

IS5 in R: Comparing Counts (Chapter 19)

Margaret Chien and Nicholas Horton (nhorton@amherst.edu)

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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. 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 19: Comparing Counts

```
library(mosaic)
library(readr)
library(janitor)
Zodiac <- read_csv("http://nhorton.people.amherst.edu/is5/data/Zodiac.csv")
```

```
## Parsed with column specification:
## cols(
##   Month = col_character(),
##   Births = col_integer(),
##   Expected = col_double(),
##   Residual = col_double()
## )
```

By default, `read_csv()` prints the variable names. These messages can be suppressed using the `message=FALSE` code chunk option to save space and improve readability.

```
Zodiac %>%
  select(Month, Births)
```

```
## # A tibble: 12 x 2
##   Month      Births
##   <chr>      <int>
## 1 Pisces      29
## 2 Aquarius    24
## 3 Aries       23
## 4 Cancer      23
## 5 Capricorn   22
## 6 Scorpio     21
## 7 Taurus      20
## 8 Leo         20
## 9 Saggitarius 19
```

```
## 10 Virgo          19
## 11 Libra          18
## 12 Gemini         18
```

Section 19.1: Goodness-of-Fit Tests

Example 19.1: Finding Expected Counts

```
# page 611
BaseballBirths <- read_csv("http://nhorton.people.amherst.edu/is5/data/Ballplayer_births.csv") %>%
  clean_names() # doesn't contain national birth %
```

```
## Parsed with column specification:
## cols(
##   Month = col_integer(),
##   `Ballplayer Count` = col_integer()
## )
```

Here we use the `clean_names()` function from the `janitor` package to sanitize the names of the columns (which would otherwise contain special characters or whitespace).

```
natbirth <- c(.08, .07, .08, .08, .08, .08, .09, .09, .09, .09, .08, .09)
BaseballBirths <- cbind(BaseballBirths, natbirth) # adding a column for national birth %
totaln <- sum(~ ballplayer_count, data = BaseballBirths)
totaln
```

```
## [1] 1478
```

```
BaseballBirths <- BaseballBirths %>%
  mutate(expected = totaln * natbirth)
BaseballBirths %>%
  select(month, expected)
```

```
##   month expected
## 1     1   118.24
## 2     2   103.46
## 3     3   118.24
## 4     4   118.24
## 5     5   118.24
## 6     6   118.24
## 7     7   133.02
## 8     8   133.02
## 9     9   133.02
## 10    10   133.02
## 11    11   118.24
## 12    12   133.02
```

Assumptions and Conditions

Calculations

Chi-Square P-values

```
# Examples of chisq p-values
qchisq(df = 2, p = .1, lower.tail = FALSE)
```

```
## [1] 4.60517
qchisq(df = 10, p = .05, lower.tail = FALSE)

## [1] 18.30704
```

Example 19.3: Doing a Goodness-of-Fit Test

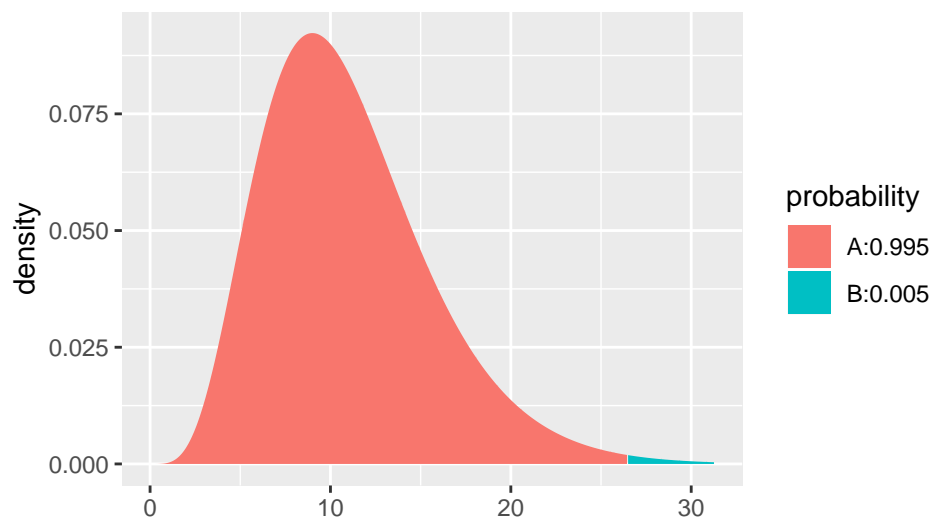
```
# page 614
df <- nrow(BaseballBirths) - 1
df

## [1] 11

BaseballBirths %>%
  mutate(chisq = ((ballplayer_count - expected)^2)/expected) %>%
  summarise(sum(chisq))

##      sum(chisq)
## 1      26.48442

xpchisq(q = 26.5, df = df, lower.tail = FALSE)
```



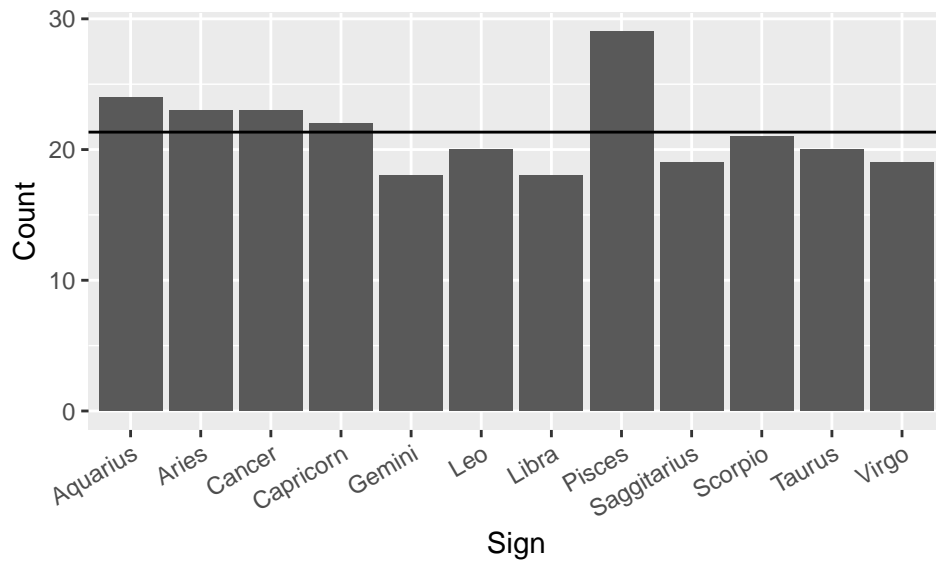
```
## [1] 0.005464563
```

Step-By-Step Example: A Chi-Square Test for Goodness-of-Fit

```
expected <- mean(~ Births, data = Zodiac)
expected

## [1] 21.33333

gf_col(Births ~ Month, data = Zodiac) %>%
  gf_hline(yintercept = expected) %>%
  gf_labs(x = "Sign", y = "Count") +
  theme(axis.text.x = element_text(angle = 30, hjust = 1)) # to adjust the angle of the x axis labels
```



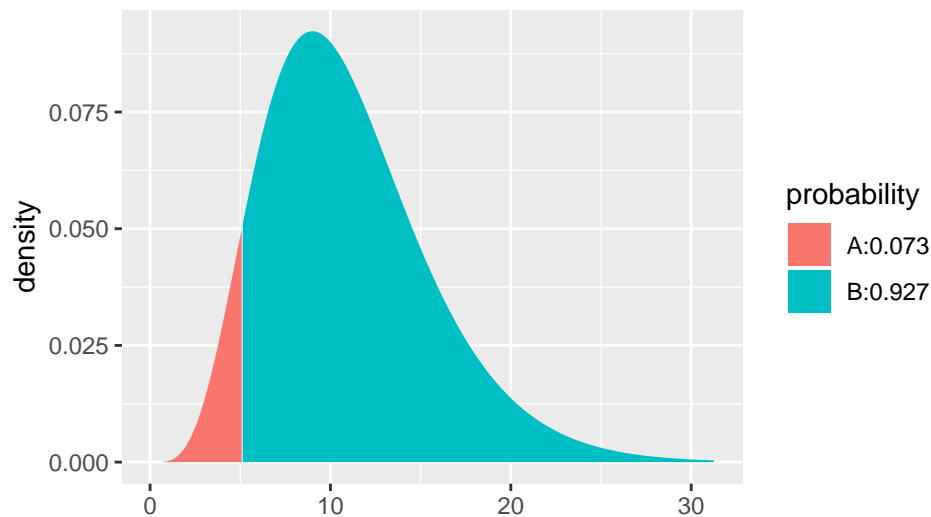
```
# Mechanics
df <- nrow(Zodiac) - 1
df

## [1] 11

Zodiac %>%
  mutate(chisq = ((Births - Expected)^2)/Expected) %>%
  summarise(sum(chisq))

## # A tibble: 1 x 1
##   `sum(chisq)`
##         <dbl>
## 1           5.09

xpchisq(q = 5.09, df = df, lower.tail = FALSE)
```



```
## [1] 0.9267297
```

The Chi-Square Calculation

```
Zodiac %>%
  mutate(residsq = Residual^2) %>%
  mutate(component = residsq/Expected)
```

```
## # A tibble: 12 x 6
##   Month      Births Expected Residual residsq component
##   <chr>      <int>    <dbl>    <dbl>    <dbl>    <dbl>
## 1 Pisces         29     21.3     7.67    58.8     2.76
## 2 Aquarius        24     21.3     2.67     7.11    0.333
## 3 Aries          23     21.3     1.67     2.78    0.130
## 4 Cancer         23     21.3     1.67     2.78    0.130
## 5 Capricorn       22     21.3     0.667    0.445    0.0209
## 6 Scorpio         21     21.3    -0.333    0.111    0.00520
## 7 Taurus          20     21.3    -1.33     1.78    0.0833
## 8 Leo             20     21.3    -1.33     1.78    0.0833
## 9 Saggitarius     19     21.3    -2.33     5.44    0.255
## 10 Virgo           19     21.3    -2.33     5.44    0.255
## 11 Libra           18     21.3    -3.33    11.1     0.521
## 12 Gemini          18     21.3    -3.33    11.1     0.521
```

The Trouble with Goodness-of-Fit Tests: What's the Alternative?

Section 19.2: Chi-Square Test of Homogeneity

```
# Create the data set
Postgrad <- rbind(
  do(209) * data.frame(activity = "Employed", school = "Agriculture"),
  do(198) * data.frame(activity = "Employed", school = "Arts & Sciences"),
  do(177) * data.frame(activity = "Employed", school = "Engineering"),
  do(101) * data.frame(activity = "Employed", school = "ILR"),
  do(104) * data.frame(activity = "Grad School", school = "Agriculture"),
  do(171) * data.frame(activity = "Grad School", school = "Arts & Sciences"),
  do(158) * data.frame(activity = "Grad School", school = "Engineering"),
  do(33) * data.frame(activity = "Grad School", school = "ILR"),
  do(135) * data.frame(activity = "Other", school = "Agriculture"),
  do(115) * data.frame(activity = "Other", school = "Arts & Sciences"),
  do(39) * data.frame(activity = "Other", school = "Engineering"),
  do(16) * data.frame(activity = "Other", school = "ILR")
)
```

```
# Table 19.1, page 618
tally(activity ~ school, data = Postgrad, margins = TRUE)
```

```
##           school
## activity  Agriculture Arts & Sciences Engineering ILR
##   Employed         209           198           177 101
##   Grad School       104           171           158 33
##   Other            135           115            39 16
##   Total            448           484           374 150
```

```
# Table 19.2
tally(activity ~ school, format = "percent", data = Postgrad, margins = TRUE)
```

```
##          school
## activity  Agriculture Arts & Sciences Engineering    ILR
##   Employed    46.65179    40.90909    47.32620  67.33333
##   Grad School   23.21429    35.33058    42.24599  22.00000
##   Other        30.13393    23.76033    10.42781  10.66667
##   Total        100.00000   100.00000   100.00000 100.00000
```

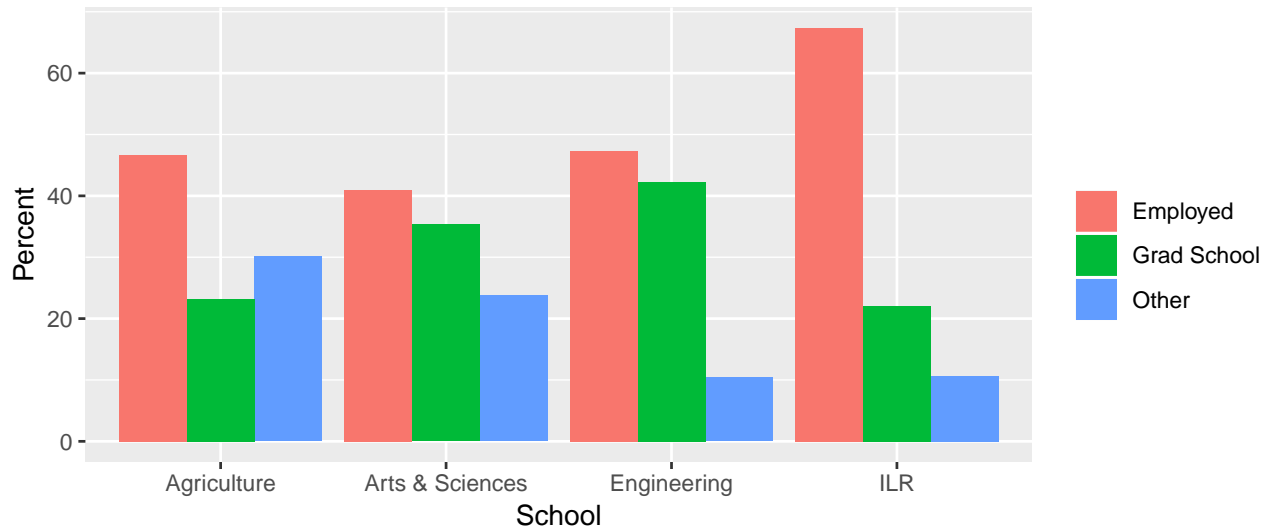
Table 19.3

```
with(chisq.test(tally(activity ~ school, data = Postgrad, margins = TRUE)), expected)
```

```
##          school
## activity  Agriculture Arts & Sciences Engineering    ILR
##   Employed   210.76923   227.7060   175.95467  70.57005
##   Grad School 143.38462   154.9066   119.70055  48.00824
##   Other       93.84615   101.3874    78.34478  31.42170
##   Total      448.00000   484.0000   374.00000 150.00000
```

Step-By-Step Example: A Chi-Square Test for Homogeneity

```
tally(activity ~ school, format = "percent", data = Postgrad) %>%
  data.frame() %>%
  gf_col(Freq ~ school, fill = ~ activity, position = "dodge") %>%
  gf_labs(x = "School", y = "Percent", fill = "")
```



Mechanics

```
tally(activity ~ school, data = Postgrad, margins = TRUE)
```

```
##          school
## activity  Agriculture Arts & Sciences Engineering ILR
##   Employed      209      198      177  101
##   Grad School    104      171      158   33
##   Other         135      115       39   16
##   Total         448      484      374  150
```

```
with(chisq.test(tally(activity ~ school, data = Postgrad, margins = TRUE)), expected)
```

```
##          school
## activity  Agriculture Arts & Sciences Engineering    ILR
##   Employed   210.76923   227.7060   175.95467  70.57005
```

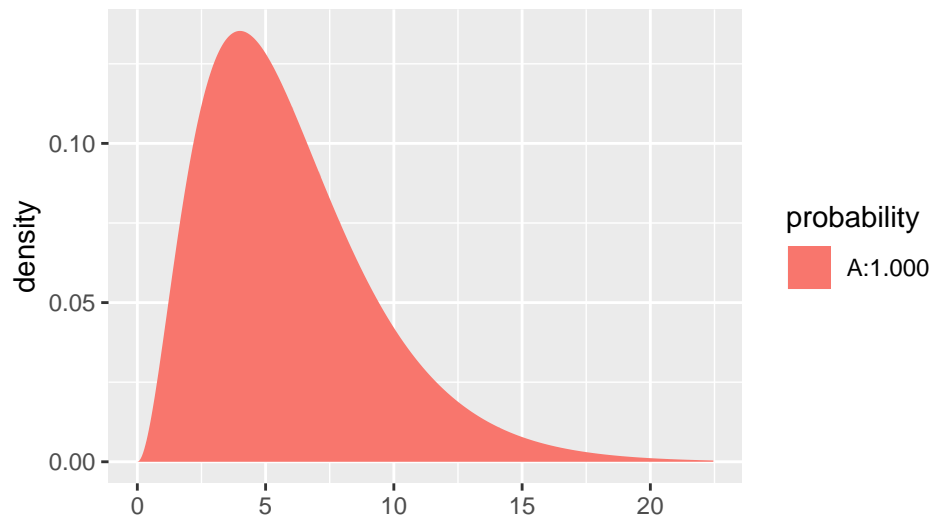
```
##   Grad School   143.38462      154.9066   119.70055  48.00824
##   Other         93.84615      101.3874    78.34478  31.42170
##   Total        448.00000      484.0000   374.00000 150.00000
```

```
with(chisq.test(tally(activity ~ school, data = Postgrad)), statistic)
```

```
## X-squared
```

```
## 93.65667
```

```
xpchisq(q = 93.7, df = 6, lower.tail = FALSE)
```



```
## [1] 5.154981e-18
```

Section 19.3: Examining the Residuals

Table 19.4, page 622

```
with(chisq.test(tally(activity ~ school, data = Postgrad, margins = TRUE)), residuals)
```

```
##           school
## activity  Agriculture Arts & Sciences Engineering      ILR
## Employed  -0.12186553   -1.96860027  0.07880484  3.62235442
## Grad School -3.28908677    1.29304319  3.50061599 -2.16606715
## Other      4.24817296    1.35191804 -4.44510568 -2.75117035
## Total      0.00000000    0.00000000  0.00000000  0.00000000
```

Example 19.4: Looking at χ^2 , Residuals

BaseballBirths %>%

```
mutate(residuals = (ballplayer_count - expected)/(expected^.5)) %>%
select(month, residuals)
```

```
##   month  residuals
## 1     1  1.72524439
## 2     2  1.72442119
## 3     3 -0.20599933
## 4     4  0.25382060
## 5     5  0.71364054
## 6     6 -0.38992730
```

```
## 7      7 -2.68957291
## 8      8  2.77280921
## 9      9  0.08497039
## 10     10 -1.56241469
## 11     11 -1.21760318
## 12     12 -0.95548335
```

Section 19.4: Chi-Square Test of Independence

```
Tattoos <- read_csv("http://nhorton.people.amherst.edu/is5/data/Tattoos.csv", skip = 1) %>%
  clean_names() # skip = 1 because first row is "Col1", "Col2"
```

```
## Parsed with column specification:
## cols(
##   Location = col_character(),
##   `Has hepatitis C` = col_character()
## )
```

Table 19.5, page 623

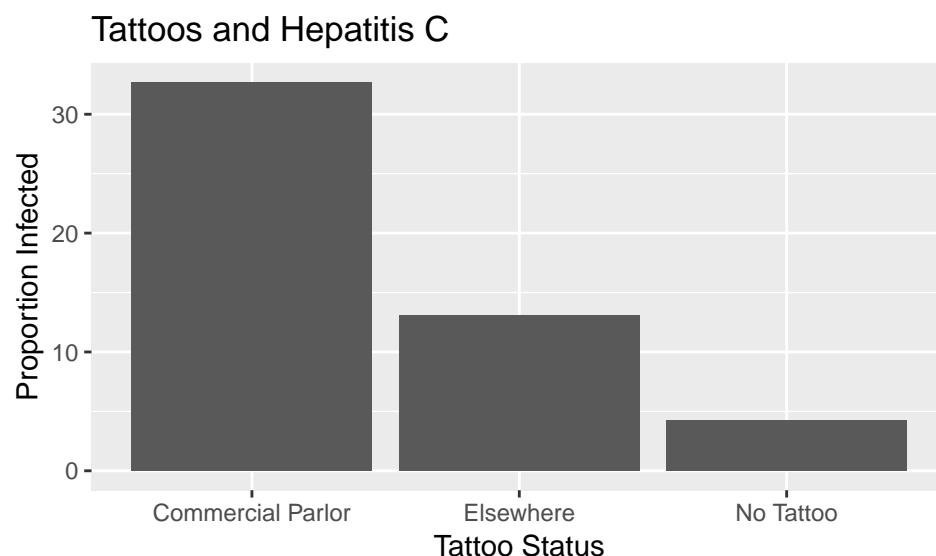
```
tally(location ~ has_hepatitis_c, data = Tattoos, margins = TRUE)
```

```
##               has_hepatitis_c
## location           No Yes
## Commercial Parlor    35  17
## Elsewhere            53   8
## No Tattoo           491  22
## Total               579  47
```

Assumptions and Conditions

Step-By-Step Example: A Chi-Square Test for Independence

```
tally(has_hepatitis_c ~ location, format = "percent", data = Tattoos) %>%
  data.frame() %>%
  filter(has_hepatitis_c == "Yes") %>%
  gf_col(Freq ~ location) %>%
  gf_labs(x = "Tattoo Status", y = "Proportion Infected", title = "Tattoos and Hepatitis C")
```

```
# Observed
tally(location ~ has_hepatitis_c, data = Tattoos, margins = TRUE)

##               has_hepatitis_c
## location                No  Yes
## Commercial Parlor    35   17
## Elsewhere            53    8
## No Tattoo           491   22
## Total               579   47

# Expected
with(chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos, margins = TRUE)), expected)

## Warning in chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos, :
## Chi-squared approximation may be incorrect

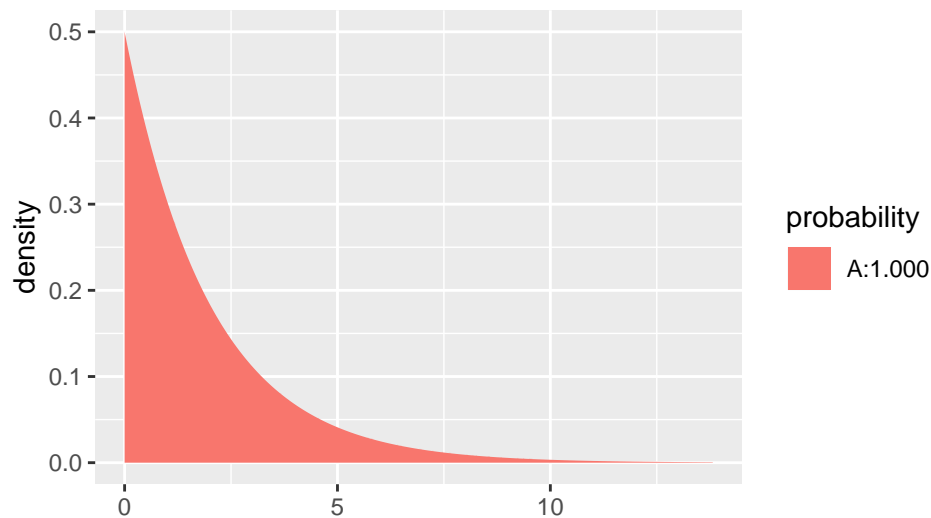
##               has_hepatitis_c
## location                No    Yes
## Commercial Parlor  48.09585  3.904153
## Elsewhere         56.42013  4.579872
## No Tattoo        474.48403 38.515974
## Total            579.00000 47.000000

# Mechanics
with(chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos)), statistic)

## Warning in chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos)):
## Chi-squared approximation may be incorrect

## X-squared
##  57.91217

xpchisq(q = 57.9, df = 2, lower.tail = FALSE)
```



```
## [1] 2.674082e-13
```

Examine the Residuals

```
# Table 19.6, page 627
with(chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos)), residuals)
```

```
## Warning in chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos)):
## Chi-squared approximation may be incorrect
```

```
##               has_hepatitis_c
## location           No       Yes
## Commercial Parlor -1.8883383  6.6278115
## Elsewhere         -0.4553290  1.5981431
## No Tattoo          0.7582168 -2.6612383
```

```
# Table 19.7, page 628
Tattoos <- Tattoos %>%
  mutate(tattoo = ifelse(location == "No Tattoo", "None", "Tattoo"))
tally(tattoo ~ has_hepatitis_c, margins = TRUE, data = Tattoos)
```

```
##               has_hepatitis_c
## tattoo           No Yes
## None           491  22
## Tattoo          88  25
## Total           579  47
```

Chi-Square and Causation