

# IS5 in R: Comparing Groups (Chapter 17)

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## Introduction and background

This document is intended to help describe how to undertake analyses introduced as examples in the Fifth Edition of *Intro Stats* (2018) by De Veaux, Velleman, and Bock. More information about the book can be found at [http://wps.aw.com/aw\\_deveaux\\_stats\\_series](http://wps.aw.com/aw_deveaux_stats_series). This file as well as the associated R Markdown reproducible analysis source file used to create it can be found at <http://nhorton.people.amherst.edu/is5>.

This work leverages initiatives undertaken by Project MOSAIC (<http://www.mosaic-web.org>), an NSF-funded effort to improve the teaching of statistics, calculus, science and computing in the undergraduate curriculum. In particular, we utilize the `mosaic` package, which was written to simplify the use of R for introductory statistics courses. A short summary of the R needed to teach introductory statistics can be found in the `mosaic` package vignettes (<http://cran.r-project.org/web/packages/mosaic>). A paper describing the `mosaic` approach was published in the *R Journal*: <https://journal.r-project.org/archive/2017/RJ-2017-024>.

## Chapter 17: Comparing Groups

```
library(mosaic)
library(readr)
library(janitor)
```

### Section 17.1: A Confidence Interval for the Difference Between Two Proportions

```
# Creating a data frame for Seatbelts
Seatbelts <- rbind(
  do(2777) * data.frame(passenger = "F", belted = TRUE),
  do(4208 - 2777) * data.frame(passenger = "F", belted = FALSE),
  do(1363) * data.frame(passenger = "M", belted = TRUE),
  do(2763 - 1363) * data.frame(passenger = "M", belted = FALSE)
) %>%
  select(passenger, belted)
```

The `do()` function constructs the correct number of rows for the data frame from provided cell counts.

```
set.seed(234)
numsim <- 10000

# What does do() do?
abs(diffmean(belted ~ passenger, data = resample(Seatbelts)))

## diffmean
## 0.1698569

# Difference of proportions from one random resample
abs(diffmean(belted ~ passenger, data = resample(Seatbelts)))

## diffmean
```

```
## 0.1776134
# Difference of proportions from another random resample

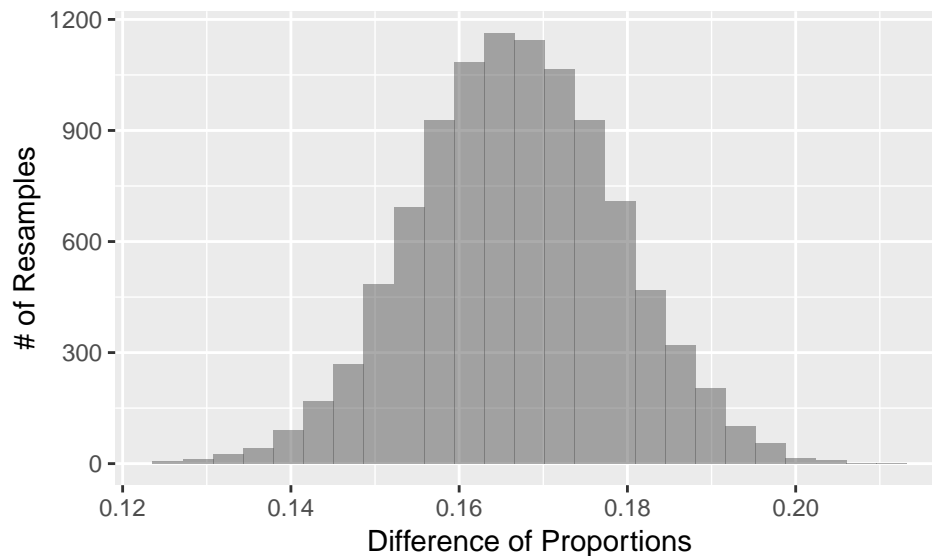
do(2) * abs(diffmean(belted ~ passenger, data = resample(Seatbelts))) # Calculates two differences

##      diffmean
## 1 0.1573754
## 2 0.1548267

# We want to calculate numsim resampled differences of proportions
seatbeltresamples <- do(numsim) * abs(diffmean(belted ~ passenger, data = resample(Seatbelts)))
```

For more information about `resample()`, refer to the resampling vignette: <https://cran.r-project.org/web/packages/mosaic/vignettes/Resampling.pdf>.

```
# Figure 17.1, page 542
gf_histogram(~ diffmean, data = seatbeltresamples) %>%
  gf_labs(x = "Difference of Proportions", y = "# of Resamples")
```



### Example 17.1: Finding the Standard Error of a Difference in Proportions

```
# Creating the data set for online profiles
OnlineProf <- rbind(
  do(141) * data.frame(gender = "M", profile = TRUE), # 248 * .57 rounds to 141
  do(107) * data.frame(gender = "M", profile = FALSE), # 248 - 141
  do(179) * data.frame(gender = "F", profile = TRUE),
  do(77) * data.frame(gender = "F", profile = FALSE)
)
tally(~ gender, data = OnlineProf)

## gender
##      M      F
## 248 256

OnlineProfM <- OnlineProf %>%
  filter(gender == "M") # Make a data set for male observations
nM <- nrow(OnlineProfM)
nM # n for males
```

```
## [1] 248
propMyes <- mean(~ profile, data = OnlineProfM)
propMyes # p for males

## [1] 0.5685484
sepboys <- ((propMyes * (1 - propMyes))/nM)^.5
sepboys # SE for males

## [1] 0.03145024
OnlineProfF <- OnlineProf %>%
  filter(gender == "F") # Make a data set for male observations
nF <- nrow(OnlineProfF)
nF # n for females

## [1] 256
propFyes <- mean(~ profile, data = OnlineProfF)
propFyes # p for females

## [1] 0.6992188
sepgirls <- ((propFyes * (1 - propFyes))/nF)^.5
sepgirls # SE for females

## [1] 0.02866236
sep <- (sepboys^2 + sepgirls^2)^.5
sep # overall SE

## [1] 0.04255171
```

### Example 17.2: Finding a Two-Proportion z-Interval

```
zstats <- qnorm(p = c(.025, .975))
(propFyes - propMyes) + zstats * sep

## [1] 0.04727054 0.21407019
# Or, you can use:
prop.test(x = c(179, 141), n = c(nF, nM), correct = FALSE)

##
## 2-sample test for equality of proportions without continuity
## correction
##
## data:  c(179, 141) out of c(nF, nM)
## X-squared = 9.2792, df = 1, p-value = 0.002318
## alternative hypothesis: two.sided
## 95 percent confidence interval:
##  0.04727054 0.21407019
## sample estimates:
##   prop 1   prop 2
## 0.6992188 0.5685484
```

The `prop.test()` function can be used to find confidence intervals and p-values of both one or two proportion z-tests.

## Section 17.2: Assumptions and Conditions for Comparing Proportions

## Section 17.3: The Two-Sample z-Test: Testing for the Difference Between Proportions

### Step-By-Step Example: A Two-Proportion z-Test

```
# Create the data set
SleepHabits <- rbind(
  do(205)      * data.frame(gen = "GenY", internet = TRUE),
  do(293 - 205) * data.frame(gen = "GenY", internet = FALSE),
  do(235)      * data.frame(gen = "GenX", internet = TRUE),
  do(469 - 235) * data.frame(gen = "GenX", internet = FALSE)
)

# Mechanics
ngeny <- nrow(filter(SleepHabits, gen == "GenY"))
ngeny # n for GenY

## [1] 293

ygeny <- nrow(filter(SleepHabits, gen == "GenY" & internet == TRUE))
ygeny # y for GenY

## [1] 205

pgeny <- mean(~ internet, data = filter(SleepHabits, gen == "GenY"))
pgeny # proportion for GenY

## [1] 0.6996587

ngenx <- nrow(filter(SleepHabits, gen == "GenX"))
ngenx # n for GenX

## [1] 469

ygenx <- nrow(filter(SleepHabits, gen == "GenX" & internet == TRUE))
ygenx # y for GenX

## [1] 235

pgenx <- mean(~ internet, data = filter(SleepHabits, gen == "GenX"))
pgenx # proportion for GenX

## [1] 0.5010661

sepgen <- ((pgeny * (1 - pgeny))/ngeny + (pgenx * (1 - pgenx))/ngenx)^.5
sepgen # overall SE

## [1] 0.03535867

pdiff <- pgeny - pgenx
pdiff # difference between proportions

## [1] 0.1985926

z <- (pdiff - 0)/sepgen
z
```

```
## [1] 5.616518
2 * pnorm(q = z, lower.tail = FALSE)

## [1] 1.948444e-08
```

## Section 17.4: A Confidence Interval for the Difference Between Two Means

The `t.test()` function can be used to generate a confidence interval for the difference between two means. The `conf.level` option can be used to create different intervals.

### Example 17.7: Finding a Confidence Interval for the Difference in Sample Means

```
# page 555
nord <- 27 # n for ordinary bowls
nref <- 27 # n for refilling bowls
yord <- 8.5 # y for ordinary bowls
yref <- 14.7 # y for refilling bowls
sord <- 6.1 # standard deviation for ordinary bowls
sref <- 8.4 # standard deviation for refilling bowls

seys <- 2.0 # overall SE
diffy <- yref - yord # difference between y's is 6.2
tstats <- qt(p = c(.025, .975), df = 47.46)
tstats

## [1] -2.011226 2.011226
me <- tstats * seys
me # margin of error

## [1] -4.022452 4.022452
diffy + me # confidence interval

## [1] 2.177548 10.222452
```

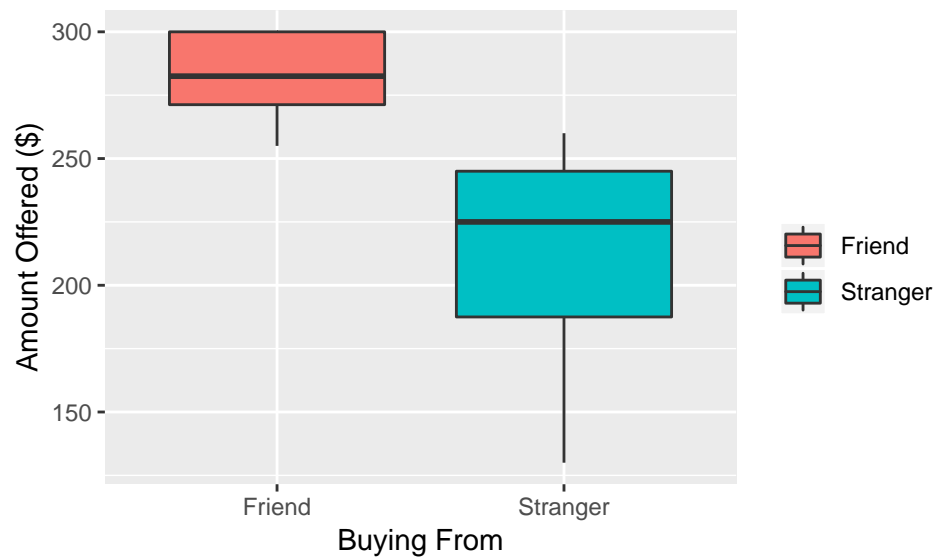
## Section 17.5: The Two-Sample *t*-Test: Testing for the Difference Between Two Means

### Step-By-Step Example: A Two-Sample *t*-Test for the Difference Between the Two Means

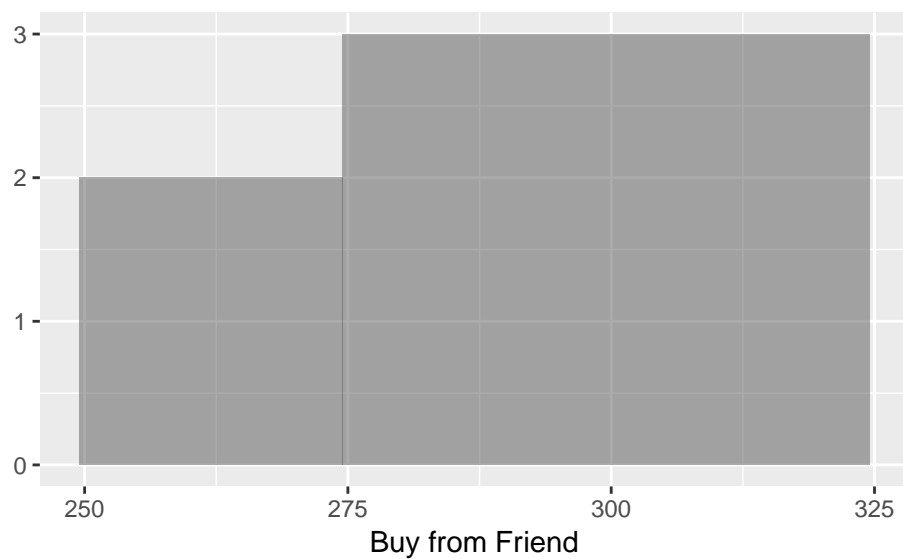
```
# page 556
BuyingCam <- read_csv("http://nhorton.people.amherst.edu/is5/data/Buy_from_a_friend.csv")

## Parsed with column specification:
## cols(
##   Friend = col_integer(),
##   Stranger = col_integer()
## )

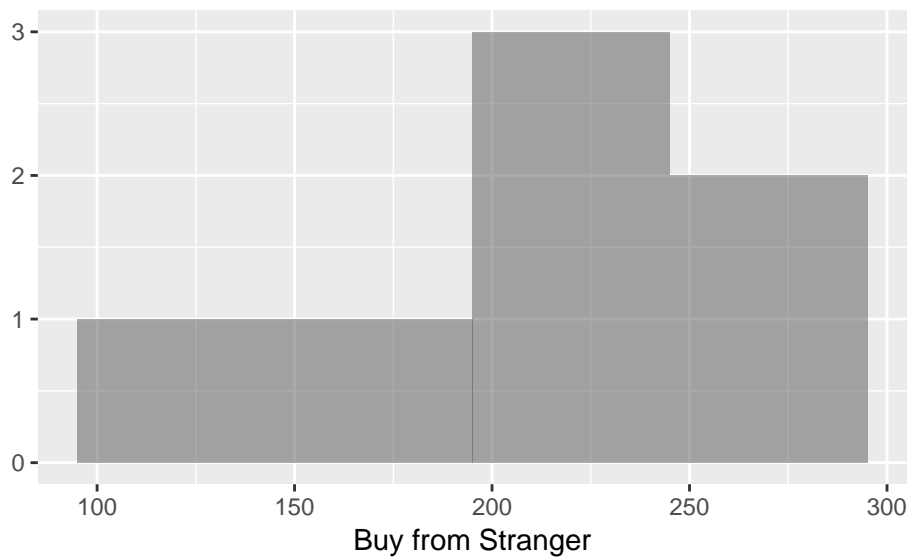
library(tidyr) # for gather() function
BuyingCam <- BuyingCam %>%
  gather(key = buying_type, value = amount_offered, Friend, Stranger)
# Model
gf_boxplot(amount_offered ~ buying_type, fill = ~ buying_type, data = BuyingCam) %>%
  gf_labs(x = "Buying From", y = "Amount Offered ($)", fill = "")
```



```
BuyingCam %>%
  filter(buying_type == "Friend") %>%
  gf_histogram(~ amount_offered, binwidth = 25, center = 12) %>%
  gf_labs(x = "Buy from Friend", y = "")
```



```
BuyingCam %>%
  filter(buying_type == "Stranger") %>%
  gf_histogram(~ amount_offered, binwidth = 50, center = 20) %>%
  gf_labs(x = "Buy from Stranger", y = "")
```



We can replicate the analyses on pages 557-558.

```
favstats(amount_offered ~ buying_type, data = BuyingCam)

##   buying_type min      Q1 median  Q3 max      mean      sd n missing
## 1      Friend 255 271.25  282.5 300 300 281.8750 18.31032 8      0
## 2     Stranger 130 187.50  225.0 245 260 211.4286 46.43223 7      1

t.test(amount_offered ~ buying_type, data = BuyingCam)

##
## Welch Two Sample t-test
##
## data:  amount_offered by buying_type
## t = 3.766, df = 7.6229, p-value = 0.006003
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  26.93688 113.95597
## sample estimates:
##   mean in group Friend mean in group Stranger
##           281.8750           211.4286
```

## Section 17.6: Randomization Tests and Confidence Intervals for Two Means

```
Cars <- read_csv("http://nhorton.people.amherst.edu/is5/data/Car_speeds.csv")

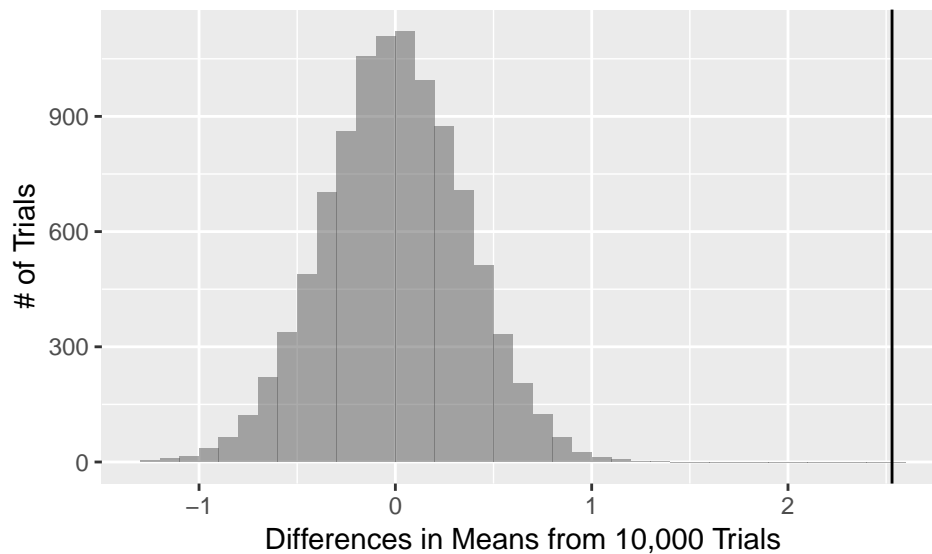
## Parsed with column specification:
## cols(
##   direction = col_character(),
##   speed = col_double()
## )

# Figure 17.2 (page 560) is the same as Figure 4.4 (page 102)
favstats(speed ~ direction, data = Cars)

##   direction  min      Q1 median  Q3  max      mean      sd  n
## 1      Down 10.27 20.4675 22.885 25.3525 32.95 22.71708 3.622006 250
```

```
## 2      Up 15.08 22.4975 25.155 28.1600 34.97 25.25172 3.856331 250
## missing
## 1      0
## 2      0
```

```
set.seed(23456)
numsim <- 10000
CarSims <- do(numsim) * diffmean(speed ~ shuffle(direction), data = Cars)
# Figure 17.3, page 560
gf_histogram(~ diffmean, data = CarSims, binwidth = .1, center = .05) %>%
  gf_vline(xintercept = 2.53) %>%
  gf_labs(x = "Differences in Means from 10,000 Trials", y = "# of Trials")
```



```
set.seed(32453)
numsim <- 10000

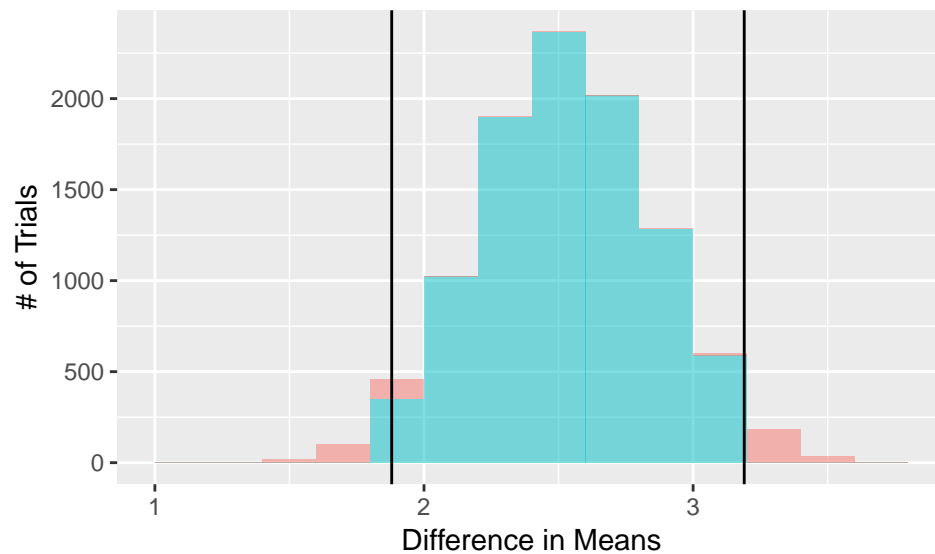
CarBoots <- do(numsim) * diffmean(speed ~ direction, data = resample(Cars))
qdata(~ diffmean, p = c(.025, .975), data = CarBoots)
```

```
##      quantile      p
## 2.5%  1.887197 0.025
## 97.5% 3.185255 0.975
```

```
CarBoots <- CarBoots %>%
  mutate(interval = ifelse(diffmean > 1.88 & diffmean < 3.19, "Within 95% Confidence",
                           "Outside 95% Confidence"))
```

```
# Figure 17.4
gf_histogram(~ diffmean, fill = ~ interval, data = CarBoots, binwidth = .2,
             center = .1) %>%
  gf_vline(xintercept = 1.88) %>%
  gf_vline(xintercept = 3.19) %>%
  gf_labs(x = "Difference in Means", y = "# of Trials") +
  guides(fill = FALSE) # to remove the legend
```





### Section 17.7: Pooling

The pooled variance t.test can be generated by using the option `var.equal = TRUE`.

```
t.test(amount_offered ~ buying_type, var.equal = TRUE, data = BuyingCam)
```

```
##
##  Two Sample t-test
##
## data:  amount_offered by buying_type
## t = 3.9699, df = 13, p-value = 0.0016
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##   32.11047 108.78238
## sample estimates:
##   mean in group Friend mean in group Stranger
##                281.8750                211.4286
```

### Section 17.8: The Standard Deviation of a Difference