

**STAT:5400**  
**Computing in Statistics**

**Introduction to R**

Lecture 5  
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Kate Cowles  
 374 SH, 335-0727  
 kate-cowles@uiowa.edu

**What R is**

- “an integrated suite of software facilities for data manipulation, calculation, and graphics display” (*An Introduction to R*, Venables, Ripley, and the R Core team)
  - data handling and storage capabilities
  - operators for calculations on arrays and matrices
  - data analysis tools
  - graphical capabilities
  - programming language
  - planned and coherent system

- an implementation of S language
  - S language was developed at AT&T-Bell Labs
    - \* first version 1976
  - S-Plus is a commercial version of S (begin in 1987)
    - \* sold and supported by Insightful Corp.
    - \* GUI
    - \* many formats supported for graphics export and data input/output
    - \* runs on Windows, UNIX, Linux (not Macintosh)

- advantages of S
  - extendible
    - \* users write new functions in S language — just as developers do
    - \* excellent documentation for adding functions to system
    - \* users can create their own data types
    - \* huge international community of users constantly contribute new capabilities
    - \* contrast with SAS
      - very hard to write new SAS procedures
      - users write in different language (SAS macro or IML) than developers
  - high-level language
    - \* only a few commands required to do complex things

- language is connected to data while executing
- example (from *Statistical Computing and Graphics* course notes by Frank Harrell)

```
if(is.factor(x) | is.character(x) |
  (is.numeric(x) & length(unique(x)) < 20))
  table(x) else quantile(x)
```

computes quantiles of **x** if **x** is numeric and has at least 20 distinct values, frequency table otherwise

- object-oriented
  - \* fewer commands to learn because the same command can be applied to different types of objects
- Harrell: “best scientific graphics available”
  - \* Harrell: “SAS graphics are ugly, inflexible, have poor defaults, difficult to program”

## Starting and running R interactively on Linux

- strongly recommended to use a separate subdirectory for each major R project. You might want one subdirectory for your homework assignments, and another for your group project.
- begin by creating the subdirectory
- copy in or download any needed data files
- then invoke R in that subdirectory

```
[kcowles@p-lnx402 ~]$ mkdir examples166
[kcowles@p-lnx402 ~]$ cd examples166
[kcowles@p-lnx402 ~/examples166]$ ls -a
.
..
[kcowles@p-lnx402 ~/examples166]$ R
```

## R

- international team of statisticians started developing R in early 1990’s
  - to provide open source alternative to S-Plus
  - to provide S implementation on Linux (not supported by S-Plus then)
- easy to download and install from web sites
- excellent documentation
- user-contributed libraries called packages expand capabilities
- runs on Windows, UNIX, Linux, Macintosh
- no GUI on most platforms
- fewer data import/export capabilities than S-Plus
  - although add-on packages provide more
  - no export specifically to Powerpoint

## Running R interactively from within Emacs

- this method is convenient when you want to record your R commands and output in a document (such as a homework assignment)
- in your subdirectory, start Emacs as a background process

```
emacs &
```

- once Emacs is up, start a second window by choosing File / New frame
- start R in one of the frames by typing

```
Alt-X R
```

You will be prompted to enter the directory in which you want R to start. Just press Enter to accept the default (if it’s what you want).

- in the other window, use File /Visit new file and type in a file name when prompted

- now you can copy R commands and output from the R window into your emacs file

## Reading in data from external files

- Use Firefox to download `Cars.dat` from “Datasets” section of course web page into this directory.

```
[kcowles@p-lnx402 ~/examples166]$ ls
Cars.dat
```

- Use a text editor to look at this file. Note that the separators between columns are tabs (You can tell because the cursor jumps) and that the decimal point in numbers is indicated by periods.
- We need to read this file into an **object** in R to analyze it. R has several functions that read in data files in different formats.
- We will use R’s built-in help facility to figure out which one to use.

```
[kcowles@p-lnx402 ~/examples166]$ R

R version 2.7.1 (2008-06-23)
Copyright (C) 2008 The R Foundation for Statistical Computing
ISBN 3-900051-07-0

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
```

```
> help(read.delim)

read.table          package:utils          R Documentation

Data Input

Description:

  Reads a file in table format and creates a data frame from it,
  with cases corresponding to lines and variables to fields in the
  file.

Usage:

  read.table(file, header = FALSE, sep = "\t", quote = "\"",
             dec = ".", row.names, col.names,
             as.is = !stringsAsFactors,
             na.strings = "NA", colClasses = NA, nrows = -1,
             skip = 0, check.names = TRUE, fill = !blank.lines.skip,
             strip.white = FALSE, blank.lines.skip = TRUE,
             comment.char = "#",
             allowEscapes = FALSE, flush = FALSE,
             stringsAsFactors = default.stringsAsFactors(),
             encoding = "unknown")
  read.csv(file, header = TRUE, sep = ",", quote = "\"", dec = ".",
           fill = TRUE, comment.char = "...")
  read.csv2(file, header = TRUE, sep = ";", quote = "\"", dec = ".",
            fill = TRUE, comment.char = "...")
  read.delim(file, header = TRUE, sep = "\t", quote = "\"", dec = ".",
             fill = TRUE, comment.char = "...")
  read.delim2(file, header = TRUE, sep = "\t", quote = "\"", dec = ".",
              fill = TRUE, comment.char = "...")

..... lots of additional detail .....
```

```

> Cars <- read.delim("Cars.dat")      # <- is assignment operator

> str(Cars)                            # find out structure of the object
'data.frame':   38 obs. of  8 variables:
 $ Country      : Factor w/ 6 levels "France","Germany",...: 6 6 6 6 6 4 4 6 2 5 ...
 $ Car          : Factor w/ 38 levels "AMC Concord D/L",...: 6 21 11 12 8 34 14 18 3 35 ...
 $ MPG         : num  16.9 15.5 19.2 18.5 30 27.5 27.2 30.9 20.3 17 ...
 $ Weight      : num  4.36 4.05 3.60 3.94 2.15 ...
 $ Drive_Ratio : num  2.73 2.26 2.56 2.45 3.7 3.05 3.54 3.37 3.9 3.5 ...
 $ Horsepower  : int  155 142 125 150 68 95 97 75 103 125 ...
 $ Displacement: int  350 351 267 360 98 134 119 105 131 163 ...
 $ Cylinders   : int  8 8 8 8 4 4 4 4 5 6 ...

```

## Data frames

- special kind of object
- like a table of data
  - row for each observation
  - column for each variable
- variables (columns) can be of different data types
  - numeric, character, factors

```

> Cars
  Country      Car  MPG Weight Drive_Ratio Horsepower
1  U.S.      Buick Estate Wagon 16.9 4.360      2.73      155
2  U.S. Ford Country Squire Wagon 15.5 4.054      2.26      142
3  U.S.      Chevy Malibu Wagon 19.2 3.605      2.56      125
4  U.S.      Chrysler LeBaron Wagon 18.5 3.940      2.45      150
5  U.S.      Chevette 30.0 2.155      3.70      68
6  Japan     Toyota Corona 27.5 2.560      3.05      95
7  Japan     Datsun 510 27.2 2.300      3.54      97
8  U.S.      Dodge Omni 30.9 2.230      3.37      75
9  Germany   Audi 5000 20.3 2.830      3.90      103
10 Sweden   Volvo 240 GL 17.0 3.140      3.50      125
11 Sweden   Saab 99 GLE 21.6 2.795      3.77      115
12 France   Peugeot 694 SL 16.2 3.410      3.58      133
.....
  Displacement Cylinders
1          350          8
2          351          8
3          267          8
4          360          8
5           98          4
6          134          4
.....

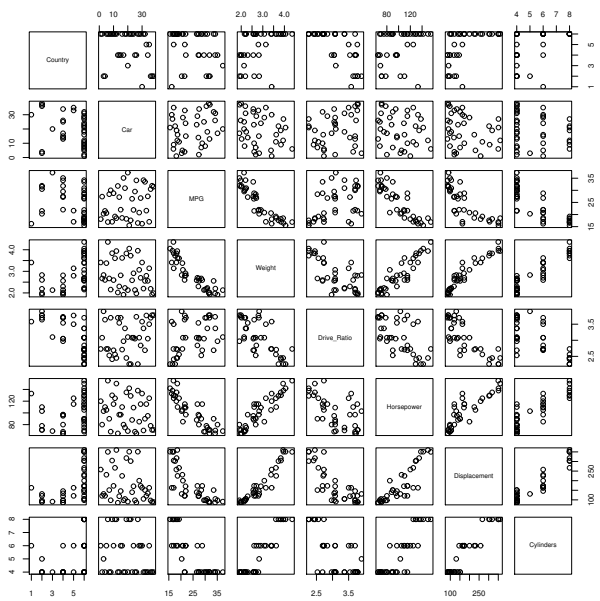
```

```

> summary(Cars)
  Country      Car      MPG      Weight
France : 1  AMC Concord D/L      : 1  Min.   :15.50  Min.   :1.915
Germany: 5  AMC Spirit          : 1  1st Qu.:18.52  1st Qu.:2.208
Italy  : 1  Audi 5000           : 1  Median :24.25  Median :2.685
Japan  : 7  BMW 320i            : 1  Mean   :24.76  Mean   :2.863
Sweden : 2  Buick Century Special: 1  3rd Qu.:30.38  3rd Qu.:3.410
U.S.   :22  Buick Estate Wagon : 1  Max.   :37.30  Max.   :4.360
      (Other)                :32
  Drive_Ratio  Horsepower  Displacement  Cylinders
Min.   :2.260  Min.   : 65.0  Min.   : 85.0  Min.   :4.000
1st Qu.:2.695  1st Qu.: 78.5  1st Qu.:105.0  1st Qu.:4.000
Median :3.080  Median :100.0  Median :148.5  Median :4.500
Mean   :3.093  Mean   :101.7  Mean   :177.3  Mean   :5.395
3rd Qu.:3.625  3rd Qu.:123.8  3rd Qu.:229.5  3rd Qu.:6.000
Max.   :3.900  Max.   :155.0  Max.   :360.0  Max.   :8.000

```

```
> plot(Cars)
```



```
> hist(Cars$MPG) # can use $ to refer to column name in data frame
```

```
> Cars[, c("Country", "MPG", "Weight")]
```

|    | Country | MPG  | Weight |
|----|---------|------|--------|
| 1  | U.S.    | 16.9 | 4.360  |
| 2  | U.S.    | 15.5 | 4.054  |
| 3  | U.S.    | 19.2 | 3.605  |
| 4  | U.S.    | 18.5 | 3.940  |
| 5  | U.S.    | 30.0 | 2.155  |
| 6  | Japan   | 27.5 | 2.560  |
| 7  | Japan   | 27.2 | 2.300  |
| 8  | U.S.    | 30.9 | 2.230  |
| 9  | Germany | 20.3 | 2.830  |
| 10 | Sweden  | 17.0 | 3.140  |
| 11 | Sweden  | 21.6 | 2.795  |
| 12 | France  | 16.2 | 3.410  |
| 13 | U.S.    | 20.6 | 3.380  |
| 14 | U.S.    | 20.8 | 3.070  |
| 15 | U.S.    | 18.6 | 3.620  |
| 16 | U.S.    | 18.1 | 3.410  |
| 17 | U.S.    | 17.0 | 3.840  |
| 18 | U.S.    | 17.6 | 3.725  |
| 19 | U.S.    | 16.5 | 3.955  |
| 20 | U.S.    | 18.2 | 3.830  |
| 21 | U.S.    | 26.5 | 2.585  |
| 22 | U.S.    | 21.9 | 2.910  |
| 23 | Japan   | 34.1 | 1.975  |
| 24 | Japan   | 35.1 | 1.915  |
| 25 | U.S.    | 27.4 | 2.670  |
| 26 | Germany | 31.5 | 1.990  |
| 27 | Japan   | 29.5 | 2.135  |
| 28 | U.S.    | 28.4 | 2.670  |
| 29 | U.S.    | 28.8 | 2.595  |
| 30 | U.S.    | 26.8 | 2.700  |
| 31 | U.S.    | 33.5 | 2.556  |
| 32 | U.S.    | 34.2 | 2.200  |
| 33 | Japan   | 31.8 | 2.020  |
| 34 | Italy   | 37.3 | 2.130  |
| 35 | Germany | 30.5 | 2.190  |
| 36 | Japan   | 22.0 | 2.815  |
| 37 | Germany | 21.5 | 2.600  |
| 38 | Germany | 31.9 | 1.925  |

### Subsetting rows and columns of a data frame

```
> Cars[1:10,]
```

|    | Country      | Car                       | MPG  | Weight | Drive_Ratio | Horsepower |
|----|--------------|---------------------------|------|--------|-------------|------------|
| 1  | U.S.         | Buick Estate Wagon        | 16.9 | 4.360  | 2.73        | 155        |
| 2  | U.S.         | Ford Country Squire Wagon | 15.5 | 4.054  | 2.26        | 142        |
| 3  | U.S.         | Chevy Malibu Wagon        | 19.2 | 3.605  | 2.56        | 125        |
| 4  | U.S.         | Chrysler LeBaron Wagon    | 18.5 | 3.940  | 2.45        | 150        |
| 5  | U.S.         | Chevette                  | 30.0 | 2.155  | 3.70        | 68         |
| 6  | Japan        | Toyota Corona             | 27.5 | 2.560  | 3.05        | 95         |
| 7  | Japan        | Datsun 510                | 27.2 | 2.300  | 3.54        | 97         |
| 8  | U.S.         | Dodge Omni                | 30.9 | 2.230  | 3.37        | 75         |
| 9  | Germany      | Audi 5000                 | 20.3 | 2.830  | 3.90        | 103        |
| 10 | Sweden       | Volvo 240 GL              | 17.0 | 3.140  | 3.50        | 125        |
|    | Displacement | Cylinders                 |      |        |             |            |
| 1  | 350          | 8                         |      |        |             |            |
| 2  | 351          | 8                         |      |        |             |            |
| 3  | 267          | 8                         |      |        |             |            |
| 4  | 360          | 8                         |      |        |             |            |
| 5  | 98           | 4                         |      |        |             |            |
| 6  | 134          | 4                         |      |        |             |            |
| 7  | 119          | 4                         |      |        |             |            |
| 8  | 105          | 4                         |      |        |             |            |
| 9  | 131          | 5                         |      |        |             |            |
| 10 | 163          | 6                         |      |        |             |            |

```
> Cars[ Cars$Country=="U.S.",]
```

|    | Country      | Car                       | MPG  | Weight | Drive_Ratio | Horsepower |
|----|--------------|---------------------------|------|--------|-------------|------------|
| 1  | U.S.         | Buick Estate Wagon        | 16.9 | 4.360  | 2.73        | 155        |
| 2  | U.S.         | Ford Country Squire Wagon | 15.5 | 4.054  | 2.26        | 142        |
| 3  | U.S.         | Chevy Malibu Wagon        | 19.2 | 3.605  | 2.56        | 125        |
| 4  | U.S.         | Chrysler LeBaron Wagon    | 18.5 | 3.940  | 2.45        | 150        |
| 5  | U.S.         | Chevette                  | 30.0 | 2.155  | 3.70        | 68         |
| 8  | U.S.         | Dodge Omni                | 30.9 | 2.230  | 3.37        | 75         |
| 13 | U.S.         | Buick Century Special     | 20.6 | 3.380  | 2.73        | 105        |
| 14 | U.S.         | Mercury Zephyr            | 20.8 | 3.070  | 3.08        | 85         |
| 15 | U.S.         | Dodge Aspen               | 18.6 | 3.620  | 2.71        | 110        |
| 16 | U.S.         | AMC Concord D/L           | 18.1 | 3.410  | 2.73        | 120        |
| 17 | U.S.         | Chevy Caprice Classic     | 17.0 | 3.840  | 2.41        | 130        |
| 18 | U.S.         | Ford LTD                  | 17.6 | 3.725  | 2.26        | 129        |
| 19 | U.S.         | Mercury Grand Marquis     | 16.5 | 3.955  | 2.26        | 138        |
| 20 | U.S.         | Dodge St Regis            | 18.2 | 3.830  | 2.45        | 135        |
| 21 | U.S.         | Ford Mustang 4            | 26.5 | 2.585  | 3.08        | 88         |
| 22 | U.S.         | Ford Mustang Ghia         | 21.9 | 2.910  | 3.08        | 109        |
| 25 | U.S.         | AMC Spirit                | 27.4 | 2.670  | 3.08        | 80         |
| 28 | U.S.         | Buick Skylark             | 28.4 | 2.670  | 2.53        | 90         |
| 29 | U.S.         | Chevy Citation            | 28.8 | 2.595  | 2.69        | 115        |
| 30 | U.S.         | Olds Omega                | 26.8 | 2.700  | 2.84        | 115        |
| 31 | U.S.         | Pontiac Phoenix           | 33.5 | 2.556  | 2.69        | 90         |
| 32 | U.S.         | Plymouth Horizon          | 34.2 | 2.200  | 3.37        | 70         |
|    | Displacement | Cylinders                 |      |        |             |            |
| 1  | 350          | 8                         |      |        |             |            |
| 2  | 351          | 8                         |      |        |             |            |
| 3  | 267          | 8                         |      |        |             |            |
| 4  | 360          | 8                         |      |        |             |            |
| 5  | 98           | 4                         |      |        |             |            |
| 8  | 105          | 4                         |      |        |             |            |
| 13 | 231          | 6                         |      |        |             |            |
| 14 | 200          | 6                         |      |        |             |            |
| 15 | 225          | 6                         |      |        |             |            |
| 16 | 258          | 6                         |      |        |             |            |
| 17 | 305          | 8                         |      |        |             |            |
| 18 | 302          | 8                         |      |        |             |            |
| 19 | 351          | 8                         |      |        |             |            |
| 20 | 318          | 8                         |      |        |             |            |
| 21 | 140          | 4                         |      |        |             |            |
| 22 | 171          | 6                         |      |        |             |            |

```

25      121      4
28      151      4
29      173      6
30      173      6
31      151      4
32      105      4

```

```

> Cars[ Cars$Country=="Japan",]
  Country      Car  MPG Weight Drive_Ratio Horsepower Displacement
6   Japan Toyota Corona 27.5 2.560      3.05      95      134
7   Japan   Datsun 510 27.2 2.300      3.54      97      119
23  Japan   Mazda GLC 34.1 1.975      3.73      65      86
24  Japan   Dodge Colt 35.1 1.915      2.97      80      98
27  Japan  Honda Accord LX 29.5 2.135      3.05      68      98
33  Japan   Datsun 210 31.8 2.020      3.70      65      85
36  Japan   Datsun 810 22.0 2.815      3.70      97      146
Cylinders
6          4
7          4
23         4
24         4
27         4
33         4
36         6

```

```

> summary(Cars[ Cars$Country=="U.S.", "MPG"])
  Min. 1st Qu.  Median    Mean 3rd Qu.  Max.
15.50 18.12   20.70   23.00 28.15   34.20

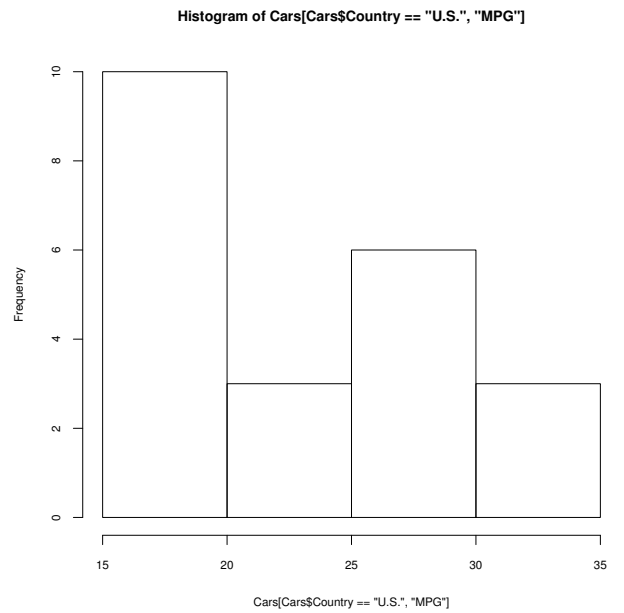
> summary(Cars[ Cars$Country=="Japan", "MPG"])
  Min. 1st Qu.  Median    Mean 3rd Qu.  Max.
22.00 27.35   29.50   29.60 32.95   35.10

```

```

> hist(Cars[ Cars$Country=="U.S.", "MPG"])

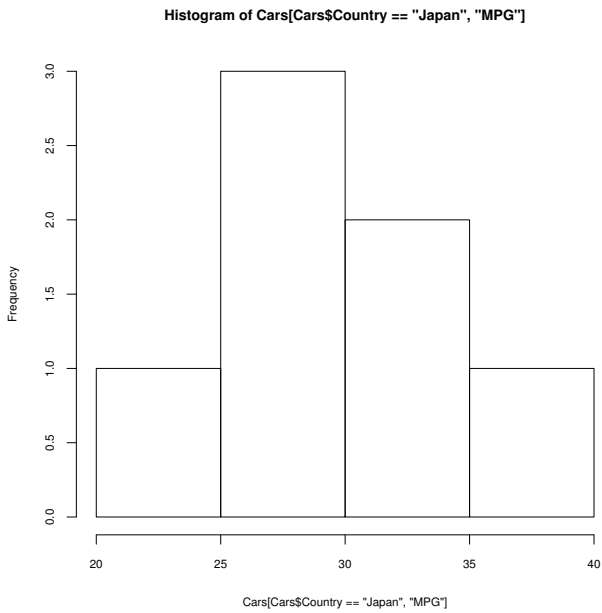
```



```

> hist(Cars[ Cars$Country=="Japan", "MPG"])

```



```
> help(t.test)

t.test                package:stats                R Documentation

Student's t-Test

Description:
  Performs one and two sample t-tests on vectors of data.

Usage:
  t.test(x, ...)

## Default S3 method:
t.test(x, y = NULL,
       alternative = c("two.sided", "less", "greater"),
       mu = 0, paired = FALSE, var.equal = FALSE,
       conf.level = 0.95, ...)

## S3 method for class 'formula':
t.test(formula, data, subset, na.action, ...)
```

Arguments:

- x: a (non-empty) numeric vector of data values.
- y: an optional (non-empty) numeric vector of data values.
- alternative: a character string specifying the alternative hypothesis, must be one of "two.sided" (default), "greater" or "less". You can specify just the initial letter.
- mu: a number indicating the true value of the mean (or difference in means if you are performing a two sample test).
- paired: a logical indicating whether you want a paired t-test.
- var.equal: a logical variable indicating whether to treat the two variances as being equal. If 'TRUE' then the pooled variance is used to estimate the variance otherwise the Welch (or

Satterthwaite) approximation to the degrees of freedom is used.

conf.level: confidence level of the interval.

Value:

A list with class "htest" containing the following components:

- statistic: the value of the t-statistic.
- parameter: the degrees of freedom for the t-statistic.
- p.value: the p-value for the test.
- conf.int: a confidence interval for the mean appropriate to the specified alternative hypothesis.
- estimate: the estimated mean or difference in means depending on whether it was a one-sample test or a two-sample test.
- null.value: the specified hypothesized value of the mean or mean difference depending on whether it was a one-sample test or a two-sample test.
- alternative: a character string describing the alternative hypothesis.
- method: a character string indicating what type of t-test was performed.
- data.name: a character string giving the name(s) of the data.

```
> t.test( Cars[ Cars$Country=="U.S.", "MPG"])
One Sample t-test

data:  Cars[Cars$Country == "U.S.", "MPG"]
t = 17.8153, df = 21, p-value = 3.739e-14
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 20.31116 25.67975
sample estimates:
mean of x
22.99545

> t.test( Cars[ Cars$Country=="U.S.", "MPG"])
One Sample t-test

data:  Cars[Cars$Country == "U.S.", "MPG"]
t = 17.8153, df = 21, p-value = 3.739e-14
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 20.31116 25.67975
sample estimates:
mean of x
22.99545
```

```

> UStout <- t.test( Cars[ Cars$Country=="U.S.", "MPG"])
> names(UStout)
[1] "statistic" "parameter" "p.value" "conf.int" "estimate"
[6] "null.value" "alternative" "method" "data.name"
> UStout$conf.int
[1] 20.31116 25.67975
attr(,"conf.level")
[1] 0.95
> UStout$estimate
mean of x
22.99545
> UStout$statistic
t
17.81533

```

```

> Japantout
One Sample t-test

data: Cars[Cars$Country == "Japan", "MPG"]
t = 17.2771, df = 6, p-value = 2.409e-06
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 25.40782 33.79218
sample estimates:
mean of x
 29.6

> t.test( Cars[ Cars$Country=="U.S.", "MPG"], Cars[ Cars$Country=="Japan", "MPG"])
Welch Two Sample t-test

data: Cars[Cars$Country == "U.S.", "MPG"] and Cars[Cars$Country == "Japan", "MPG"]
t = -3.0789, df = 13.502, p-value = 0.008466
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -11.221244 -1.987847
sample estimates:
mean of x mean of y
22.99545 29.60000

```

## Reading directly from web into dataframes

You can use the URL of a dataset from the web as the argument to a `read.table` or `read.delim` function.

```
read.delim("http://www.stat.uiowa.edu/~kcowles/Datasets/Cars.dat")
```