Northeastern University

Toronto

Hypothesis Testing: Chi-square and ANOVA

Soni Manan[a]

[a] *College of Professional Studies, Master of Professional Studies in Analytics.*

Subject*: ALY6015* ***NUID****: 002982645*

Under the guidance of

Dr. Prof. Alex Maizlish

Introduction

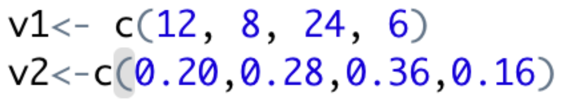
We have provided with questions with the learning purpose which are of hypothesis testing using Chi-square and ANOVA tests.

About Chi-Square and ANOVA

- A Chi-square test is a hypothesis testing. Chi-square tests involves p-value, lower bound and upper bound and X^2 value to judge or determine significance. If all the variables are categorical we can't use ANOVA but Chi-Square.
- The less X^2 squared value is, more correlation. They have inverse relationship.
- **ANOVA** stands for **Analysis of Variance** and to be specific, used to determine significance between variables ranges from one, two or three. If all the variables have numerical and you need to check between difference in significance like making interaction, ANOVA is used.

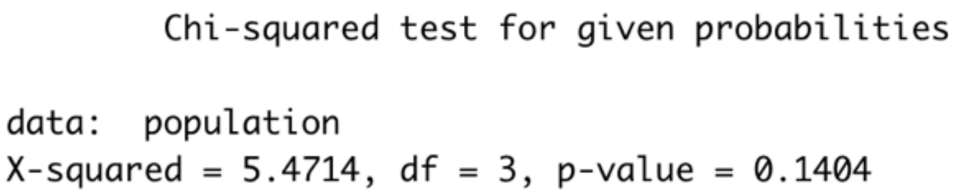
11-1 (A) Blood Types

- Distribution of blood types for the general populations provided and they are type A, type B, Type O, type AB respective 20%, 28%, 36% and 16% and taking random samples from that population of 50 to determine and they got 12 having type A blood, 8 having type B, 24 having type O, and 6 having type AB blood.
- Level of significance has provided which is 0.1.
- **H0**: Random sample distributions are same as the general population's.
- **H1:** Random sample distributions are not same as the general population's.
- Two vectors for test. Converted percentage into values.

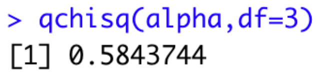


```
v1<- c(12, 8, 24, 6)
v2<-c(0.20,0.28,0.36,0.16)
```

- From the Chi-square test, p-value is 0.14 which is greater than 0.1. So we don't have enough evidence to reject. In addition, X^2 statistic value is greater than critical value which is 0.584. So we can't reject **H0.**
- This **qchisq()** method does same as we manually find value from table.



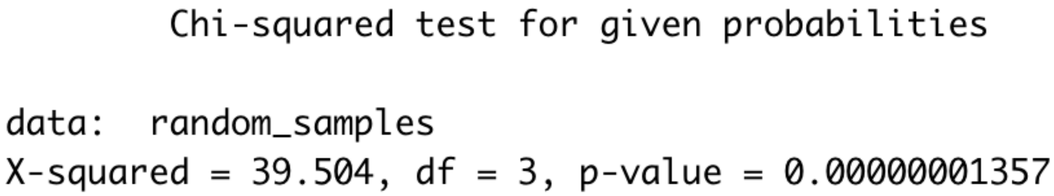
```
        Chi-squared test for given probabilities

data:  population
X-squared = 5.4714, df = 3, p-value = 0.1404
```



```
> qchisq(alpha,df=3)
[1] 0.5843744
```

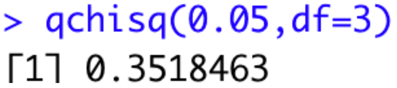
11-1 (B) On-Time Performance By Airlines

- Statistics of flights from airline and their punctuality was provided by the Bureau of Transportation Statistics. Probability of flight like whether it will be on-time or some kind of delay will be there. So 70.8% on-time departure, 8.2% delay because of National Aviation System delay, 9% Late arrival at the airport and 12% due to other reasons.
- To test, 200 samples has taken in which 125 of samples were on time, 40 were delayed because of some reason (other), 10 because of National Aviation System delay.
- We have to find for 95% level of significance.
- **H0**: The provided probabilities of flights and results of samples are same.
- **H1:** The provided probabilities of flights and results of samples aren't same.



```
	Chi-squared test for given probabilities

data:  random_samples
X-squared = 39.504, df = 3, p-value = 0.00000001357
```

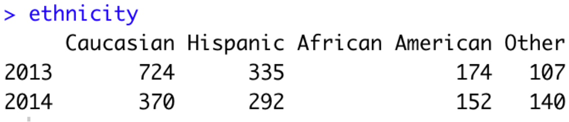
- Note that p-value is just 0 which is less than alpha (0.05). So, we reject the null hypothesis.
- Critical value for this test is 0.3518 which is less than X^2.



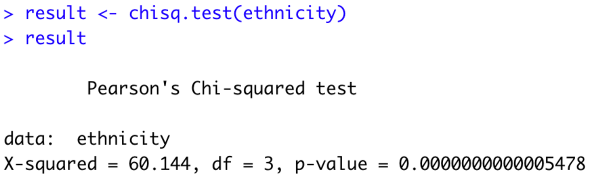
```
> qchisq(0.05,df=3)
[1] 0.3518463
```

11-2 (A) Ethnicity and Movie Admissions

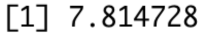
- Content of ethnicity is provided for two years which are 2013 and 2014 for movie admissions like Caucasian, Hispanic, African, etc.
- For this, 95% level of significance was provided.
- **H0**: Movie admissions are independent on ethnicity.
- **H1**: Movie admissions are not free of ethnicity.
- There is Table of movie admissions and ethnicity.



```
> ethnicity
     Caucasian Hispanic African American Other
2013       724      335              174   107
2014       370      292              152   140
```



```
> result <- chisq.test(ethnicity)
> result

	Pearson's Chi-squared test

data:  ethnicity
X-squared = 60.144, df = 3, p-value = 0.0000000000005478
```

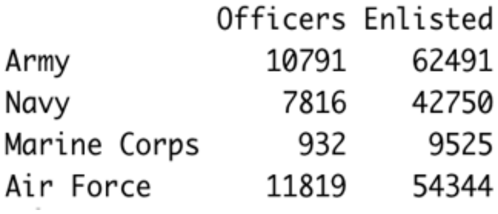


```
[1] 7.814728
```

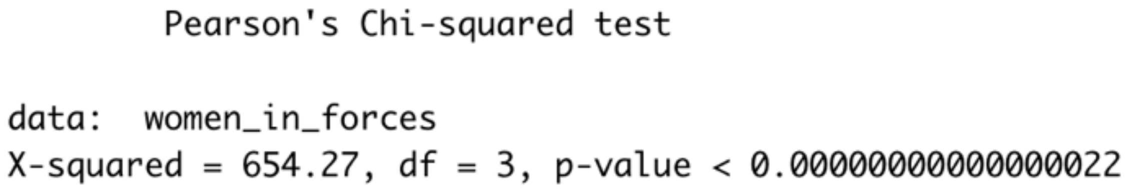
- Note that p-value is 0 with X^2 value and Critical value is 7.814.
- Value of p is less than alpha and X^2 is greater than critical value. So for both evidence, we reject the null hypothesis.

11-2 (B) Women in Military

- Table of data containing women in military has provided. For different, Arm forces like Army and Navy, and ranks are provided
- First needs to create a matrix. Then provide row names, column names according to table.
- All of the data is of women no other than that.
- **H0**: Ranks of officers have no relation with different arm forces.
- **H1:** There is dependency between rank and branch of forces.
- We need to check that at 95% level of significance which is 0.05 for statistically (alpha).



```
             Officers Enlisted
Army            10791    62491
Navy             7816    42750
Marine Corps      932     9525
Air Force       11819    54344
```

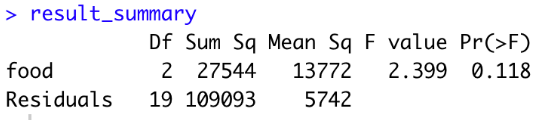


```
	Pearson's Chi-squared test

data:  women_in_forces
X-squared = 654.27, df = 3, p-value < 0.00000000000000022
```

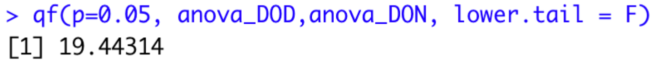
- Note that X^2 value is high due to number but it is greater than critical value and p-value is also 0 which is less than value of alpha. In that case, we reject the null hypothesis and we found there is a relationship exists.

12-1 Sodium Content of Food

- Samples have been given in which amount of sodium in one serving of 3 different foods Items like Condiments, Cereals and Desserts.
- **H0**: The mean sodium difference in three of them are same. (u1 = u2 = u3)
- **H1:** Anyone of them has different mean of sodium.
- We need to find for 95% level of significance.
- We will use **ANOVA** for this problem as problem have numeric for 3 categories. By mean, Not all variables are categorical.



```
> result_summary
            Df Sum Sq Mean Sq F value Pr(>F)
food         2  27544   13772   2.399  0.118
Residuals   19 109093    5742
```

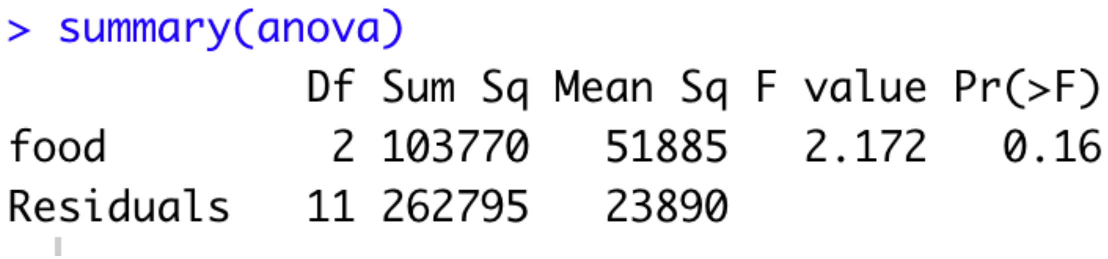


```
> qf(p=0.05, anova_DOD,anova_DON, lower.tail = F)
[1] 19.44314
```

- Value of F is 2.399 and p is 0.118 which is less than 0.05.
- So we reject the null hypothesis.
- The high F-value in ANOVA, the high variance of sample with respect to variation within sample.

12-2 (A) Sales for Leading Companies

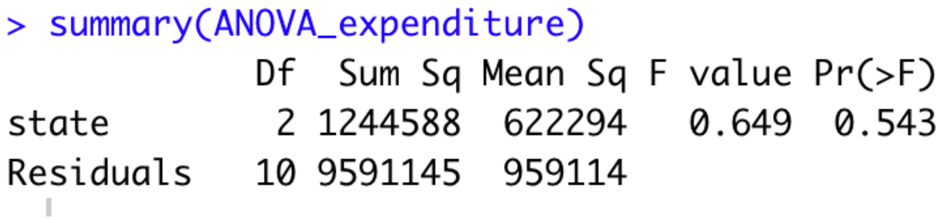
- The sales in millions of dollars for a specific year of leading companies are given. At 99% the level of significance to determine if there is difference in means are same.
- **H0:** The mean difference in the sales of products is same.
- **H1:** The mean difference in the sales of products is not same.
- F-value is 2.17 and value of p is 0.16 which greater than 0.01.
- So, we cannot reject the null hypothesis.
- One way is used to identify if one variable affects a response variable or not.



```
> summary(anova)
            Df Sum Sq Mean Sq F value Pr(>F)
food         2 103770   51885   2.172   0.16
Residuals   11 262795   23890
```

12-2 (B) Per-Pupil Expenditures

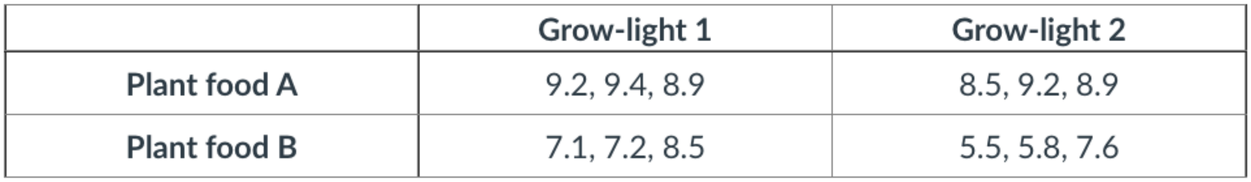
- Expenditures per pupils of states of three sections of country have given.
- We need to determine at 95% level of significance.
- **H0:** In all of the parts means of expenditures are same.
- **H1:** In all of the parts means of expenditures are not same. (μ1 != μ2 != μ3)
- For this test F-value is low which explains less variation and value of p is 0.543 which greater than alpha.
- Due to no evidence, we cannot reject the null hypothesis.



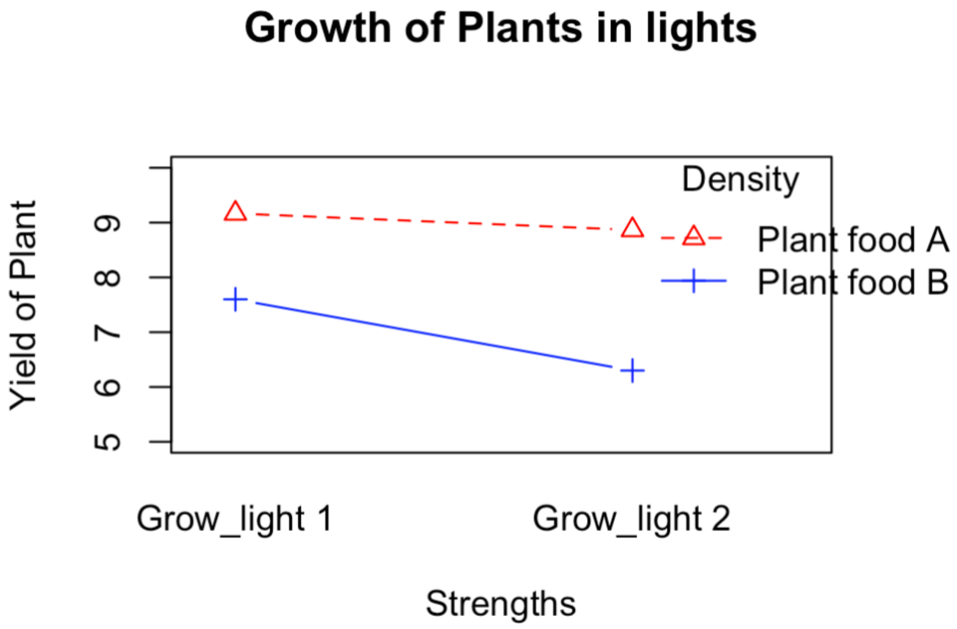
```
> summary(ANOVA_expenditure)
            Df  Sum Sq Mean Sq F value Pr(>F)
state        2 1244588  622294   0.649  0.543
Residuals   10 9591145  959114
```

12-3

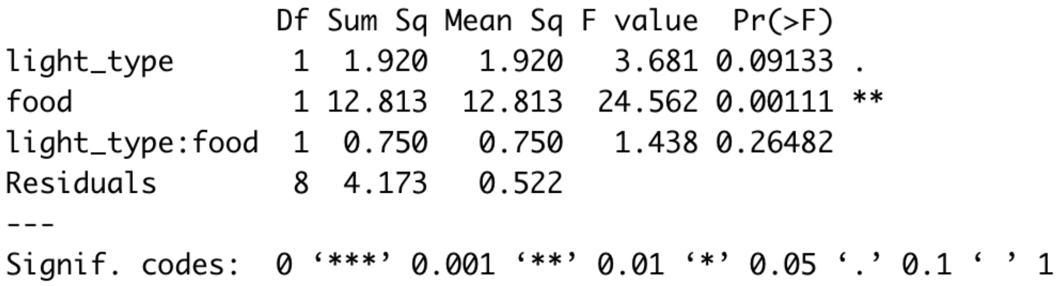
- A table of experiments conducted on one plant. It shows numbers regarding one plant can grow in two different strengths of grow-light and plant foods (A and B) supplement by a gardening company.



	Grow-light 1	Grow-light 2
Plant food A	9.2, 9.4, 8.9	8.5, 9.2, 8.9
Plant food B	7.1, 7.2, 8.5	5.5, 5.8, 7.6



- Graph we can see that growth is good when there is interaction of Grow-light 1 and Plant food A where as comparing to that Grow-Light 2 slightly less effective impact on growth while using Plant food A. Plant food B has some kind of problem which has not good impact on growth as Plant food A in both the strenths of light
- Interaction has the value of p 0.26482 which is greater than the alpha. So we can't reject the hypothesis.



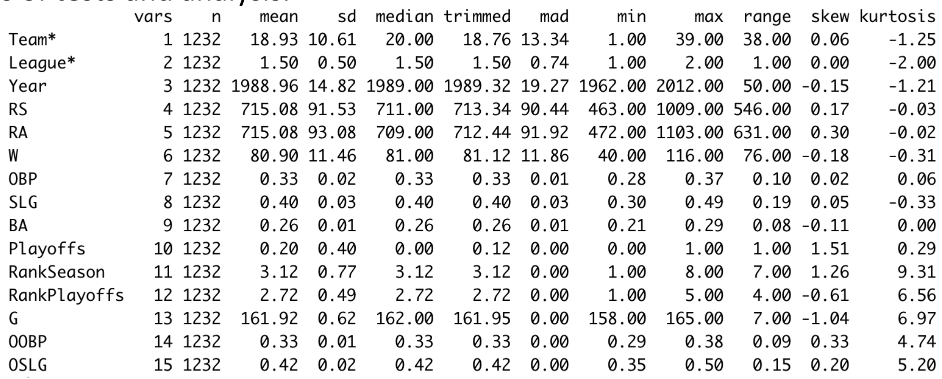
```
                Df Sum Sq Mean Sq F value  Pr(>F)   
light_type       1  1.920   1.920   3.681 0.09133 . 
food             1 12.813  12.813  24.562 0.00111 **
light_type:food  1  0.750   0.750   1.438 0.26482   
Residuals        8  4.173   0.522                   
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- Lowest value of F can also notice for the interaction.

Analysis of Baseball Game

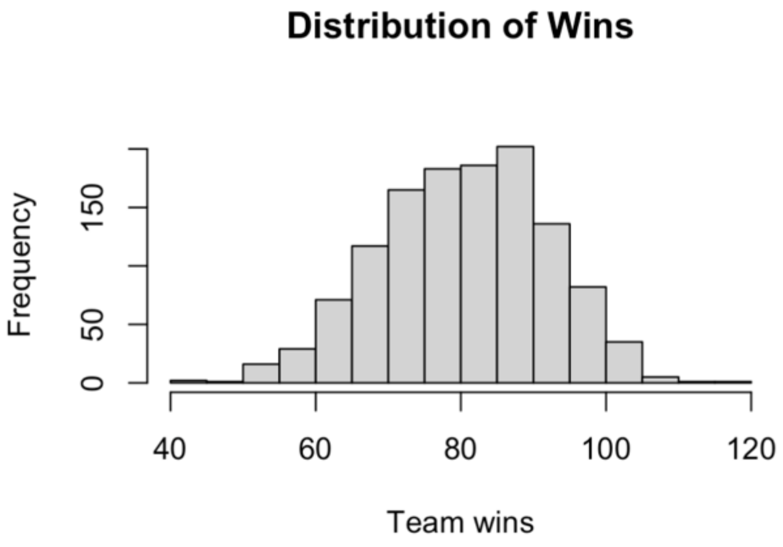
1. Descriptive Analysis

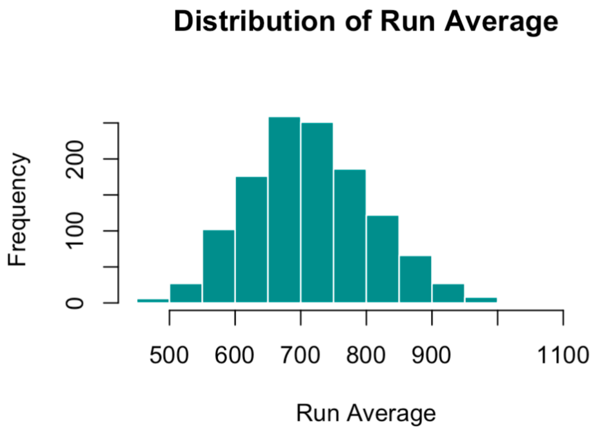
- Dataset was totally uncleaned, Approx. 70% of samples were affected with null values. So replaced mean instead removing rows. Total row count is 1232 with 15 columns.
- Note that Skewness is almost 0 for all variables which is good for normality check for all kinds of tests and analysis.

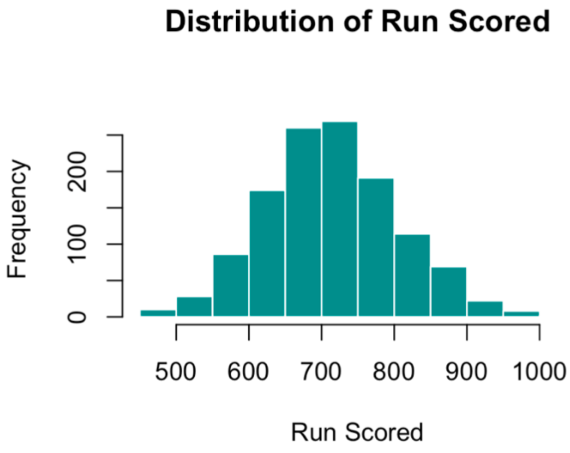


```
             vars    n    mean    sd  median trimmed   mad     min     max  range  skew kurtosis
Team*           1 1232   18.93 10.61   20.00   18.76 13.34    1.00   39.00  38.00  0.06    -1.25
League*         2 1232    1.50  0.50    1.50    1.50  0.74    1.00    2.00   1.00  0.00    -2.00
Year            3 1232 1988.96 14.82 1989.00 1989.32 19.27 1962.00 2012.00  50.00 -0.15    -1.21
RS              4 1232  715.08 91.53  711.00  713.34 90.44  463.00 1009.00 546.00  0.17    -0.03
RA              5 1232  715.08 93.08  709.00  712.44 91.92  472.00 1103.00 631.00  0.30    -0.02
W               6 1232   80.90 11.46   81.00   81.12 11.86   40.00  116.00  76.00 -0.18    -0.31
OBP             7 1232    0.33  0.02    0.33    0.33  0.01    0.28    0.37   0.10  0.02     0.06
SLG             8 1232    0.40  0.03    0.40    0.40  0.03    0.30    0.49   0.19  0.05    -0.33
BA              9 1232    0.26  0.01    0.26    0.26  0.01    0.21    0.29   0.08 -0.11     0.00
Playoffs       10 1232    0.20  0.40    0.00    0.12  0.00    0.00    1.00   1.00  1.51     0.29
RankSeason     11 1232    3.12  0.77    3.12    3.12  0.00    1.00    8.00   7.00  1.26     9.31
RankPlayoffs   12 1232    2.72  0.49    2.72    2.72  0.00    1.00    5.00   4.00 -0.61     6.56
G              13 1232  161.92  0.62  162.00  161.95  0.00  158.00  165.00   7.00 -1.04     6.97
OOBP           14 1232    0.33  0.01    0.33    0.33  0.00    0.29    0.38   0.09  0.33     4.74
OSLG           15 1232    0.42  0.02    0.42    0.42  0.00    0.35    0.50   0.15  0.20     5.20
```

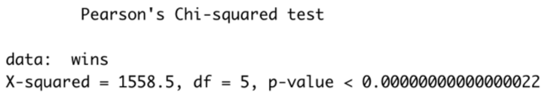
- From the histograms we can see that Run scored and Run Average both are around 700. However, there are some samples with run average over 1000.
- Run scored and run Average have almost same mean with same standard deviation so we can predict from mid of the match if how much score can be expected.
- Mean of other variables are just around 0.



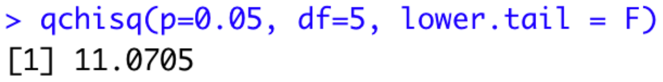




2. Hypothesis testing of Wins with Decade

- Data of Count of wins with Decades. If we can determine if there is something driving between two variables.
- For this test, level of significance Is 95%.
- To test, we need to state hypothesis, Therefore,
- **H0**: Count of win has some existing relation with decades.
- **H1**: Count of win is independent from time.
- 

```
        Pearson's Chi-squared test

data:  wins
X-squared = 1558.5, df = 5, p-value < 0.00000000000000022
```

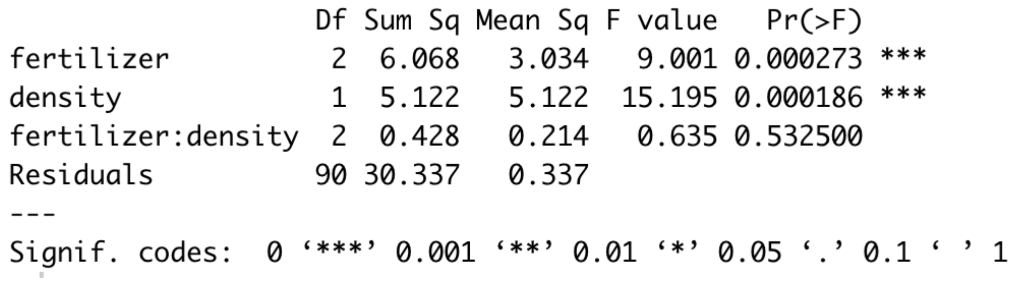
- 

```
> qchisq(p=0.05, df=5, lower.tail = F)
[1] 11.0705
```

- Note that value of p is almost 0 which is less than the value of significance 0.05 and X^2 statistics is 1558 which is far greater than 11.0705 which is critical value of test.
- So we have enough evidence to reject the null hypothesis.

Hypothesis testing of Crop Data

- After importing dataset, I’ve generated a data frame for it.
- Data has 4 variables like Block, Fertilizer, Yield and Density of crop.
- We need to identify if fertilizer and density have an impact on yield of crops.
- This will be two factor ANOVA test as specific interaction is required to test.
- **H0**: There is no effect on yield of crop from other factors like fertilizer, density and their interaction.
- **H1**: There is effect on yield of crop from the usage of fertilizer, density and their interaction.
- As from the P values the interaction has value 0.532. So we can’t reject the null hypothesis.
- So for interaction we can reject H0, but for other two independent, we can reject as p-values are 0. As we can note F-values decreased to 0 when they interacted.
-



```
                   Df Sum Sq Mean Sq F value   Pr(>F)    
fertilizer          2  6.068   3.034   9.001 0.000273 ***
density             1  5.122   5.122  15.195 0.000186 ***
fertilizer:density  2  0.428   0.214   0.635 0.532500    
Residuals          90 30.337   0.337                     
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

References

Statology, *2022.* One-way vs Two-way ANOVA with: When to Use Each *Source:* https://www.statology.org/one-way-vs-two-way-anova/

Wikipedia, *2022. Interleague play Source:* https://en.wikipedia.org/wiki/Interleague_play

Scribbr, Rebecca Bevans, PhD 2022. Two-way ANOVA | When and How to Use it, With Examples *Source:* https://www.scribbr.com/statistics/two-way-anova/

Littleballparks, 2022. What does RA, RS MEAN in Baseball *Source:* https://littleballparks.com/what-does-ra-rd-and-rs-mean-in-baseball/

Appendix

```
setwd(dirname(rstudioapi::getActiveDocumentContext()$path))
library(DescTools)
library(dplyr)
library(tidyverse)
library(psych)
library(ggplot2)

# 11.1 (A)

#Creating the vector values of result of samples
v1<- c(12, 8, 24, 6)
v2<-c(0.20,0.28,0.36,0.16)
#Creating vector of distribution of general


#Result of chi square test
?chisq.test()
test_result=chisq.test(x=random_samples, p=general_population)
test_result
#Getting the the critical value
#df = n-1 for samples
qchisq(alpha,df=3)

t.test(p,population,conf.level=0.90)

# 11.1 (B)

#Significance value
alpha<- 0.05

#Creating the vector values.
random_samples<- c(125, 40, 10, 25)

#Creating vector probabilities
flight_probs<-c(0.708,0.082,0.090,0.12)

#Result of chi square test
test_result<-chisq.test(x=random_samples, p=flight_probs)
```

```
test_result

#Findind the critical value
qchisq(0.05,df=3)

# 11.2 (A)

#Creating vector
r1 <- c(724,335,174,107)
r2 <- c(370,292,152,140)
rows=2
ethnicity = matrix(c(r1,r2),nrow = rows,ncol=4,byrow=TRUE)
rownames(ethnicity) = c(2013,2014)
colnames(ethnicity) = c("Caucasian","Hispanic","African American","Other")
ethnicity
result <- chisq.test(ethnicity)

#Summary results
result$statistic
result$p.value
result$parameter
result$statistic

#Calculation critical value
qchisq(p=.05, df=3, lower.tail=FALSE)

# 11.2 (B)

#Creating Vector
r1 <- c(10791,62491)
r2 <- c(7816,42750)
r3 <- c(932,9525)
r4 <- c(11819,54344)
rows=4

women_in_forces = matrix(c(r1,r2,r3,r4),nrow = rows,byrow=TRUE)

rownames(women_in_forces) = c("Army","Navy","Marine Corps","Air Force")
colnames(women_in_forces) = c("Officers","Enlisted")
women_in_forces
result <- chisq.test(women_in_forces)
result
```

```
#Summary results
result$statistic
result$p.value
result$parameter
result$statistic

#Calculating critical value
a <- qchisq(p=.05, df=3, lower.tail=FALSE)

# 12.1
condiments<- data.frame('sodium' = c(270, 130, 230, 180, 80, 70, 200), 'type' = rep('condiments', 7), stringsAsFactors =F)
cereals <- data.frame('sodium' = c(260, 220, 290, 290, 200, 320, 140), 'type' =rep('cereals', 7), stringsAsFactors = FALSE)
desserts <- data.frame('sodium' = c(100, 180, 250, 250, 300, 360, 300, 160), 'type'= rep('desserts', 8), stringsAsFactors =F)
value_sodium<-rbind(condiments, cereals, desserts)
value_sodium$type<- as.factor(sodium$type)
value_sodium

#probs
p<-c(0.708,0.082,0.090,0.12)

#ANOVA test
s.anova<- aov(value_sodium~food, data=value_sodium)
smmry<-summary(s.anova)
smmry

# k - 1
nume <- a.summary[[1]][1, "Df"]
# N - k
domi <- a.summary[[1]][2, "Df"]
domi

#Finding critical value
qf(p=0.05, domi,nume, lower.tail = F)

# 12-2 (A)
alpha = 0.01
cereal <- data.frame('sales'=c(578,320,264,249,237),'food' = rep('cereal',5),stringsAsFactors = FALSE)
chocolate_candy<- data.frame('sales'=c(311,106,109,125,173),'food'=rep('chocolate_candy',5),stringsAsFactors = FALSE)
```

```
coffee <- data.frame('sales'=c(261,185,302,689),'food'=rep('coffee',4),stringsAsFactors = FALSE)

qf(p=.01, df1=2, df2=11, lower.tail=FALSE)
sales <- rbind(cereal,chocolate_candy,coffee)
sales$food <- as.factor(sales$food)

anova <- aov(sales~food,data = sales)
summary(anova)

# 12.2.2 (B)
alpha = 0.05
Eastern_third<- data.frame('expenditure'=c(4946,5953,6202,7243,6113),'state' = rep('Eastern
third',5),stringsAsFactors = FALSE)
Middle_third<- data.frame('expenditure'=c(6149,7451,6000,6479),'state'=rep('Middle third',4),stringsAsFactors =
FALSE)
Western_third<- data.frame('expenditure'=c(5282,8605,6528,6911),'state'=rep('Western third',4),stringsAsFactors
= FALSE)

expenditure <- rbind(Eastern_third,Middle_third,Western_third)
expenditure$state <- as.factor(expenditure$state)

anova1 <- aov(expenditure~state,data = expenditure)
ANOVA_expenditure = anova1
summary(ANOVA_expenditure)

# 12.3

#Creating dataframe
plantA1<- data.frame('growth'=c(9.2,9.4,8.9),'light_type' = rep('Grow_light 1',3),'food'=rep("Plant food
A",3),stringsAsFactors = FALSE)
plantA2<- data.frame('growth'=c(8.5,9.2,8.9),'light_type' = rep('Grow_light 2',3),'food'=rep("Plant food
A",3),stringsAsFactors = FALSE)

plantB1<- data.frame('growth'=c(7.1,7.2,8.5),'light_type' = rep('Grow_light 1',3),'food'=rep("Plant food
B",3),stringsAsFactors = FALSE)
plantB2<- data.frame('growth'=c(5.5,5.8,7.6),'light_type' = rep('Grow_light 2',3),'food'=rep("Plant food
B",3),stringsAsFactors = FALSE)

company <- rbind(plantA1,plantA2,plantB1,plantB2)
company$light_type <- as.factor(company$light_type)
company$food <- as.factor(company$food)

#Visualization
interaction.plot(company$light_type , company$food, company$growth ,
        type = "b" , col = c("red","blue"),xlab='Strengths',trace.label = "Density",
        pch = c(2,3) ,ylab = "Yield of Plant", ylim = c(5,10),
        main='Growth of Plants in lights')

#Applying ANOVA
anova1 <- aov(growth~light_type+food+light_type:food,data=company)
anova.summary <-summary(anova1)
anova.summary

# ON YOUR OWN #
#Importing dataset
df<-read.csv("baseball.csv")
summary(df)
str(df)
psych::describe(df)
# MEAN instead NA
for(i in 1:ncol(df)){
  df[is.na(df[,i]), i] <- mean(df[,i], na.rm = TRUE)
}

# SUMMARIES
summary(df)
psych::describe(df)

win <- df %>% group_by(Team) %>% summarize(wins = sum(W)) %>% as.tibble()
win_by_league <- df %>%
  group_by(League) %>% summarize(wins = sum(W)) %>%
  as.tibble()
hist(df$W,main="Distribution of Winings",xlab='Team wins',col='cyan4',border='white')
hist(df$RS,main="Distribution of Run Scored",xlab='Run Scored',col='cyan4',border='white')
hist(df$RA,main="Distribution of Run Average",xlab='Run Average',col='cyan4',border='white')

# Extract decade from year
df$Decade <- df$Year - (df$Year %% 10)

# Create a wins table by summing the wins by decade
wins <- df %>%
  group_by(Decade) %>% summarize(wins = sum(W)) %>%
  as.tibble()

#Creating the vector values.
r1<- c(125, 40, 10, 25)
```

```
#Creating vector probabilities
p<-c(0.708,0.082,0.090,0.12)

#Result of chi square test
outcome<-chisq.test(wins)
outcome
qchisq(p=0.05, df=5, lower.tail = F)

crop <- read.csv("crop_data.csv")

sum(is.na(crop))

#Data cleaning and preparing
crop$density <- as.factor(crop$density)
crop$block <- as.factor(crop$block)
crop$fertilizer <- as.factor(crop$fertilizer)

#Applying ANOVA
anova <- aov(yield ~ fertilizer+density+fertilizer:density , data = crop)
anova_summary<-summary(anova)
anova_summary
```