

Basic Course on **R**:  
Hypothesis Testing and Confidence Intervals 1  
Practical Answers

Elizabeth Ribble\*

28 Oct - 1 Nov 2019

## Contents

1	Baby Data	2
---	-----------	---

---

\*emcclel3@msudenver.edu

# 1 Baby Data

1. Read in the data “R\_data\_January2015.csv” with a header and row names from the first column. Assign it to the object `babydata` and allow strings be converted to factors. Attach the data to the environment.

```
babydata <- read.csv("R_data_January2015.csv", header = T, row.names = 1)
attach(babydata)
```

```
## The following objects are masked from babies (pos = 4):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,
##   pregnancy_length_weeks, SAH, SAM, smoking, Status,
##   triglycerides, vitaminB12
##
## The following objects are masked from babies (pos = 5):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,
##   pregnancy_length_weeks, SAH, SAM, smoking, Status,
##   triglycerides, vitaminB12
##
## The following objects are masked from babies (pos = 8):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,
##   pregnancy_length_weeks, SAH, SAM, smoking, Status,
##   triglycerides, vitaminB12
##
## The following objects are masked from babies (pos = 10):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,
##   pregnancy_length_weeks, SAH, SAM, smoking, Status,
##   triglycerides, vitaminB12
##
## The following objects are masked from babies (pos = 11):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
```

```

##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babydata (pos = 18):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babies (pos = 19):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babydata (pos = 20):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babydata (pos = 33):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babydata (pos = 34):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babies (pos = 35):
##

```

```

##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babydata (pos = 36):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babies (pos = 37):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babydata (pos = 38):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babydata (pos = 39):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

## The following objects are masked from babies (pos = 40):
##
##      alcohol, birthweight, BMI, cholesterol, educational_level,
##      folicacid_erys, folicacid_serum, HDL, homocysteine,
##      iodine_deficiency, medication, pregnancy_length_days,
##      pregnancy_length_weeks, SAH, SAM, smoking, Status,
##      triglycerides, vitaminB12

```

```

## The following objects are masked from babydata (pos = 41):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,
##   pregnancy_length_weeks, SAH, SAM, smoking, Status,
##   triglycerides, vitaminB12
## The following objects are masked from babies (pos = 42):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,
##   pregnancy_length_weeks, SAH, SAM, smoking, Status,
##   triglycerides, vitaminB12
## The following objects are masked from babies (pos = 43):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,
##   pregnancy_length_weeks, SAH, SAM, smoking, Status,
##   triglycerides, vitaminB12
## The following objects are masked from babydata (pos = 48):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,
##   pregnancy_length_weeks, SAH, SAM, smoking, Status,
##   triglycerides, vitaminB12
## The following objects are masked from babies (pos = 50):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,
##   pregnancy_length_weeks, SAH, SAM, smoking, Status,
##   triglycerides, vitaminB12
## The following objects are masked from babydata (pos = 51):
##
##   alcohol, birthweight, BMI, cholesterol, educational_level,
##   folicacid_erys, folicacid_serum, HDL, homocysteine,
##   iodine_deficiency, medication, pregnancy_length_days,

```

```
## pregnancy_length_weeks, SAH, SAM, smoking, Status,
## triglycerides, vitaminB12
```

2. What are the dimensions of `babydata`? What is the class? Answer these questions separately with two functions and then together with one function.

```
dim(babydata)

## [1] 190 19

class(babydata)

## [1] "data.frame"

str(babydata)

## 'data.frame': 190 obs. of 19 variables:
## $ Status : Factor w/ 2 levels "intellectual disability",...: 1 2 1
## $ iodine_deficiency : Factor w/ 2 levels "no","yes": 1 1 1 2 1 1 2 2 2 2 ...
## $ BMI : int 32 23 29 22 22 24 24 28 33 32 ...
## $ educational_level : Factor w/ 3 levels "high","intermediate",...: 2 2 3 3 3
## $ alcohol : Factor w/ 2 levels "no","yes": 1 2 1 1 2 2 2 2 2 1 ...
## $ smoking : Factor w/ 2 levels "no","yes": 1 2 1 1 1 1 1 1 2 1 ...
## $ medication : Factor w/ 2 levels "no","yes": 1 1 1 1 1 1 1 1 1 1 ...
## $ birthweight : int 2618 3541 2619 3810 4136 4030 3377 2500 4255 2952
## $ pregnancy_length_weeks: int 38 40 38 40 42 41 40 37 42 39 ...
## $ pregnancy_length_days : int 4 2 3 5 3 1 4 1 0 2 ...
## $ SAM : num 54.5 84 61 43 83 69 79 71.5 56 42.5 ...
## $ SAH : num 14.8 23.6 18.7 23.2 17.1 19.6 22.4 18 20 23.4 ..
## $ homocysteine : num 18.8 15.6 15.2 16.5 19.5 17.5 14.9 22.2 19.1 16 .
## $ cholesterol : num 16.5 17.5 16.4 16.4 16.9 15.9 16.9 16 18.6 16.7 .
## $ HDL : num 26.1 26.7 26.2 25.9 26.7 ...
## $ triglycerides : num 8.84 7.78 7.54 8.95 7.57 7.35 7.63 7.38 8.25 8.27
## $ vitaminB12 : int 303 370 533 346 389 611 604 518 288 520 ...
## $ folicacid_serum : num 26.4 37.8 33.7 35.1 29 28.3 33.8 31.1 27.7 33.4 .
## $ folicacid_erys : num 1132 1467 1528 1539 1178 ...
```

3. Answer the following questions pertaining to the variable `SAH`:

- (a) What are the 20% quantiles of `SAH`?

```
quantile(SAH,seq(0,1,.2))

##      0%      20%      40%      60%      80%     100%
##  9.40 14.80 16.46 18.00 19.82 28.50
```

- (b) What are the mean, median, variance and standard deviation of SAH?

```
summary(SAH)

##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   9.40   15.22   17.30   17.59   19.07   28.50

## or
mean(SAH)

## [1] 17.59053

median(SAH)

## [1] 17.3

vs <- var(SAH)
vs

## [1] 11.26901

sqrt(vs)

## [1] 3.356935
```

- (c) Create a stem and leaf plot of SAH.

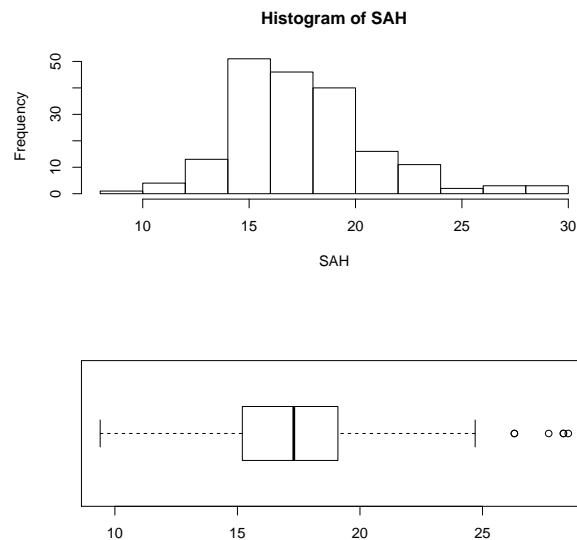
```
stem(SAH)

##
##      The decimal point is at the |
##
##      9 | 4
##     10 | 7
##     11 | 355
##     12 | 135
##     13 | 146677999
##     14 | 0111122333455666777888899
##     15 | 0000123333455777889999
##     16 | 0000011233345557788999
##     17 | 001111223333456777788889
```

```
## 18 | 0000011122223344445555666789
## 19 | 000011222368889
## 20 | 0022245567899
## 21 | 2669
## 22 | 014
## 23 | 011124567
## 24 | 67
## 25 |
## 26 | 33
## 27 | 7
## 28 | 335
```

- (d) Create a histogram and a horizontal boxplot of SAH in one graphics window where the plot of the histogram is above the boxplot.

```
par(mfrow=c(2,1))
hist(SAH)
boxplot(SAH, horizontal=TRUE)
```



- (e) Utilize all 3 graphs to describe the shape of the distribution of SAH.

The distribution is unimodal and slightly skewed to the right.

- (f) Log-transform SAH (assign it to logSAH).



```
logSAH <- log(SAH)
```

- (g) What are the 20% quantiles of logSAH?

```
quantile(logSAH,seq(0,1,.2))  
##          0%          20%          40%          60%          80%         100%  
## 2.240710 2.694627 2.800929 2.890372 2.986689 3.349904
```

- (h) What are the mean, median, variance and standard deviation of logSAH?

```
summary(logSAH)  
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.   
##  2.241   2.723   2.851   2.850   2.948   3.350   
  
## or  
mean(logSAH)  
## [1] 2.849985  
  
median(logSAH)  
## [1] 2.850707  
  
vls <- var(logSAH)  
vls  
## [1] 0.03460558  
  
sqrt(vls)  
## [1] 0.1860257
```

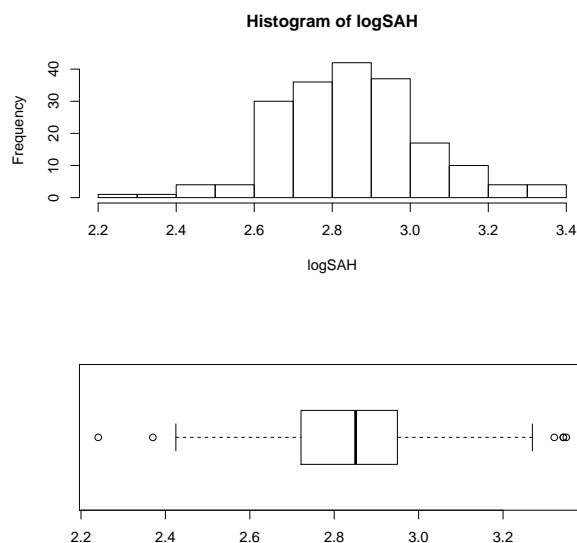
- (i) Create a stem and leaf plot of logSAH.

```
stem(logSAH)  
##  
## The decimal point is 1 digit(s) to the left of the |  
##  
## 22 | 4  
## 23 | 7  
## 24 | 2449  
## 25 | 137  
## 26 | 0112233345555556667778889999999
```

```
## 27 | 00111112333334455556677777777889999
## 28 | 0000222233333444444555566777778888899999
## 29 | 00000001111112222222334444455555689999
## 30 | 001112223334457799
## 31 | 01444445667
## 32 | 0177
## 33 | 2445
```

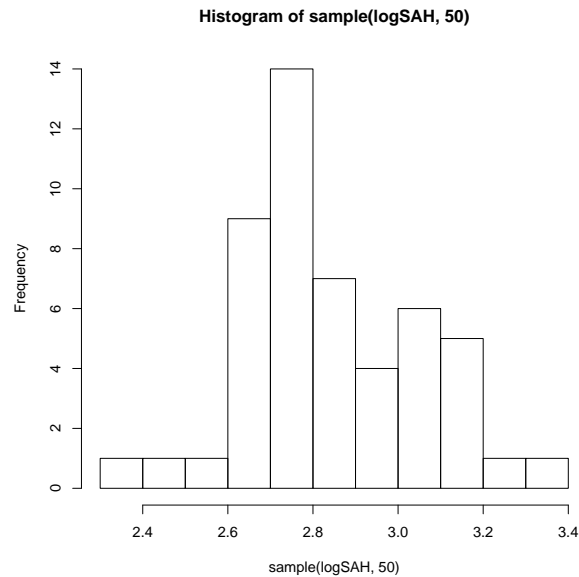
- (j) Create a histogram and a horizontal boxplot of  $\log\text{SAH}$  in one graphics window where the plot of the histogram above the boxplot.

```
par(mfrow=c(2,1))
hist(logSAH)
boxplot(logSAH, horizontal=TRUE)
```



- (k) Utilize all 3 graphs to describe the shape of the distribution of  $\log\text{SAH}$ .  
The distribution is unimodal, symmetric and appears normal.
- (l) What did the log transformation do to the values of  $\text{SAH}$ ?  
Dampened the effect of skewness to make the distribution more normal and symmetric.
- (m) Take a random sample of size 50 from  $\log\text{SAH}$  and make a histogram. Does this distribution have a similar shape compared to that of all  $\log\text{SAH}$  values?

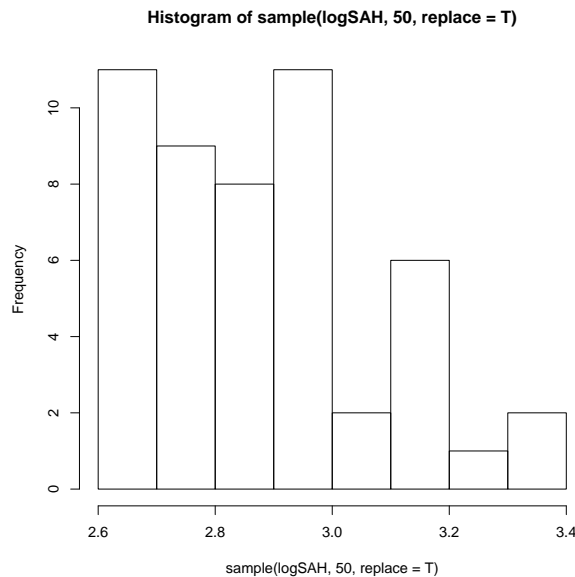
```
set.seed(1234)
hist(sample(logSAH, 50))
```



The distribution looks somewhat similar to that of the complete data.

- (n) Take a random sample of size 50 with replacement from `logSAH` and make a histogram. Does this distribution have a similar shape compared to that of all `logSAH` values?

```
set.seed(1234)
hist(sample(logSAH, 50, replace=T))
```



The distribution looks quite different from the original distribution.

4. Answer the following questions pertaining to the variable `medication`:

- (a) Use a function to create frequency table of the number of mothers taking medication and not taking medication.

```
table(medication)

## medication
##  no yes
## 159  31
```

- (b) Calculate the percent of the mothers are taking medication; what is the percentage?

```
table(medication)/length(medication)

## medication
##          no          yes
## 0.8368421 0.1631579
```

So 16.3% of mothers are taking medication.

5. Answer the following questions pertaining to the variable `educational_level`:

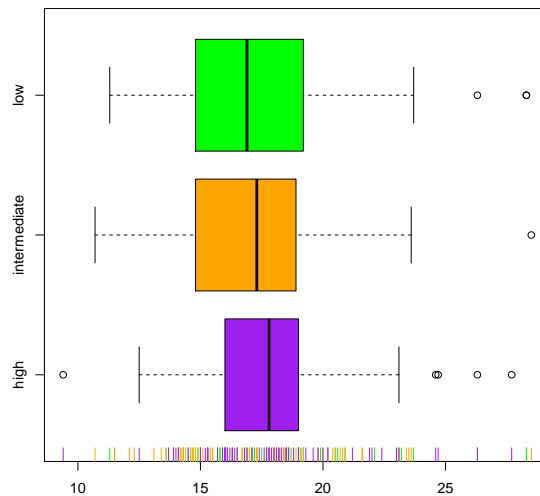
- (a) Create a frequency table of the number of mothers in each education level.

```
table(educational_level)
```

```
## educational_level
##           high intermediate          low
##           63           82           45
```

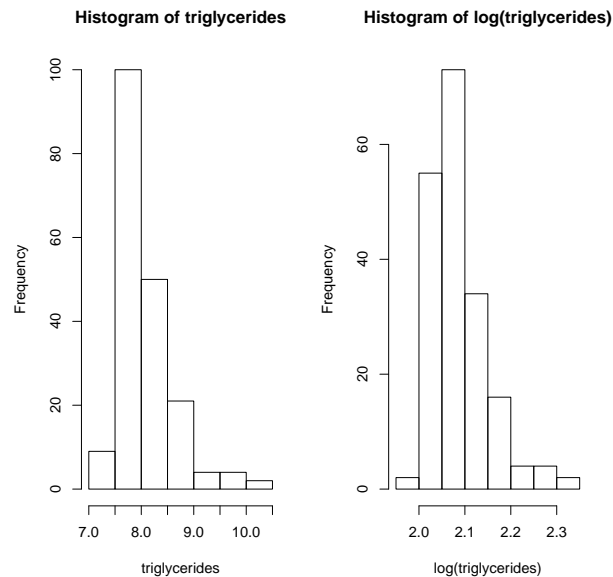
- (b) Create a horizontal boxplot of the **SAH** values for the different levels of education and color each box a different color. Add a rug plot of the values where the ticks for each group have the same color as their corresponding box.

```
boxplot(SAH ~ educational_level, horizontal=TRUE,
        col=c("purple", "orange", "green"))
rug(SAH[educational_level=="low"], col="green")
rug(SAH[educational_level=="intermediate"], col="orange")
rug(SAH[educational_level=="high"], col="purple")
```



- (c) Are **triglycerides** normally distributed (make a plot to answer this question)? If not, log-transform them. Are the log-transformed values normal?

```
par(mfrow=c(1,2))
hist(triglycerides)
hist(log(triglycerides))
```

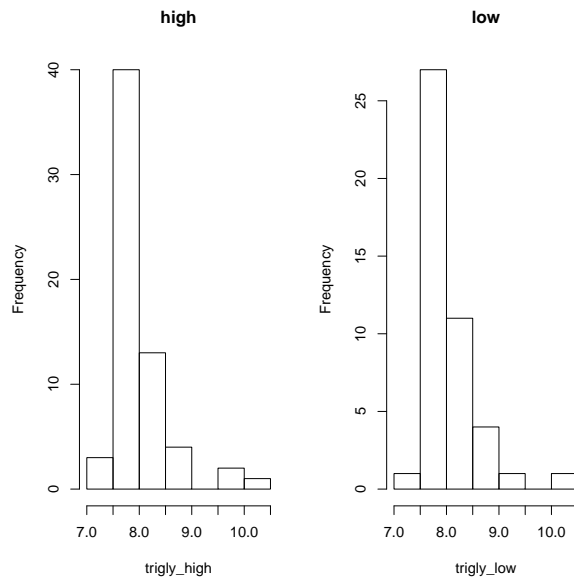


The values are skewed to the right and are still skewed after a log transformation.

- (d) Is the average triglyceride level for highly educated mothers different from that of mothers with a low education level? Formulate a hypothesis, test it, and make a decision about whether or not you can reject the null hypothesis. Can you use a  $t$ -test (either on the raw or log-transformed data)? Why or why not (hint: how are the data distributed)?

We cannot use the  $t$ -test because the data are not normally distributed, even after a log transformation! However, since the shapes of the distributions are similar, as evidence by the below plot, we can perform a Wilcoxon Rank Sum test.

```
trigly_high <- triglycerides[educational_level=="high"]
trigly_low <- triglycerides[educational_level=="low"]
par(mfrow=c(1,2))
hist(trigly_high, main = "high")
hist(trigly_low, main = "low")
```



Our null hypothesis is that the difference in location between the low and high education levels is 0. The alternative hypothesis is that there is a difference.

```
wilcox.test(trigly_high, trigly_low)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  trigly_high and trigly_low
## W = 1328, p-value = 0.5791
## alternative hypothesis: true location shift is not equal to 0
```

The  $p$ -value is not less than 0.05 so we fail to reject the null and conclude that we do not have enough evidence to show a statistically significant difference between the centers of the high and low mothers' triglycerides.

- (e) Now re-do the test and make your decision to reject/not reject the null based on the confidence interval. Challenge: extract the confidence interval from the test output and use logical operators to answer the question of whether the interval contains the null value.

```
wtest <- wilcox.test(trigly_high, trigly_low, conf.int=TRUE)
ciw <- wtest$conf.int
0 > ciw[1] & 0 < ciw[2]

## [1] TRUE
```

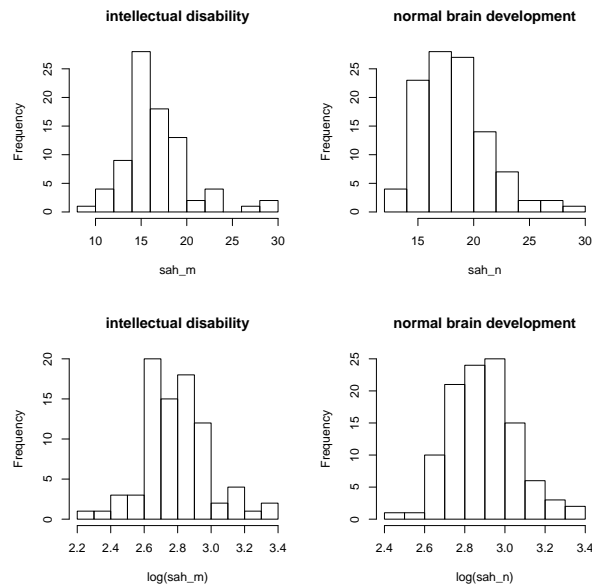
Since the confidence interval contains 0, we fail to reject the null.

6. Answer the following questions pertaining to the variable **Status**:

- (a) Are the average SAH values for the two levels of **Status** (normal brain development or intellectual disability) different? Formulate a hypothesis, test it, and make a decision about whether or not you can reject the null hypothesis. Can you use a  $t$ -test (either on the raw or log-transformed data)? Why or why not (hint: check distributions with plots)?

We can use the  $t$ -test on the log-transformed data, since they are normally distributed, as shown in the plots below.

```
sah_m <- SAH[Status=="intellectual disability"]
sah_n <- SAH[Status=="normal brain development"]
par(mfrow=c(2,2))
hist(sah_m, main = "intellectual disability")
hist(sah_n, main = "normal brain development")
hist(log(sah_m), main = "intellectual disability")
hist(log(sah_n), main = "normal brain development")
```



Our null hypothesis is that the difference in mean SAH between the two groups is 0. The alternative hypothesis is that there is a difference in means.

```
sstest <- t.test(log(SAH)~Status)
sstest

##
##  Welch Two Sample t-test
##
```



```
## data: log(SAH) by Status
## t = -3.8522, df = 152.24, p-value = 0.0001721
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
## -0.15753466 -0.05072509
## sample estimates:
## mean in group intellectual disability
## 2.790795
## mean in group normal brain development
## 2.894925

sstest$p.value

## [1] 0.0001720599

sstest$conf.int

## [1] -0.15753466 -0.05072509
## attr(,"conf.level")
## [1] 0.95
```

The  $p$ -value is less than 0.05 (and 0 is not in the CI) so we can reject the null hypothesis that the difference in means between the two groups is 0. We conclude that there is a statistically significant difference between the average log-SAH of mothers with intellectually disabled children and the average log-SAH of those women whose children have normal brain development.

- (b) What is the fold change of log-SAH between the 2 groups? Calculate it two ways: use the output from the previous test and also use the data itself (function `mean` plus logical operators).

```
sstest$estimate[2]/sstest$estimate[1]

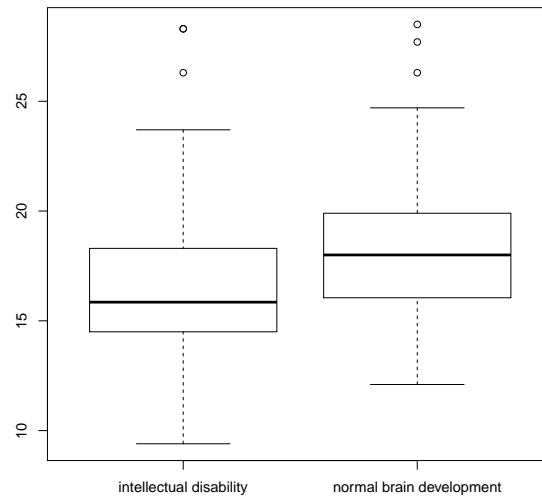
## mean in group normal brain development
## 1.037312

mean(log(SAH)[Status=="normal brain development"])/
  mean(log(SAH)[Status=="intellectual disability"])

## [1] 1.037312
```

- (c) Make a boxplot of the SAH values of the 2 groups and calculate the fold change of SAH between the 2 groups. Does the difference seem clinically relevant? Why or why not?

```
boxplot(SAH ~ Status)
```



```
mean(SAH[Status=="normal brain development"])/  
  mean(SAH[Status=="intellectual disability"])  
  
## [1] 1.101694
```

The fold change is really close to one and there is actually quite a bit of overlap in the boxplots. The statistically significant difference of the log-transformed data is quite subtle and may not be relevant, though further investigation of confounding factors may elucidate the true relationship between SAH and brain development.