.7 years old in the full sample (i.e., gun users *do not* have a mean age of 43.7 years old)

Step 2: Calculate the test statistic

```
# select the gun users from the clean data
nhanes.2012.gun.users <- nhanes.2012.cleaned %>%
   filter(gun.use == "Yes")

# compare mean age of gun users to everyone
t.test(x = nhanes.2012.gun.users$age, mu = 43.7)
```

```
##
##  One Sample t-test
##
## data:  nhanes.2012.gun.users$age
## t = 0.26907, df = 1612, p-value = 0.7879
## alternative hypothesis: true mean is not equal to 43.7
## 95 percent confidence interval:
##  43.09988 44.49094
## sample estimates:
## mean of x
##  43.79541
```


Step 3: Calculate the probability that your test statistic is at least this big if the null hypothesis were true

- The probability that your t-statistic is .27 under the null hypothesis is shown in the output as p = .79
- So, there is a large probability that you'd have a t-statistic this big or bigger *if the mean age was no different from 43.7* (i.e., the null hypothesis was true)

Step 4 & 5: Reject or retain the null hypothesis

- The null hypothesis is retained. The mean age of gun users was 43.8 years old. The mean age of gun users was *not* statistically significantly different from the hypothesized mean age of 43.7 years old ($t = .27$; $p = .79$).

Assumptions of one-sample t-test

- One continuous variable, one binary variable
  - *If failed, use a different statistical test*
- The continuous variable is normally distributed
  - *If failed, use the **sign test** to compare medians instead*
- Independent observations
  - *If failed, use descriptive statistics instead*

One-way ANOVA review

- One-way ANOVA is used to compare means across more than two groups

Research question: Is mean age different by gun usage?

Step 1: ANOVA null and alternate hypotheses

H0: Mean age does not differ by gun usage

HA: Mean age differs by gun usage

Step 2: Calculate the test statistic

```
# ANOVA mean age by rounds fired group
oneway.test(formula = age ~ rounds.fired,
            data = nhanes.2012.gun.users,
            var.equal = TRUE)
```

```
##
##  One-way analysis of means
##
## data:  age and rounds.fired
## F = 2.5864, num df = 4, denom df = 1582, p-value = 0.03539
```


Step 3: Calculate the probability that your test statistic is at least this big

- The probability that your F-statistic is 2.59 under the null hypothesis is shown in the output as p = .035
- So, there is a small probability that you'd have a t-statistic this big or bigger *if mean age was no different from 43.7* (i.e., the null hypothesis was true)

Step 4 & 5: Reject or retain the null hypothesis

- The null hypothesis is rejected. The mean age of gun users differs by the number of rounds fired (F = 2.59; p = .035). ## Add some context
- Use mutate to get group means

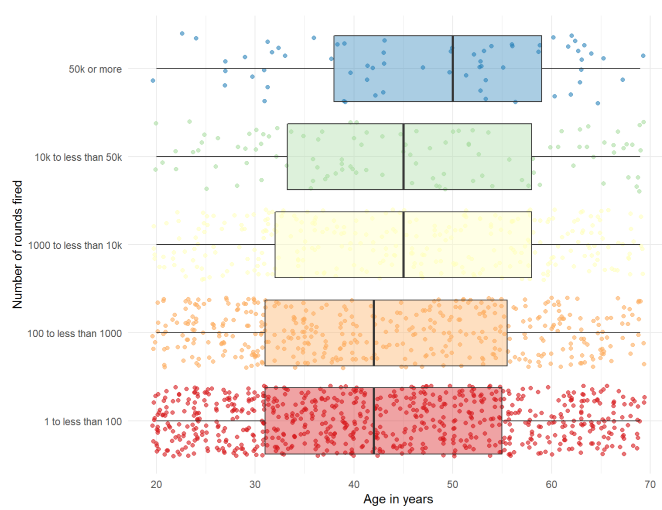
```
# mean of age by rounds fired groups
nhanes.2012.gun.users %>%
    drop_na(age) %>%
    drop_na(rounds.fired) %>%
    group_by(rounds.fired) %>%
    summarize(mean.age = mean(age),
              sd.age = sd(age))
```

```
## # A tibble: 5 x 3
##   rounds.fired          mean.age sd.age
##   <fct>                    <dbl>  <dbl>
## 1 1 to less than 100        42.9   14.1
## 2 100 to less than 1000     43.2   14.2
## 3 1000 to less than 10k     44.9   14.2
## 4 10k to less than 50k      45.2   14.6
## 5 50k or more               47.2   13.2
```


Add some context

- Use ggplot to examine boxplots

```
# graph mean ages by rounds fired groups
nhanes.2012.gun.users %>%
  drop_na(age) %>%
  drop_na(rounds.fired) %>%
  ggplot(aes(y = age, x = rounds.fired)) +
  geom_jitter(aes(color = rounds.fired), alpha = .6) +
  geom_boxplot(aes(fill = rounds.fired), alpha = .4) +
  scale_fill_brewer(palette = "Spectral", guide = FALSE) +
  scale_color_brewer(palette = "Spectral", guide = FALSE) +
  theme_minimal() +
  coord_flip() +
  labs(x = "Number of rounds fired", y = "Age in years")
```



ANOVA assumptions

- Continuous variable and three or more independent groups
- Independent observations
- Data are normally distributed by group
- Variances are equal by group (homogeneity of variances)

We will discuss all of these in detail later this semester!

The End