An introduction to R
Sponsored by
The Association of Psychological Science
and
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William Revelle

Department of Psychology
Northwestern University
Evanston, Illinois USA

NORTHWESTERN
UNIVERSITY

Outline

R: Statistics for all us

1. What is it?
2. Why use it?
3. Common (mis)perceptions of R
4. Examples for psychologists
   - graphical displays
   - basic statistics
   - advanced statistics
   - Although programming is easy in R, that is beyond the scope of today

R: What is it?

1. R: An international collaboration
2. R: The open source - public domain version of S+
3. R: Written by statistician (and all of us) for statisticians (and the rest of us)
4. R: Not just a statistics system, also an extensible language.
   - This means that as new statistics are developed they tend to appear in R far sooner than elsewhere.
   - R facilitates asking questions that have not already been asked.

Statistical Programs for Psychologists

- General purpose programs
  - R
  - S+
  - SAS
  - SPSS
  - STATA
  - Systat
- Specialized programs
  - Mx
  - EQS
  - AMOS
  - LISREL
  - MPlus
  - Your favorite program

Statistical Programs for Psychologists

- General purpose programs
  - R
  - $+
  - A
  - $P$$
  - $TATA
  - $y$tat
- Specialized programs
  - Mx (OpenMx is part of R)
  - EQ$
  - AMO$
  - LI$REL
  - MPIu$
  - Your favorite program

R: A way of thinking

- "R is the lingua franca of statistical research. Work in all other languages should be discouraged."
- "This is R. There is no if. Only how."
- "Overall, SAS is about 11 years behind R and S-Plus in statistical capabilities (last year it was about 10 years behind) in my estimation."

Taken from the R.-fortunes (selections from the R.-help list serve)

R is open source, how can you trust it?

- Q: "When you use it [R], since it is written by so many authors, how do you know that the results are trustable?"
- A: "The R engine [...] is pretty well uniformly excellent code but you have to take my word for that. Actually, you don't. The whole engine is open source so, if you wish, you can check every line of it. If people were out to push dodgy software, this is not the way they'd go about it."
- Q: Are R packages bug free?
- A: No. But bugs are fixed rapidly when identified.
- Q: How does function x work? May I adapt it for my functions.
- A: Look at the code. Borrow what you need.

What is R?: Technically

- R is an open source implementation of S (S-Plus is a commercial implementation)
- R is available under GNU Copy-left
- The current version of R is 2.15.0
- R is a group project run by a core group of developers (with new releases semiannually)

(Adapted from Robert Gentleman)

R: A brief history

- 1991-93: Ross Dhaka and Robert Gentleman begin work on R project at U. Auckland
- 1995: R available by ftp under the GPL
- 96-97: mailing list and R core group is formed
- 2000: John Chambers, designer of S joins the Rcore (wins a prize for best software from ACM for S)
- 2001-2013: Core team continues to improve base package with a new release every 6 months.
- Many others contribute "packages" to supplement the functionality for particular problems
  - 2003-04-01: 250 packages
  - 2004-10-01: 500 packages
  - 2007-04-12: 1,000 packages
  - 2009-10-04: 2,000 packages
  - 2011-05-12: 3,000 packages
  - 2012-05-12: 3,786 packages

Misconception: R is hard to use

1. R doesn't have a GUI (Graphical User Interface)
   - Partly true, many use syntax.
   - Partly not true, GUIs exist (e.g., R Commander, R-Studio).
   - Quasi GUIs for Mac and PCs make syntax writing easier.
2. R syntax is hard to use
   - Not really, unless you think an iPhone is hard to use.
   - Easier to give instructions of 1-4 lines of syntax rather than pictures of what menu to pull down.
   - Keep a copy of your syntax, modify it for the next analysis.
3. R is not user friendly: A personological description of R
   - R is introverted: it will tell you what you want to know if you ask, but not if you don't ask.
   - R is conscientious: it wants commands to be correct.
   - R is not agreeable: its error messages are at best cryptic.
   - R is stable: it does not break down under stress.
   - R is open: new ideas about statistics are easily developed.

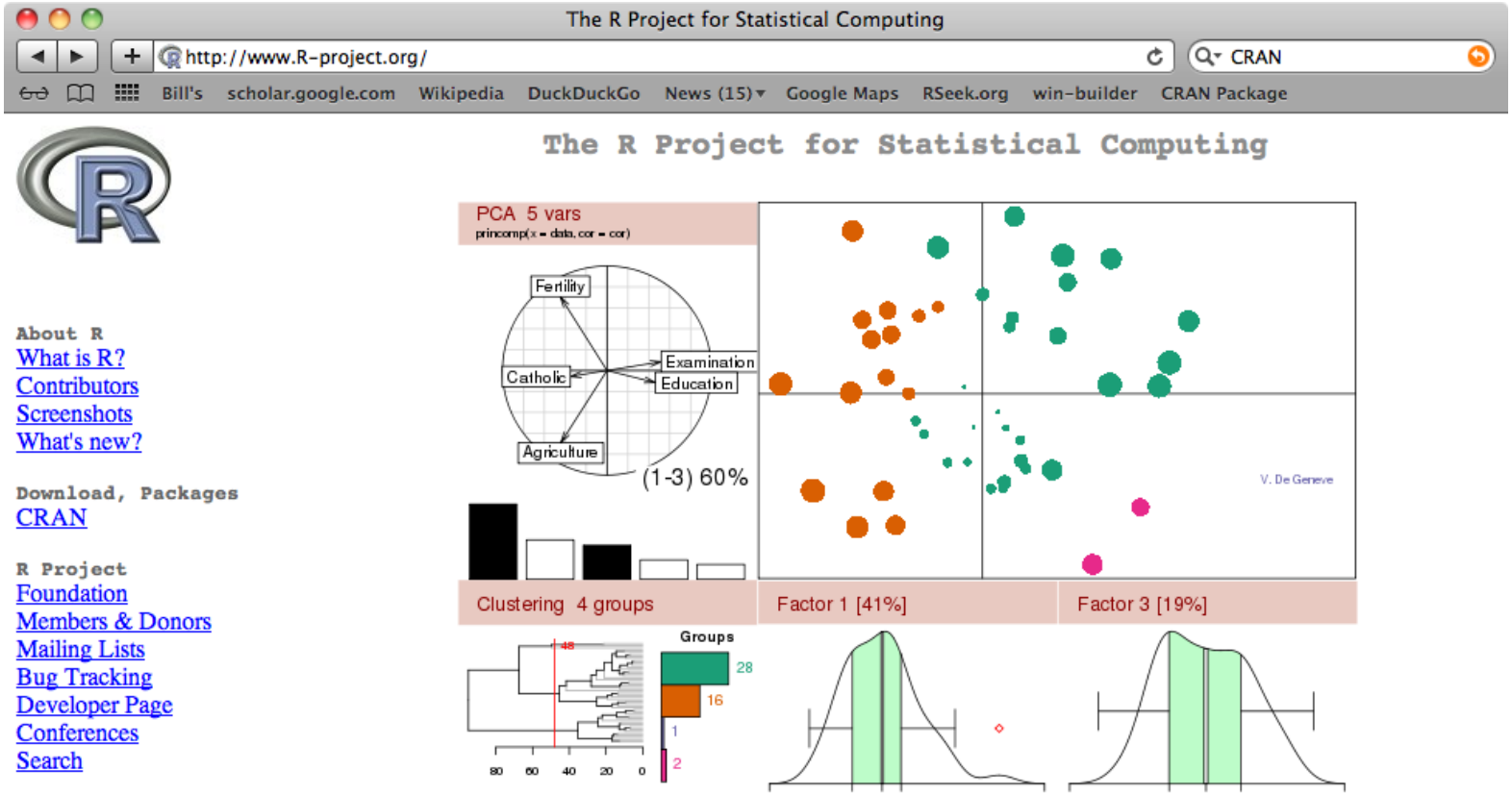
Misconceptions: R is hard to learn – some interesting facts

1. With a brief web based tutorial http://personality-project.org/r, 2nd and 3rd year undergraduates in psychological methods and personality research courses are using R for descriptive and inferential statistics and producing publication quality graphics.
2. More and more psychology departments are using it for graduate and undergraduate instruction.
3. R is easy to learn, hard to master
   - R-help newsgroup is very supportive
   - Multiple web based and pdf tutorials see (e.g., http://www.r-project.org/)
   - Short courses using R for many applications
4. Books and websites for SPSS and SAS users trying to learn R (e.g., http://r4stats.com/) by Bob Muenchen (look for link to free version)).

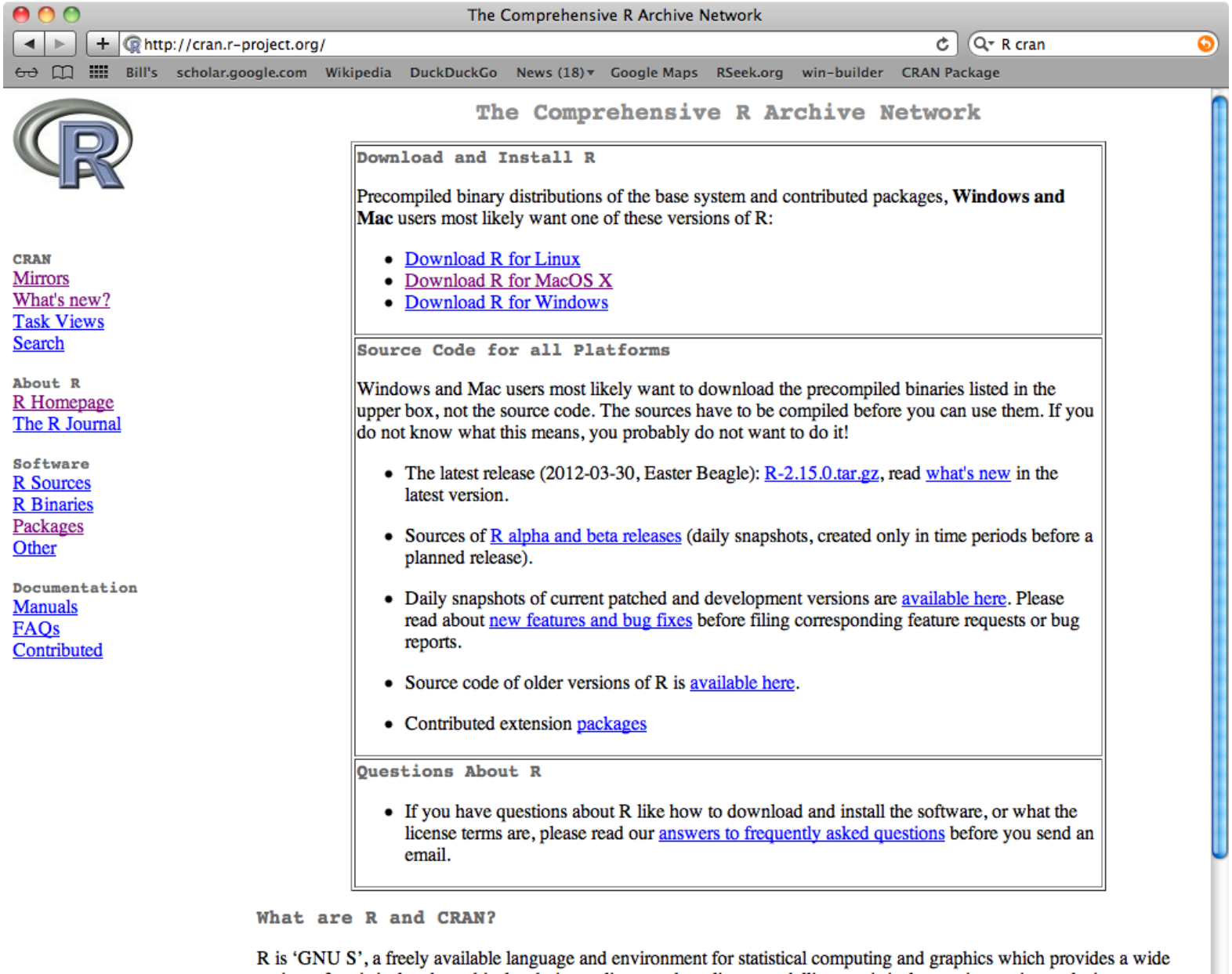
Ok, how do I get it: Getting started with R

- Download from R Cran (http://cran.r-project.org/)
  - Choose appropriate operating system and download compiled R
- Install R (current version is 2.15.0)
- Start R
- Add useful packages (just need to do this once)
  - install.packages("ctv") #this downloads the task view package
  - library(ctv) #this activates the ctv package
  - install.views("Psychometrics") #among others
  - Take a 5 minute break
- Activate the package(s) you want to use today (e.g., *psych*)
  - library(psych) #necessary for most of today's examples
- Use R

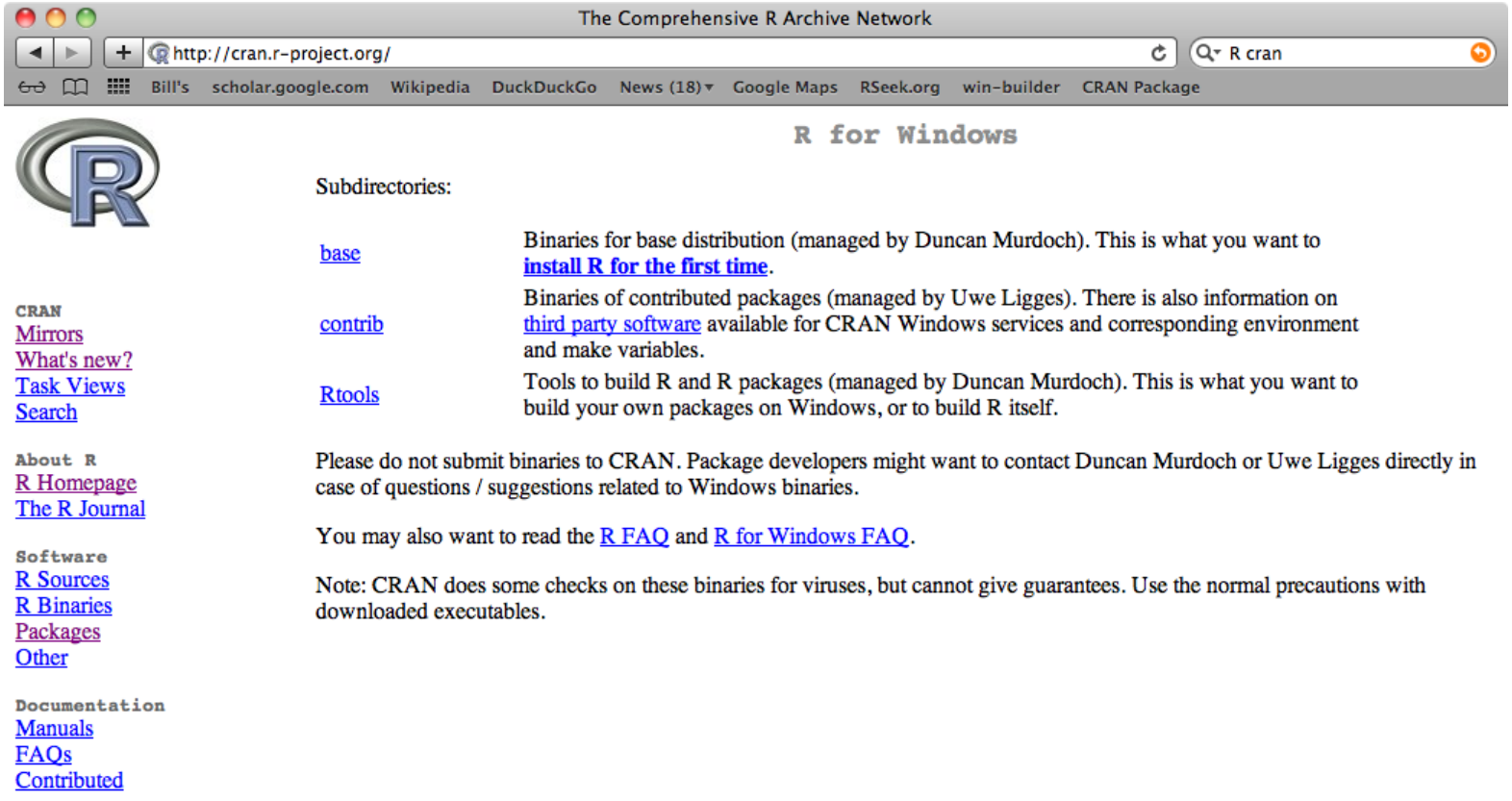
Go to the R.project.org



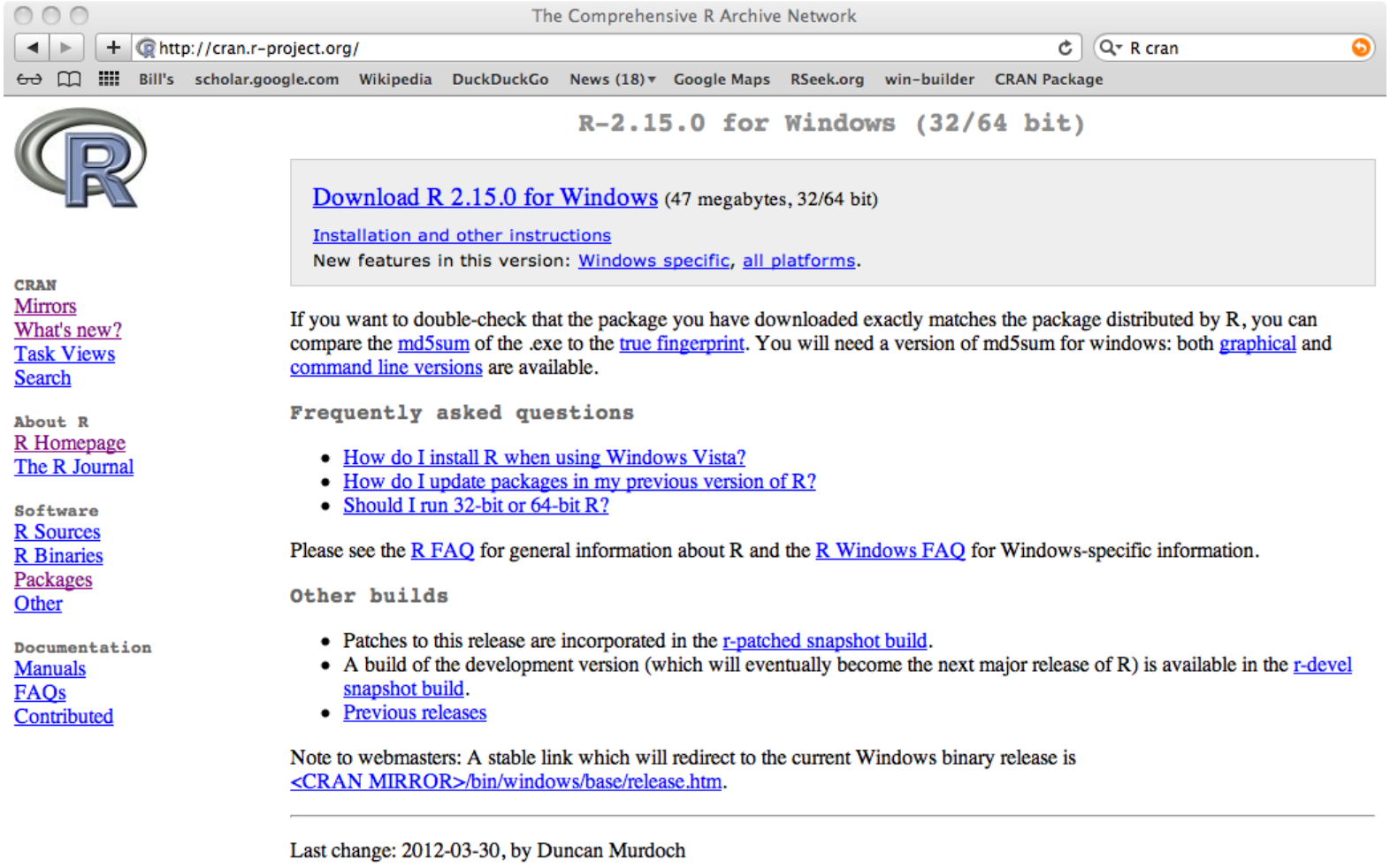
Go to the Comprehensive R Archive Network (CRAN)



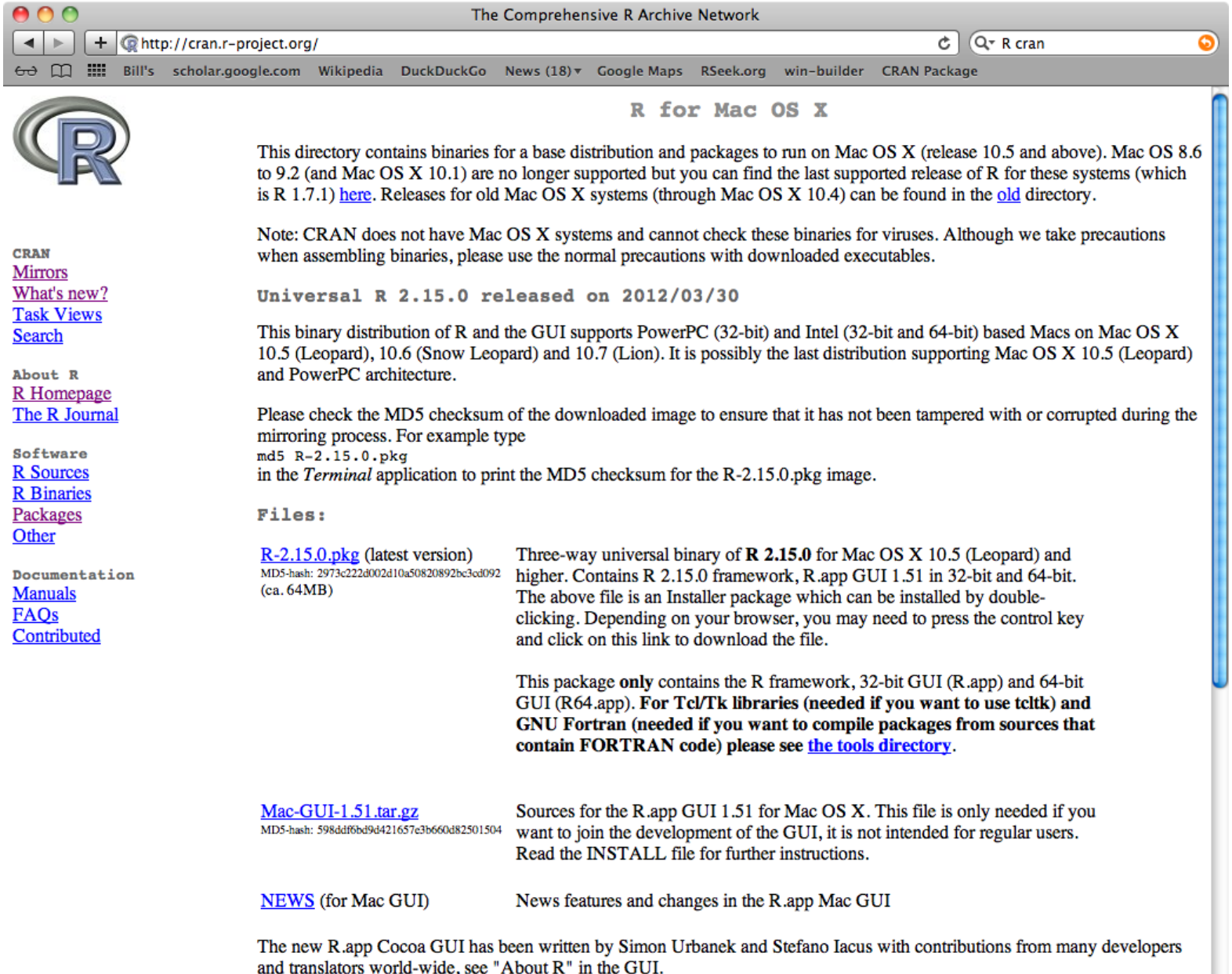
Download and install the appropriate version – PC



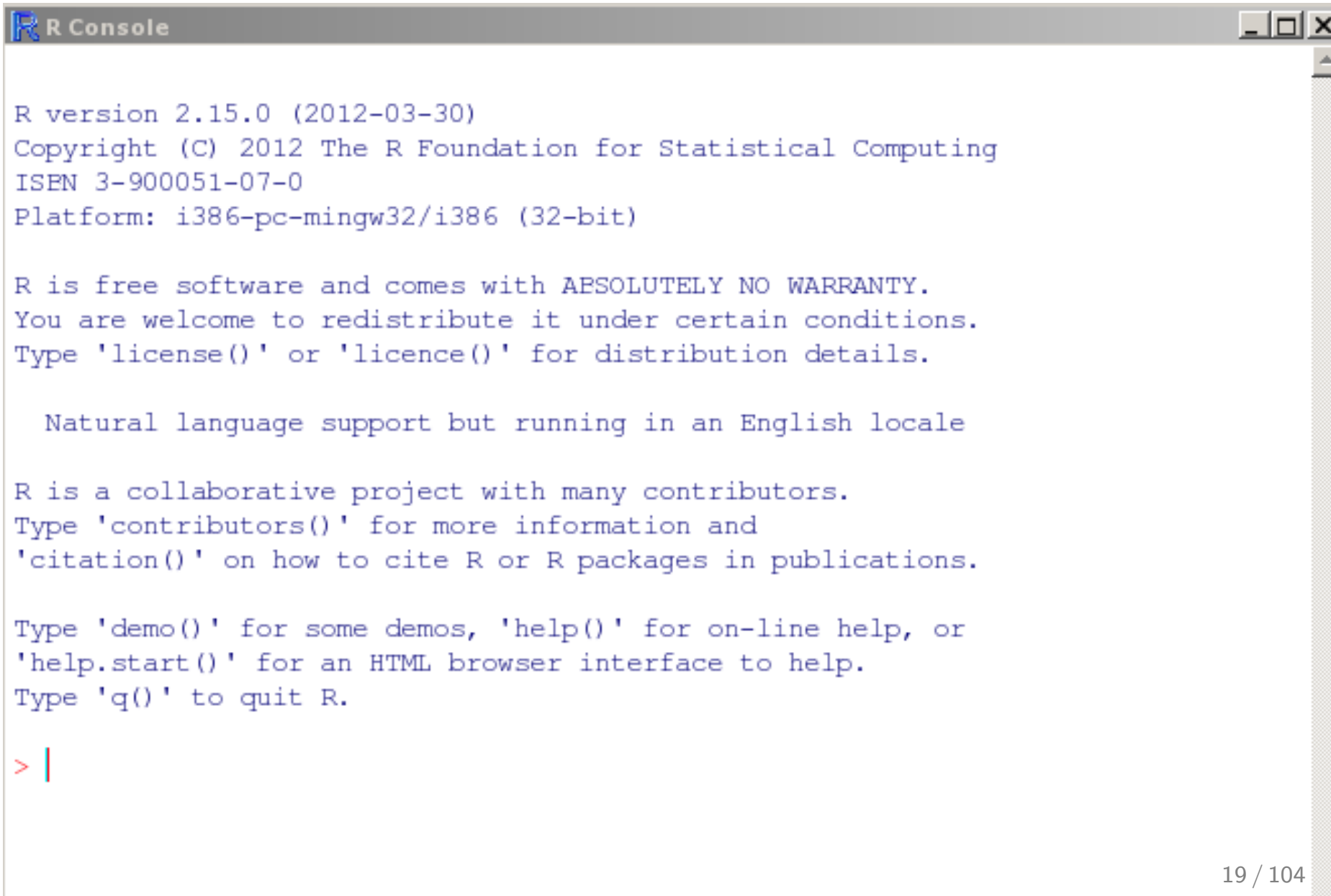
Download and install the appropriate version – PC



Download and install the appropriate version – Mac



Starting R on a PC



Start up R and get ready to play (Mac version)

```
R version 2.15.0 Patched (2012-03-30 r58887) -- "Easter Beagle"
Copyright (C) 2012 The R Foundation for Statistical Computing
ISBN 3-900051-07-0
Platform: x86_64-apple-darwin9.8.0/x86_64 (64-bit)

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.

[R.app GUI 1.43 (5920) x86_64-apple-darwin9.8.0]

[Workspace restored from /Users/revelle/.RData]
[History restored from /Users/revelle/.Rapp.history]
```

Annotated installation guide: don't type the >

```
> install.packages("ctv")
```

- Install the task view installer package. You might have to choose a "mirror" site.

```
> library(ctv)
```

- Make it active

```
> install.views("Psychometrics")
```

- Install all the packages in the "Psychometrics" task view. This will take a few minutes.

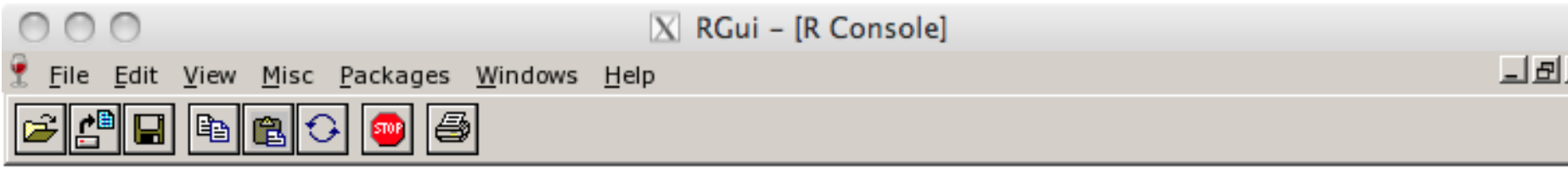
```
#or just install a few packages
> install.packages("psych")
```

- Or, just install one package (e.g., psych)

```
> install.packages("GPArotation")
> install.packages("MASS")
> install.packages("mvtnorm")
```

- as well as a few suggested packages that add functionality for factor rotation, multivariate normal distributions, etc.

Installing just the psych package




```
R version 2.13.0 (2011-04-13)
Copyright (C) 2011 The R Foundation for Statistical Computing
ISBN 3-900051-07-0
Platform: i386-pc-mingw32/i386 (32-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
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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.

> install.packages("psych")
--- Please select a CRAN mirror for use in this session ---
trying URL 'http://cran.stat.ucla.edu/bin/windows/contrib/2.13/psych_1.0-97.zip'
Content type 'application/zip' length 1952216 bytes (1.9 Mb)
opened URL
downloaded 1.9 Mb
```
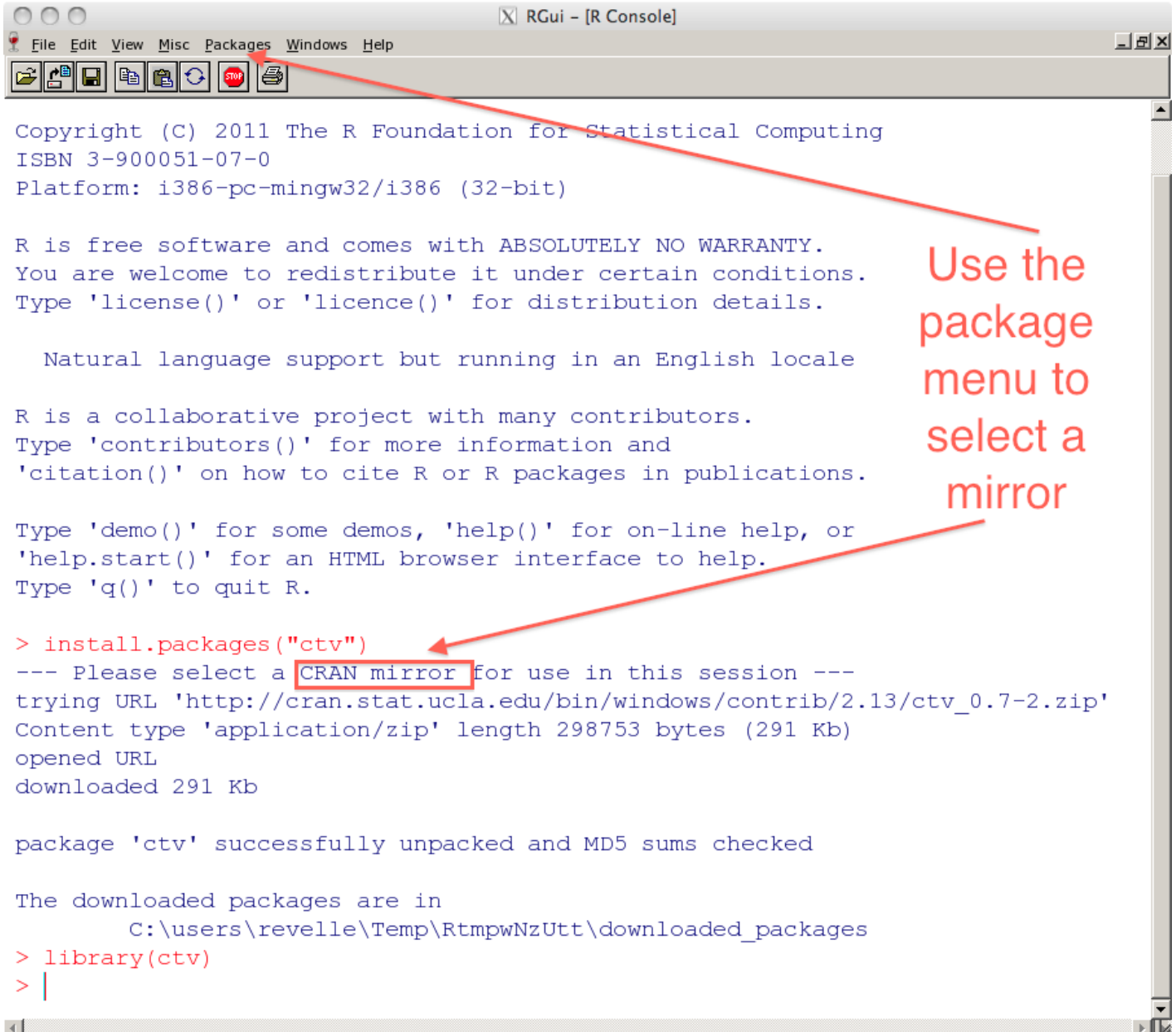

Or, install and use ctv package to load a task view on a PC



Check the version number for R (should be $\geq$ 2.15.0) and for psych ($\geq$1.2.5)

```
> library(psych)
> sessionInfo()

R version 2.15.0 Patched (2012-03-30 r58887)
Platform: x86_64-apple-darwin9.8.0/x86_64 (64-bit)

locale:
[1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8

attached base packages:
[1] stats     graphics  grDevices utils     datasets  methods   base

other attached packages:
[1] MASS_7.3-17           GPArotation_2010.07-1 psych_1.2.5
```

R is extensible: The use of "packages"

- More than 3750 packages are available for R (and growing daily)
- Can search all packages that do a particular operation by using the sos package
  - `install.packages("sos")` #if you haven't already
  - library(sos) # make it active once you have it
    - `findFn`("X") #will search a web data base for all packages/functions that have "X"
    - `findFn`("factor analysis") #will return 9881 matches and reports the top 400
    - `findFn`("Item Response Theory") # will return 199 matches
    - `findFn`("INDSCAL ") # will return 8 matches.
- install.packages("X") will install a particular package (add it to your R library – you need to do this just once)
- library(X) #will make the package X available to use if it has been installed (and thus in your library)

A small subset of very useful packages

- General use
  - core R
  - MASS
  - lattice
  - lme4 (core)
  - psych
  - Zelig
- Special use
  - ltm
  - sem
  - lavaan
  - OpenMx
  - GPArotation
  - mvtnorm
  - $>$ 3750 known
  - + ?
- General applications
  - most descriptive and inferential stats
  - Modern Applied Statistics with S
  - Lattice or Trellis graphics
  - Linear mixed-effects models
  - Personality and psychometrics
  - General purpose toolkit
- More specialized packages
  - Latent Trait Model (IRT)
  - SEM and CFA (one group)
  - SEM and CFA (multiple groups)
  - SEM and CFA (multiple groups +)
  - Jennrich rotations
  - Multivariate distributions
  - Thousands of more packages on CRAN
  - Code on webpages/journal articles

Questions?

Basic R commands – remember don't enter the >

R is just a fancy calculator. Add, subtract, sum, products, group

```
> 2 + 2
[1] 4
> 3^4
[1] 81
> sum(1:10)
[1] 55
> prod(c(1, 2, 3, 5, 7))
[1] 210
```

It is also a statistics table (the normal distribution, the t distribution)

```
> pnorm(q = 1)
[1] 0.8413447
> pt(q = 2, df = 20)
[1] 0.9703672
```

R is a set of distributions. Don't buy a stats book with tables!

Table: To obtain the density, prefix with *d*, probability with *p*, quantiles with *q* and to generate random values with *r*. (e.g., the normal distribution may be chosen by using dnorm, pnorm, qnorm, or rnorm.)

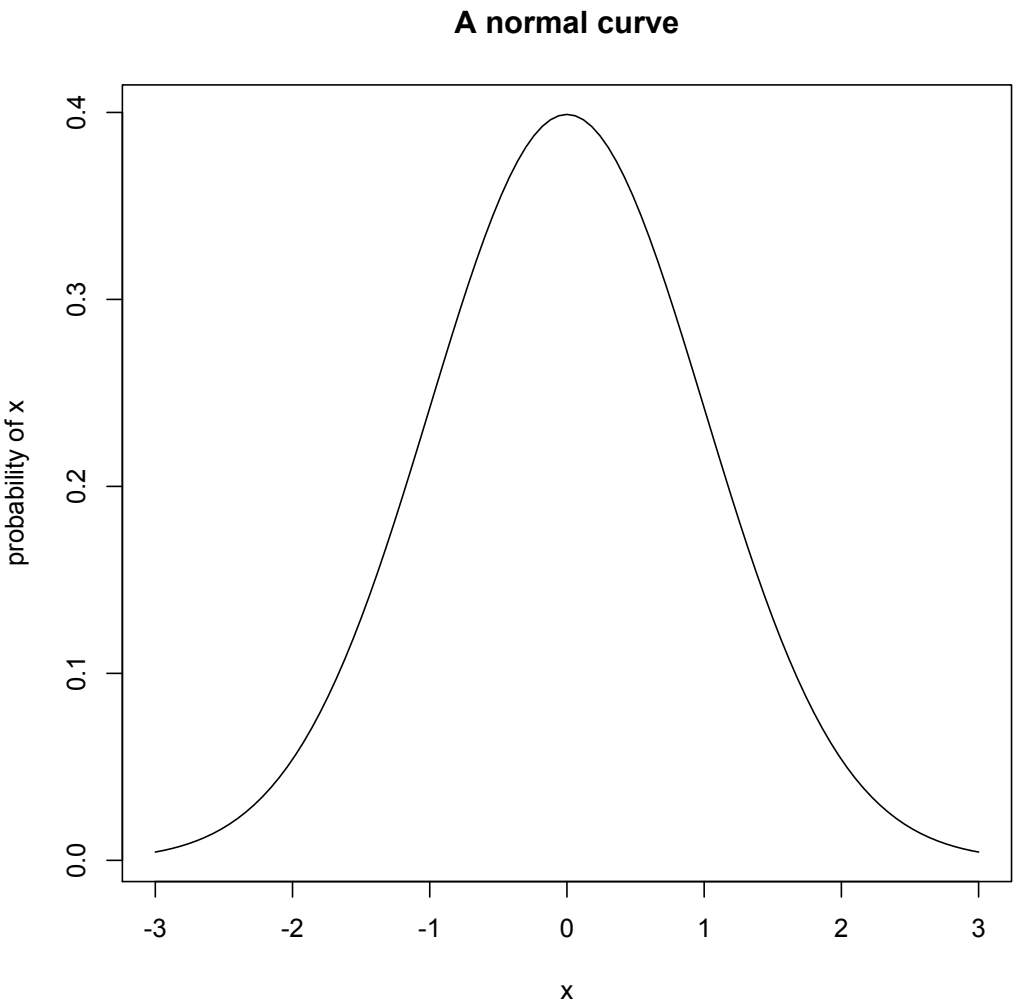
Distribution	base name	P 1	P 2	P 3	example application
Normal	norm	mean	sigma		Most data
Multivariate normal	mvnorm	mean	r	sigma	Most data
Log Normal	lnorm	log mean	log sigma		income or reaction time
Uniform	unif	min	max		rectangular distributions
Binomial	binom	size	prob		Bernuilli trials (e.g. coin flips)
Student's t	t	df		nc	Finding significance of a t-test
Multivariate t	mvt	df	corr	nc	Multivariate applications
Fisher's F	f	df1	df2	nc	Testing for significance of F test
χ^2	chisq	df		nc	Testing for significance of χ^2
Exponential	exp	rate			Exponential decay
Gamma	gamma	shape	rate	scale	distribution theoryh
Hypergeometric	hyper	m	n	k	
Logistic	logis	location	scale		Item Response Theory
Poisson	pois	lambda			Count data
Weibull	weibull	shape	scale		Reaction time distributions

A very small list of the many data sets available

```
> data()

> data(package="psych")

> data(Titanic)
> ? Titanic

> data(cushny)
> ? cushney
```

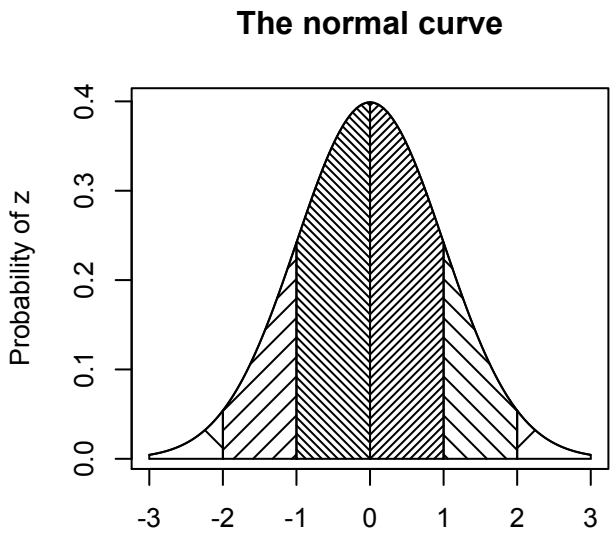
1. This opens up a separate text window and lists all of the data sets in the currently loaded packages.
2. Show the data sets available in a particular package (e.g., *psych*).
3. Gets the particular data set with its help file (e.g., the survival rates on the Titanic cross classified by age, gender and class).
4. Another original data set used by "student" (Gossett) for the t-test.

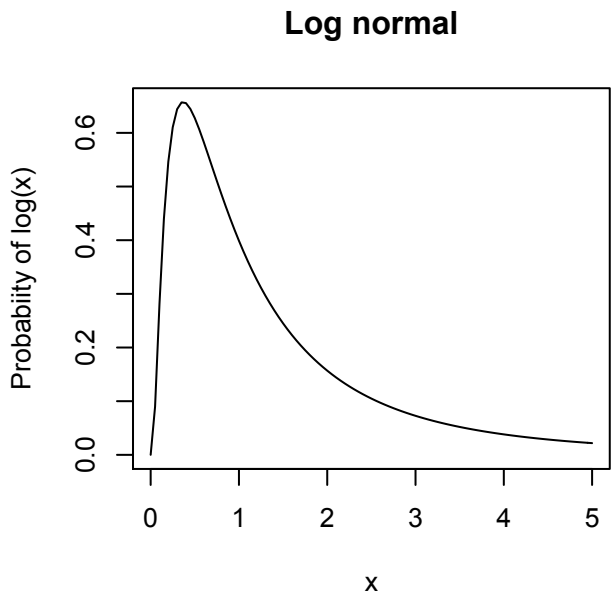
R can draw distributions

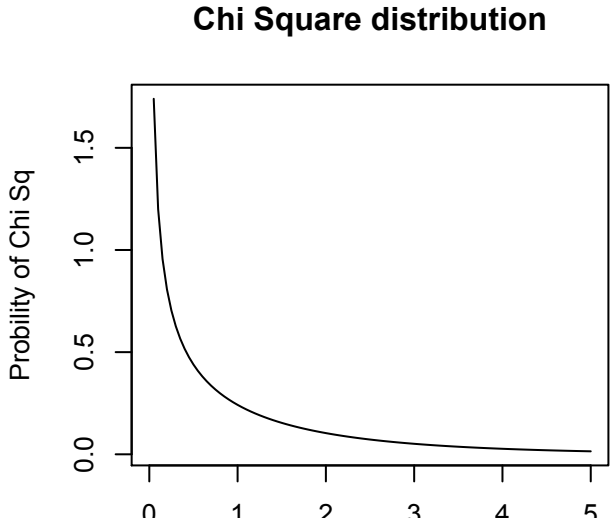


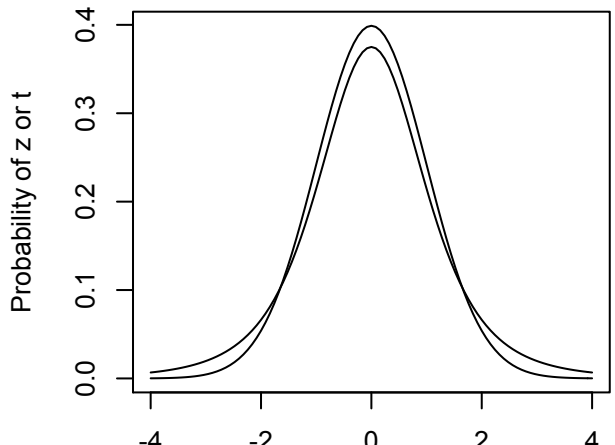

```
curve(dnormal(x),-3,3,
ylab="probability of
x",main="A normal
curve")
```

R can draw more interesting distributions







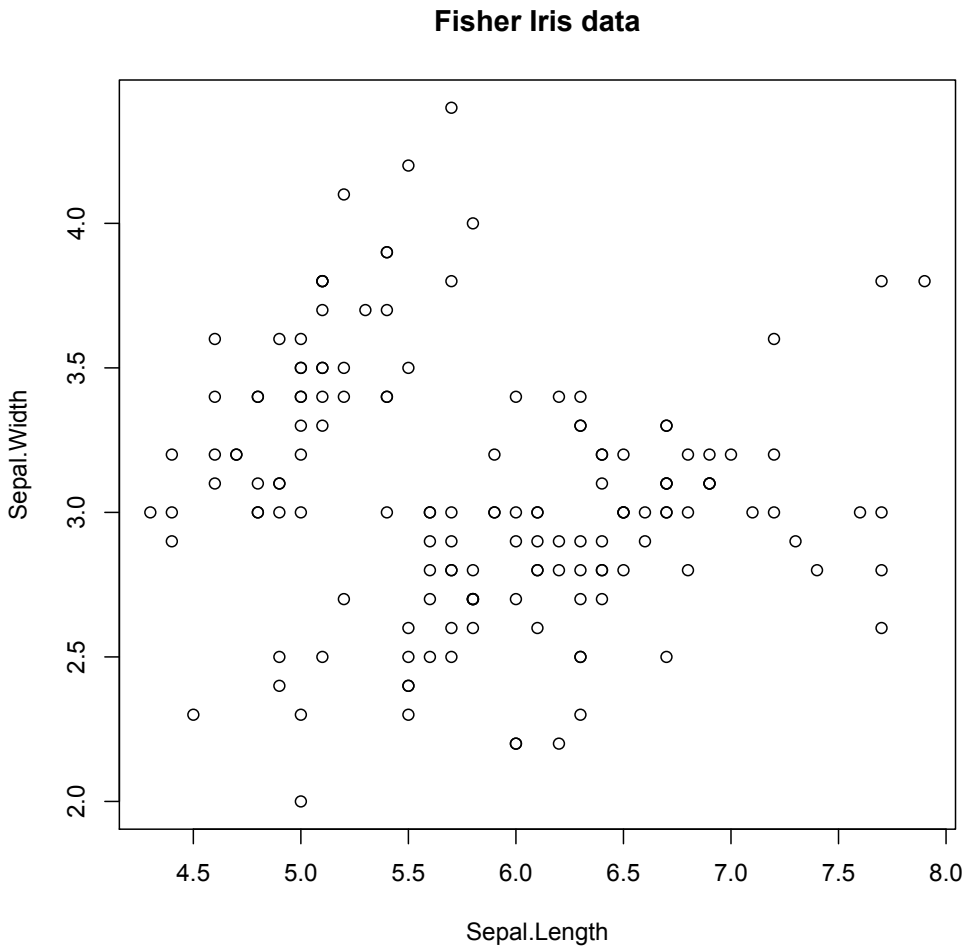


R is also a graphics calculator

The first line draws the normal curve, the second prints the title, the next lines draw the cross hatching.

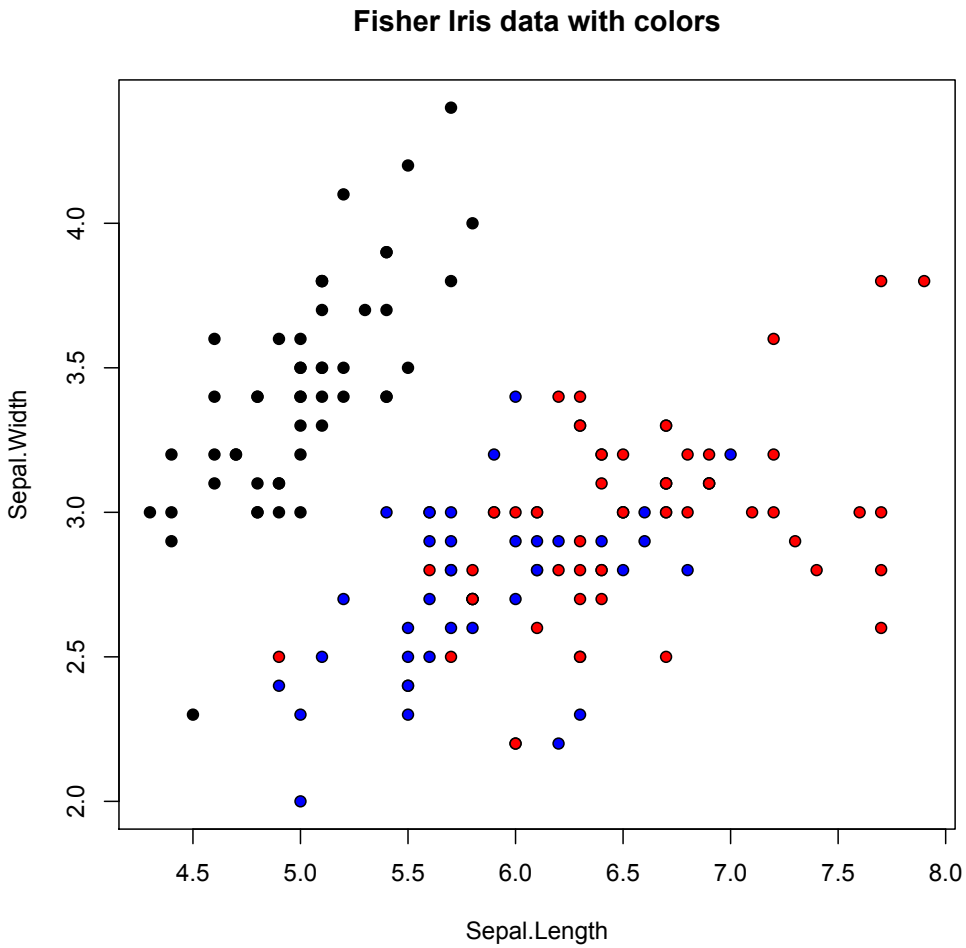
```
op <- par(mfrow=c(2,2))       #set up a 2 x 2 graph
curve(dnorm(x),-3,3,xlab="",ylab="Probability of z")
title(main="The normal curve",outer=FALSE)
xvals <-  seq(-3,-2,length=100)
dvals <- dnorm(xvals)
polygon(c(xvals,rev(xvals)),c(rep(0,100),rev(dvals)),density=2,angle=-45)
xvals <-  seq(-2,-1,length=100)
dvals <- dnorm(xvals)
polygon(c(xvals,rev(xvals)),c(rep(0,100),rev(dvals)),density=14,angle=45)
xvals <-  seq(-1,-0,length=100)
dvals <- dnorm(xvals)
polygon(c(xvals,rev(xvals)),c(rep(0,100),rev(dvals)),density=34,angle=-45)
xvals <-  seq(2,3,length=100)
dvals <- dnorm(xvals)
polygon(c(xvals,rev(xvals)),c(rep(0,100),rev(dvals)),density=2,angle=45)
xvals <-  seq(1,2,length=100)
dvals <- dnorm(xvals)
polygon(c(xvals,rev(xvals)),c(rep(0,100),rev(dvals)),density=14,angle=-45)
xvals <-  seq(0,1,length=100)
dvals <- dnorm(xvals)
polygon(c(xvals,rev(xvals)),c(rep(0,100),rev(dvals)),density=34,angle=45)
curve(dlnorm(x),0,5,ylab='Probabiity of log(x)',main='Log normal')
curve(dchisq(x,1),0,5,ylab='Probility of Chi Sq',xlab='Chi Sq',main='Chi Square distribution')
curve(dnorm(x),-4,4,ylab='Probability of z or t',xlab='z or t',main='Normal and t with 4 df')
curve(dt(x,4),add=TRUE)
op <- par(mfrow=c(1,1))
```

A simple scatter plot using `plot`




```
plot(iris[1:2],xlab="Sepal.Length",ylab="Sepal.Width"
,main="Fisher Iris data")
```

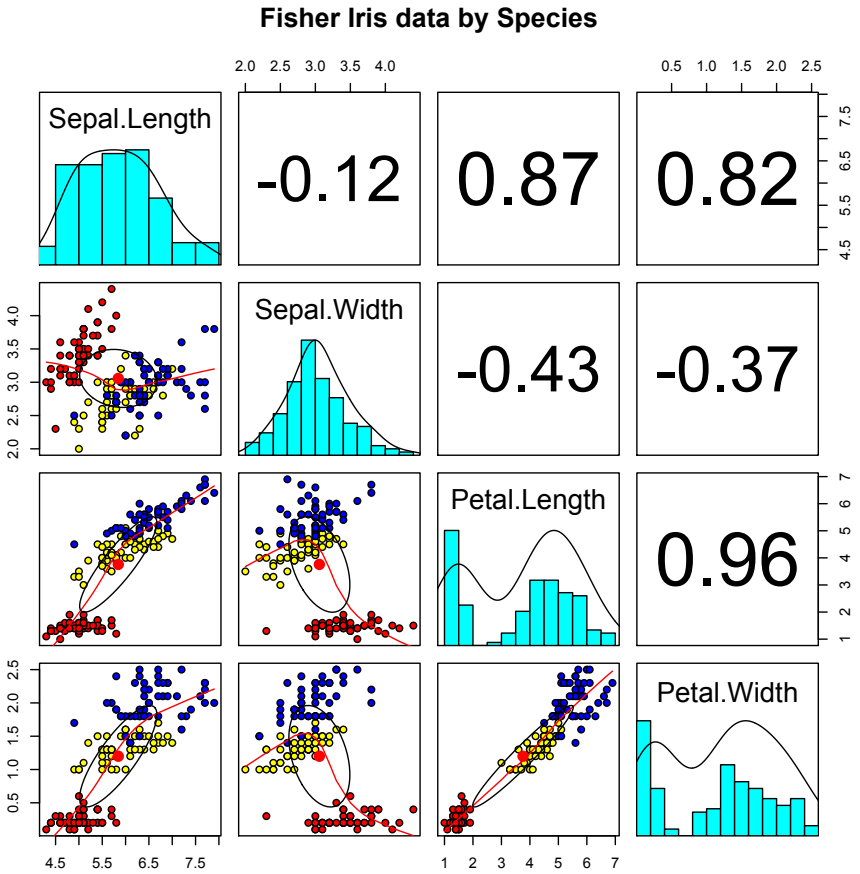
A simple scatter plot using `plot` with some colors



1. Set parameters
2. bg for background colors
3. pch chooses the plot character

```
plot(iris[1:2],xlab="Sepal.Length",ylab="Sepal.Width"
+ ,main="Fisher Iris data with
colors",bg=c("black","blue","red")[iris[,5]],pch=21)
```

A scatter plot matrix plot with loess regressions using `pairs.panels`



1. Correlations above the diagonal
2. Diagonal shows histograms and densities
3. scatter plots below the diagonal with correlation ellipse
4. locally smoothed (loess) regressions for each pair
5. optional color coding of grouping variables.

```
pairs.panels(iris[1:4],bg=c("red","yellow","blue")
[iris$Species],pch=21,main="Fisher Iris data by
Species")
```

A brief example with real data

1. Get the data
2. Descriptive statistics
   - Graphic
   - Numerical
3. Inferential statistics using the linear model
   - regressions
4. More graphic displays

Get the data and describe it

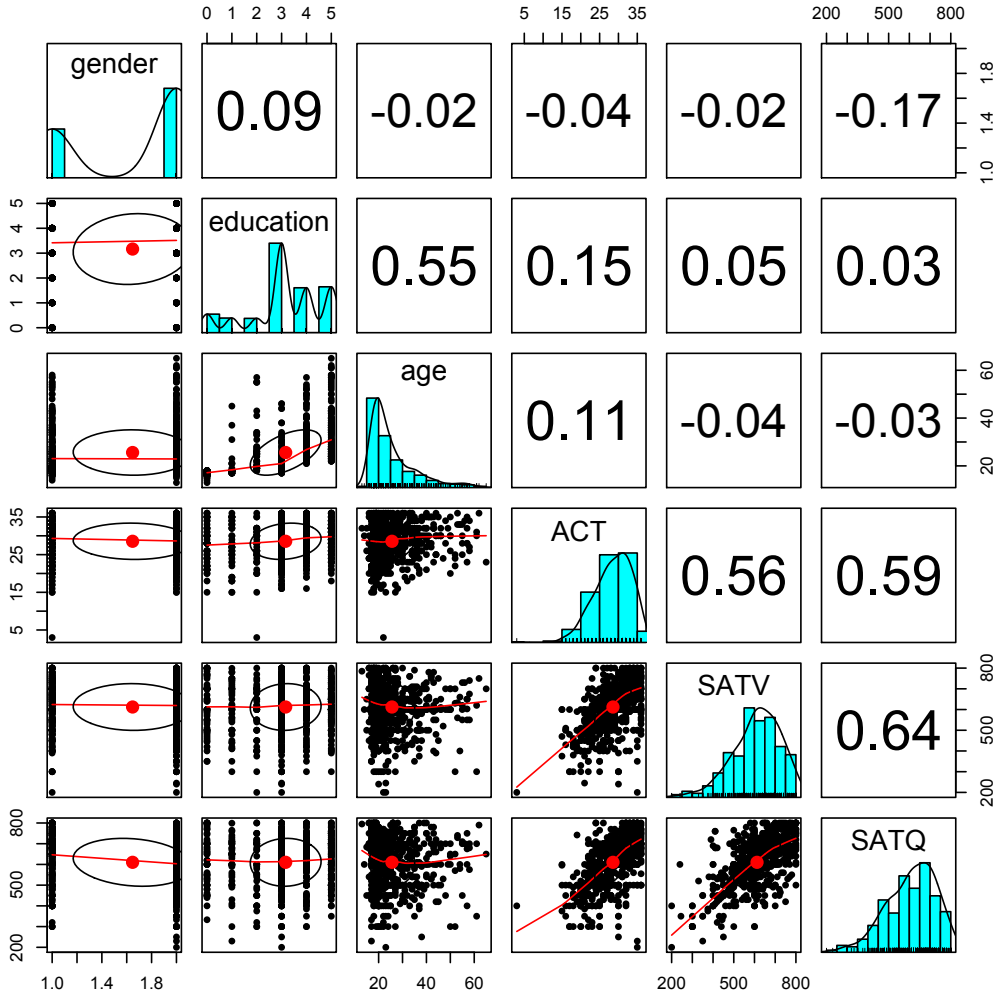
1. First read the data, either from a built in data set, a local file, a remote file, or from the clipboard.
2. Describe the data using the `describe` function from *psych*

```
> my.data <- sat.act  #an example data file that is part of psych
#or
> file.name <- file.choose()      #look for it on your hard drive
#or
> file.name <-"http://personality-project.org/r/aps/sat.act.txt"
#now read it
> my.data <- read.table(file.name,header=TRUE)
#or
> my.data <- read.clipboard()  #if you have copied the data to the clipboard
> describe(my.data) #report basic descriptive statistics
```

	var	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurto
gender	1	700	1.65	0.48	2	1.68	0.00	1	2	1	-0.61	-1
education	2	700	3.16	1.43	3	3.31	1.48	0	5	5	-0.68	-0
age	3	700	25.59	9.50	22	23.86	5.93	13	65	52	1.64	2
ACT	4	700	28.55	4.82	29	28.84	4.45	3	36	33	-0.66	0
SATV	5	700	612.23	112.90	620	619.45	118.61	200	800	600	-0.64	0
SATQ	6	687	610.22	115.64	620	617.25	118.61	200	800	600	-0.59	0

Graphic display of data using `pairs.panels`

pairs.panels(my.data) #Note the outlier for ACT



Clean up the data using `scrub`

```
> cleaned <- scrub(my.data,"ACT",min=4)
> describe(cleaned)
```

	var	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
gender	1	700	1.65	0.48	2	1.68	0.00	1	2	1	-0.61	-1.62	0.02
education	2	700	3.16	1.43	3	3.31	1.48	0	5	5	-0.68	-0.06	0.05
age	3	700	25.59	9.50	22	23.86	5.93	13	65	52	1.64	2.47	0.36
ACT	4	699	28.58	4.73	29	28.85	4.45	15	36	21	-0.50	-0.36	0.18
SATV	5	700	612.23	112.90	620	619.45	118.61	200	800	600	-0.64	0.35	4.27
SATQ	6	687	610.22	115.64	620	617.25	118.61	200	800	600	-0.59	0.00	4.41

Find the pairwise correlations, round to 2 decimals

```
> round(cor(cleaned,use="pairwise"),2)
```

	gender	education	age	ACT	SATV	SATQ
gender	1.00	0.09	-0.02	-0.05	-0.02	-0.17
education	0.09	1.00	0.55	0.15	0.05	0.03
age	-0.02	0.55	1.00	0.11	-0.04	-0.03
ACT	-0.05	0.15	0.11	1.00	0.55	0.59
SATV	-0.02	0.05	-0.04	0.55	1.00	0.64
SATQ	-0.17	0.03	-0.03	0.59	0.64	1.00

Display it differently using the lowerCor function

`lowerCor` finds the pairwise correlations, rounds to 2 decimals, and displays the lower half of the correlation matrix.

```
> lowerCor(sat.act)
```

```
          gendr edctn age   ACT   SATV  SATQ
gender     1.00
education  0.09  1.00
age       -0.02  0.55  1.00
ACT       -0.04  0.15  0.11  1.00
SATV      -0.02  0.05 -0.04  0.56  1.00
SATQ      -0.17  0.03 -0.03  0.59  0.64  1.00
```

Test the correlations for significance using `corr.test`

```
> corr.test(cleaned)
Call:corr.test(x = sat.act)
Correlation matrix
          gender education   age   ACT  SATV  SATQ
gender      1.00      0.09 -0.02 -0.04 -0.02 -0.17
education   0.09      1.00  0.55  0.15  0.05  0.03
age        -0.02      0.55  1.00  0.11 -0.04 -0.03
ACT        -0.04      0.15  0.11  1.00  0.56  0.59
SATV       -0.02      0.05 -0.04  0.56  1.00  0.64
SATQ       -0.17      0.03 -0.03  0.59  0.64  1.00
Sample Size
          gender education age ACT SATV SATQ
gender       700       700 700 700  700  687
...
SATQ          687       687 687 687  687  687
Probability values (Entries above the diagonal are adjusted for multiple tests.
          gender education  age  ACT SATV SATQ
gender      0.00      0.17 1.00 1.00    1    0
education   0.02      0.00 0.00 0.00    1    1
age         0.58      0.00 0.00 0.03    1    1
ACT         0.33      0.00 0.00 0.00    0    0
SATV        0.62      0.22 0.26 0.00    0    0
SATQ        0.00      0.36 0.37 0.00    0    0
```

Are education and gender independent? χ^2 Test of association

```
T <- with(my.data,table(gender,education))
```

```
> T
      education
gender   0   1   2   3   4   5
     1  27  20  23  80  51  46
     2  30  25  21 195  87  95
```

1. First create a table of associations
   - Do this on our data (my.data)
   - Use the "with" command to specify the data set
2. Show the table
3. Apply χ^2 test

```
> chisq.test(T)
Pearson's Chi-squared test

data:  T
X-squared = 16.0851, df = 5, p-value = 0.006605
```

Multiple regression

1. Use the sat.act data example
2. Do the linear model
3. Summarize the results

```
 mod1 <- lm(SATV ~ education + gender + SATQ,data=my.data)
> summary(mod1,digits=2)

Call:
lm(formula = SATV ~ education + gender + SATQ, data = my.data)
Residuals:
    Min      1Q  Median      3Q     Max
-372.91  -49.08    2.30   53.68  251.93
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 180.87348   23.41019   7.726 3.96e-14 ***
education     1.24043    2.32361   0.534  0.59363
gender       20.69271    6.99651   2.958  0.00321 **
SATQ          0.64489    0.02891  22.309  < 2e-16 ***
Signif. codes:  0 Ô***Õ 0.001 Ô**Õ 0.01 Ô*Õ 0.05 Ô.Õ 0.1 Ô Õ 1
Residual standard error: 86.24 on 683 degrees of freedom
  (13 observations deleted due to missingness)
Multiple R-squared: 0.4231, Adjusted R-squared: 0.4205
F-statistic:   167 on 3 and 683 DF,  p-value: < 2.2e-16
```

Zero center the data before examining interactions

In order to examine interactions using multiple regression, we must first "zero center" the data. This may be done using the `scale` function. By default, `scale` will standardize the variables. So to keep the original metric, we make the scaling parameter FALSE.

```
zsat <- data.frame(scale(my.data,scale=FALSE))
describe(zsat)
```

```
          var   n mean     sd median trimmed    mad     min    max range  skew
gender      1 700    0   0.48   0.35    0.04   0.00   -0.65   0.35     1 -0.61
education   2 700    0   1.43  -0.16    0.14   1.48   -3.16   1.84     5 -0.68
age         3 700    0   9.50  -3.59   -1.73   5.93  -12.59  39.41    52  1.64
ACT         4 700    0   4.82   0.45    0.30   4.45  -25.55   7.45    33 -0.66
SATV        5 700    0 112.90   7.77    7.22 118.61 -412.23 187.77   600 -0.64
SATQ        6 687    0 115.64   9.78    7.04 118.61 -410.22 189.78   600 -0.59
```

Note that we need to take the output of scale (which comes back as a matrix) and make it into a dataframe if we want to use the linear model on it.

Zero center the data before examining interactions

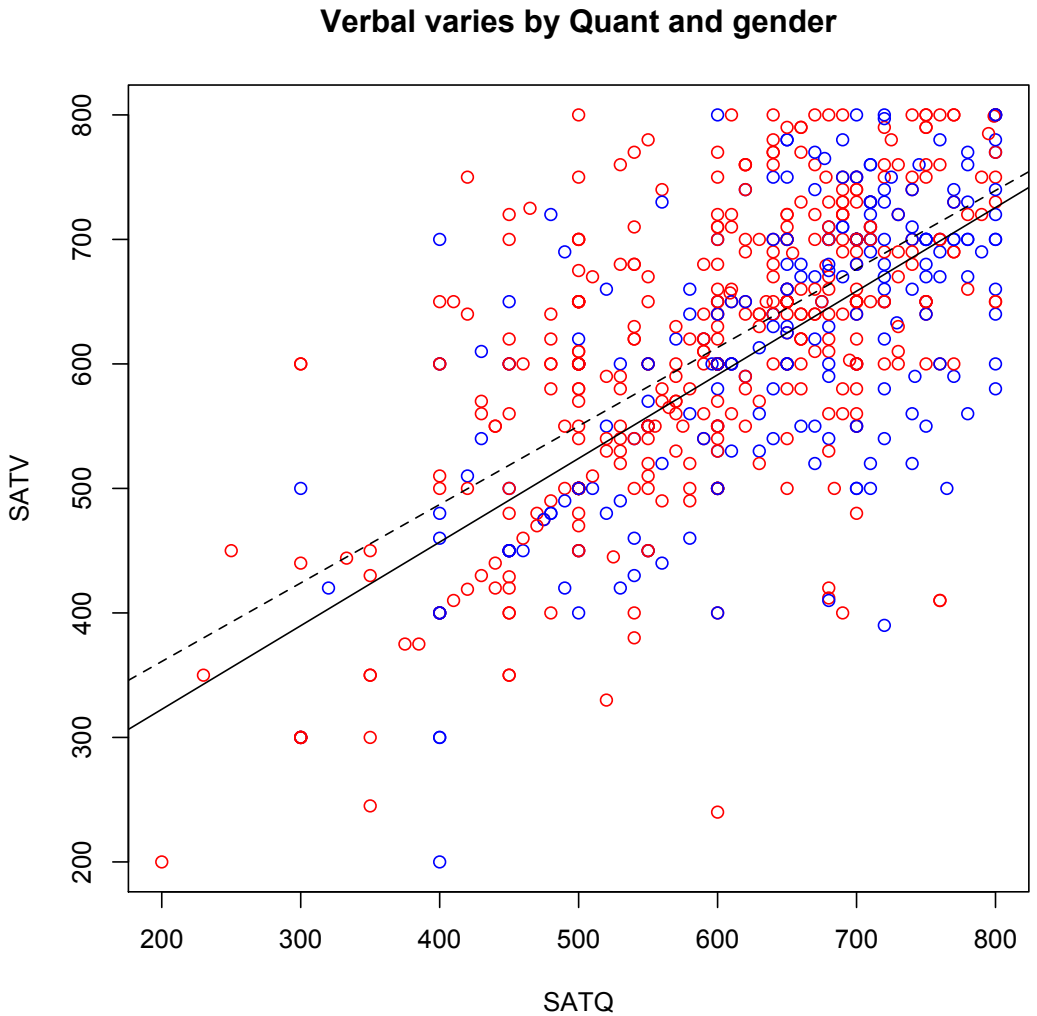
```
> zsat <- data.frame(scale(my.data,scale=FALSE))
> mod2 <-  lm(SATV  ~ education * gender * SATQ,data=zsat)
> summary(mod2)

Call:
lm(formula = SATV ~ education * gender * SATQ, data = zsat)

Residuals:
    Min      1Q  Median      3Q     Max
-372.53  -48.76    3.33   51.24  238.50

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)           0.773576   3.304938   0.234  0.81500
education             2.517314   2.337889   1.077  0.28198
gender               18.485906   6.964694   2.654  0.00814 **
SATQ                  0.620527   0.028925  21.453  < 2e-16 ***
education:gender      1.249926   4.759374   0.263  0.79292
education:SATQ       -0.101444   0.020100  -5.047 5.77e-07 ***
gender:SATQ           0.007339   0.060850   0.121  0.90404
education:gender:SATQ 0.035822   0.041192   0.870  0.38481
---
Signif. codes:  0 Ô***Õ 0.001 Ô**Õ 0.01 Ô*Õ 0.05 Ô.Õ 0.1 Ô Õ 1
```

Compare model 1 and model 2

Test the difference between the two linear models

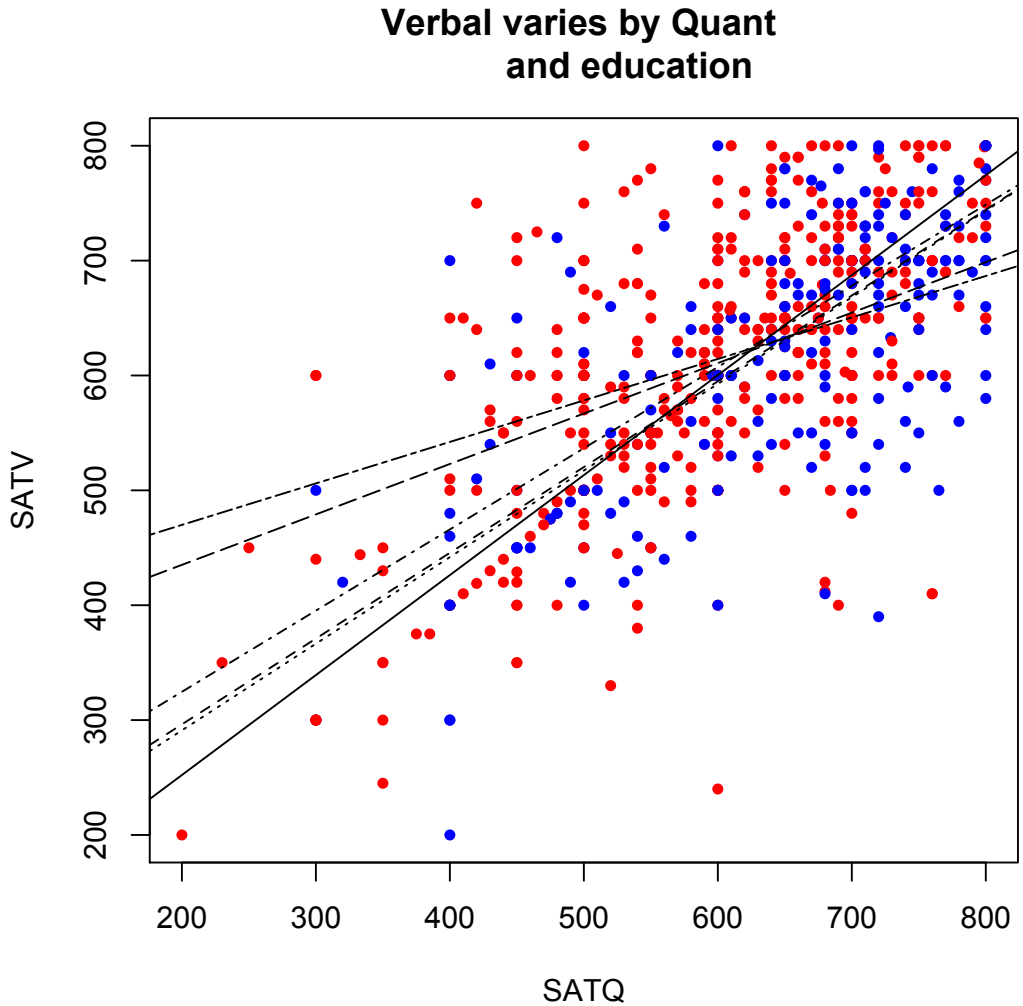
```
> anova(mod1,mod2)

Analysis of Variance Table

Model 1: SATV ~ education + gender + SATQ
Model 2: SATV ~ education * gender * SATQ
  Res.Df     RSS Df Sum of Sq      F    Pr(>F)
1    683 5079984
2    679 4870243  4    209742 7.3104 9.115e-06 ***
---
Signif. codes:  0 Ô***Õ 0.001 Ô**Õ 0.01 Ô*Õ 0.05 Ô.Õ 0.1 Ô
```

Show the regression lines by gender




```
> with(my.data,plot(SATV~SATQ,
    col=c("blue","red")[gender]))
> by(my.data,my.data$gender,
     function(x) abline
          (lm(SATV~SATQ,data=x),
          lty=c("solid","dashed"))
> title("Verbal varies by Quant
         and gender")
```

Show the regression lines by education




```
> with(my.data,plot(SATV~SATQ,
    col=c("blue","red")[gender]))
by(my.data,my.data$education,
   function(x) abline   (lm(SATV~S
    lty=c("solid", "dashed", "dott
    "dotdash", "longdash",
      "twodash")[(x$education+1)])

> title("Verbal varies by Quant
        and education")
```

Questions?

Using R for psychological statistics: Basic statistics

1. Writing syntax
   - For a single line, just type it
   - Mistakes can be redone by using the up arrow key
   - For longer code, use a text editor (built into some GUIs)
2. Data entry
   - Using built in data sets for examples
   - Copying from another program
   - Reading a text or csv file
   - Importing from SPSS or SAS
   - Simulate it (using various simulation routines)
3. Descriptives
   - Graphical displays
   - Descriptive statistics
   - Correlation
4. Inferential
   - the t test
   - the F test
   - the linear model

Data entry overview

1. Using built in data sets for examples
   - `data()` will list $>$ 100 data sets in the `datasets` package as well as all sets in loaded packages.
   - Most packages have associated data sets used as examples
   - *psych* has $>$ 40 example data sets
2. Copying from another program
   - use copy and paste into R using `read.clipboard` and its variations
3. Reading a text or csv file
   - read a local or remote file
4. Importing from SPSS or SAS
5. Simulate it (using various simulation routines)

Examples of built in data sets from the psych package

```
> data(package="psych")
```

```
Bechtoldt                Seven data sets showing a bifactor solution.
Dwyer                    8 cognitive variables used by Dwyer for an examp
Reise                    Seven data sets showing a bifactor solution.
all.income (income)      US family income from US census 2008
bfi                      25 Personality items representing 5 factors
blot                     Bond's Logical Operations Test - BLOT
burt                     11 emotional variables from Burt (1915)
cities                   Distances between 11 US cities
epi.bfi                  13 personality scales from the Eysenck Personali
                         and Big 5 inventory
flat (affect)            Two data sets of affect and arousal scores as a
                         personality and movie conditions
galton                   Galton's Mid parent child height data
income                   US family income from US census 2008
iqitems                  14 multiple choice IQ items
msq                      75 mood items from the Motivational State Questi
                         3896 participants
neo                      NEO correlation matrix from the NEO_PI_R manual
sat.act                  3 Measures of ability: SATV, SATQ, ACT
Thurstone                Seven data sets showing a bifactor solution.
veg (vegetables)         Paired comparison of preferences for 9 vegetable
```

Reading data from another program –using the clipboard

1. Read the data in your favorite spreadsheet or text editor
2. Copy to the clipboard
3. Execute the appropriate `read.clipboard` function with or without various options specified

```
my.data <- read.clipboard()   #assumes headers and tab or space delimited
my.data <- read.clipboard.csv()   #assumes headers and comma delimited
my.data <- read.clipboard.tab()   #assumes headers and tab delimited
                                        (e.g., from Excel)
my.data <- read.clipboard.lower()  #read in a matrix given the lower
my.data <- read.clipboard.upper() #  or upper  off diagonal
my.data <- read.clipboard.fwf()  #read in data using a fixed format width
                                        (see read.fwf for instructions)
```

4. `read.clipboard()` has default values for the most common cases and these do not need to be specified. Consult ?read.clipboard for details.

Reading from a local or remote file

1. Perhaps the standard way of reading in data is using the `read` command.
   - First must specify the location of the file
   - Can either type this in directly or use the `file.choose` function
   - The file name/location can be a remote URL
2. Two examples of reading data

```
file.name <- file.choose() #this opens a window to allow you find the file
my.data <- read.table(file.name)
datafilename="http://personality-project.org/r/datasets/R.appendix1.data"
data.ex1=read.table(datafilename,header=TRUE)   #read the data into a table
```

```
> dim(data.ex1)  #what are the dimensions of what we read?
[1] 18  2
> describe(data.ex1) #do the data look right?
           var  n  mean   sd median trimmed  mad min max range skew kurtosi
Dosage*      1 18  1.89 0.76      2    1.88 1.48   1   3     2 0.16    -1.1
Alertness    2 18 27.67 6.82     27   27.50 8.15  17  41    24 0.25    -0.6
```

read a "foreign" file e.g., an SPSS sav file

`read.spss` reads a file stored by the SPSS save or export commands.

```
read.spss(file, use.value.labels = TRUE, to.data.frame = FALSE,
          max.value.labels = Inf, trim.factor.names = FALSE,
          trim_values = TRUE, reencode = NA, use.missings = to.data.frame)
```

file	Character string: the name of the file or URL to read.
use.value.labels	Convert variables with value labels into R factors with those levels?
to.data.frame	return a data frame? Defaults to FALSE, probably should be TRUE in most cases.
max.value.labels	Only variables with value labels and at most this many unique values will be converted to factors if use.value.labels = *TRUE*.
trim.factor.names	Logical: trim trailing spaces from factor levels?
trim_values	logical: should values and value labels have trailing spaces ignored when matching for use.value.labels = *TRUE*?
use.missings	logical: should information on user-defined missing values be used to set the corresponding values to NA?

An example of reading from an SPSS file

```
> library(foreign)

> datafilename <- "http://personality-project.org/r/datasets/finkel.sav"

>  eli <- read.spss(datafilename,to.data.frame=TRUE,
                            use.value.labels=FALSE)

> describe(eli,skew=FALSE)

          var  n  mean    sd median trimmed   mad min max range   se
USER*       1 69 35.00 20.06     35   35.00 25.20   1  69    68 2.42
HAPPY       2 69  5.71  1.04      6    5.82  0.00   2   7     5 0.13
SOULMATE    3 69  5.09  1.80      5    5.32  1.48   1   7     6 0.22
ENJOYDEX    4 68  6.47  1.01      7    6.70  0.00   2   7     5 0.12
UPSET       5 69  0.41  0.49      0    0.39  0.00   0   1     1 0.06
```

1. Make the *foreign* package active
2. Specify the name (and location) of the file to read
3. Read from a SPSS file
4. Describe it to make sure it is right

Simulate data

For many demonstration purposes, it is convenient to generate simulated data with a certain defined structure. The *psych* package has a number of built in simulation functions. Here are a few of them.

1. Simulate various item structures
   - sim.congeneric A one factor congeneric measure model
   - sim.items A two factor structure with either simple structure or a circumplex structure.
   - sim.rasch Generate items for a one parameter IRT model.
   - sim.irt Generate items for a one-four parameter IRT Model
2. Simulate various factor structures
   - sim.simplex Default is a four factor structure with a three time point simplex structure.
   - sim.hierarchical Default is 9 variables with three correlated factors.

Get the data and look at it

Read in some data, look at the first and last few cases (using `headtail`), and then get basic descriptive statistics. For this example, we will use a built in data set.

```
> my.data <- epi.bfi
> headtail(my.data)
```

	epiE	epiS	epiImp	epilie	epiNeur	bfagree	bfcon	bfext	bfneur	bfopen	bdi	traitanx	stateanx
1	18	10	7	3	9	138	96	141	51	138	1	24	22
2	16	8	5	1	12	101	99	107	116	132	7	41	40
3	6	1	3	2	5	143	118	38	68	90	4	37	44
4	12	6	4	3	15	104	106	64	114	101	8	54	40
...	...	...	...	...	...	...	...	...	...	...	...	...	...
228	12	7	4	3	15	155	129	127	88	110	9	35	34
229	19	10	7	2	11	162	152	163	104	164	1	29	47
230	4	1	1	2	10	95	111	75	123	138	5	39	58
231	8	6	3	2	15	85	62	90	131	96	24	58	58

epi.bfi has 231 cases from two personality measures.

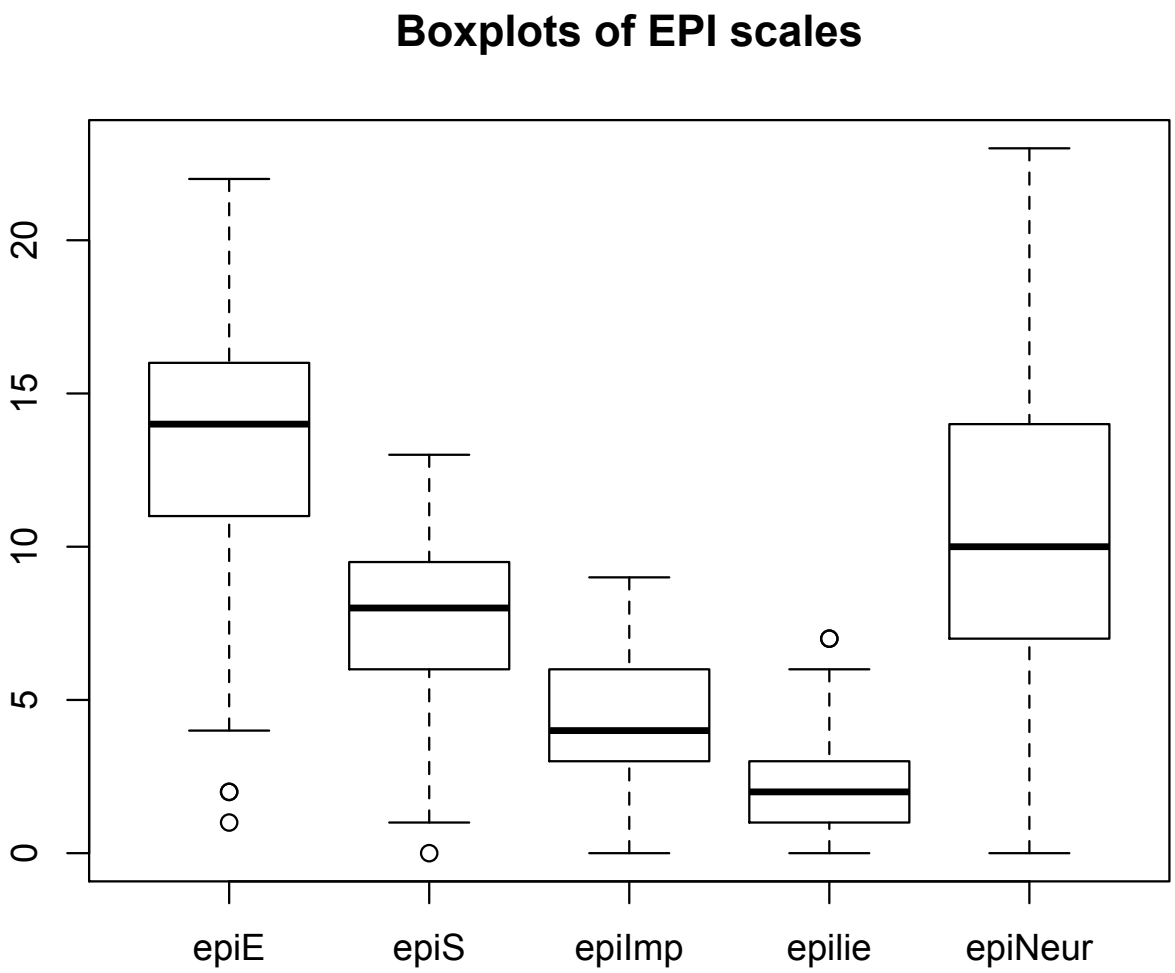
Now find the descriptive statistics for this data set

```
> describe(my.data)
```

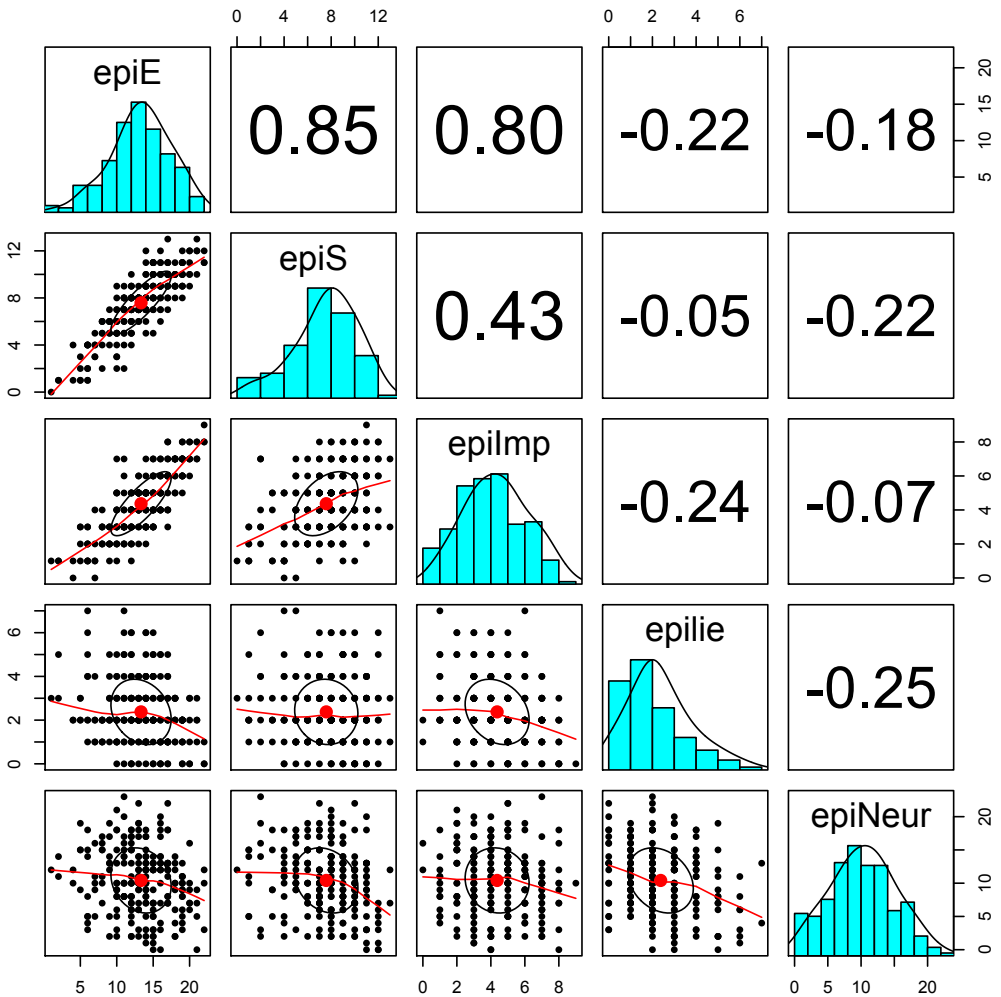
	var	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
epiE	1	231	13.33	4.14	14	13.49	4.45	1	22	21	-0.33	-0.01	0.27
epiS	2	231	7.58	2.69	8	7.77	2.97	0	13	13	-0.57	0.04	0.18
epiImp	3	231	4.37	1.88	4	4.36	1.48	0	9	9	0.06	-0.59	0.12
epilie	4	231	2.38	1.50	2	2.27	1.48	0	7	7	0.66	0.30	0.10
epiNeur	5	231	10.41	4.90	10	10.39	4.45	0	23	23	0.06	-0.46	0.32
bfagree	6	231	125.00	18.14	126	125.26	17.79	74	167	93	-0.21	-0.22	1.19
bfcon	7	231	113.25	21.88	114	113.42	22.24	53	178	125	-0.02	0.29	1.44
bfext	8	231	102.18	26.45	104	102.99	22.24	8	168	160	-0.41	0.58	1.74
bfneur	9	231	87.97	23.34	90	87.70	23.72	34	152	118	0.07	-0.51	1.54
bfopen	10	231	123.43	20.51	125	123.78	20.76	73	173	100	-0.16	-0.11	1.35
bdi	11	231	6.78	5.78	6	5.97	4.45	0	27	27	1.29	1.60	0.38
traitanx	12	231	39.01	9.52	38	38.36	8.90	22	71	49	0.67	0.54	0.63
stateanx	13	231	39.85	11.48	38	38.92	10.38	21	79	58	0.72	0.04	0.76

Boxplots are a convenient descriptive device

Show the Tukey "boxplot" for the Eysenck Personality Inventory



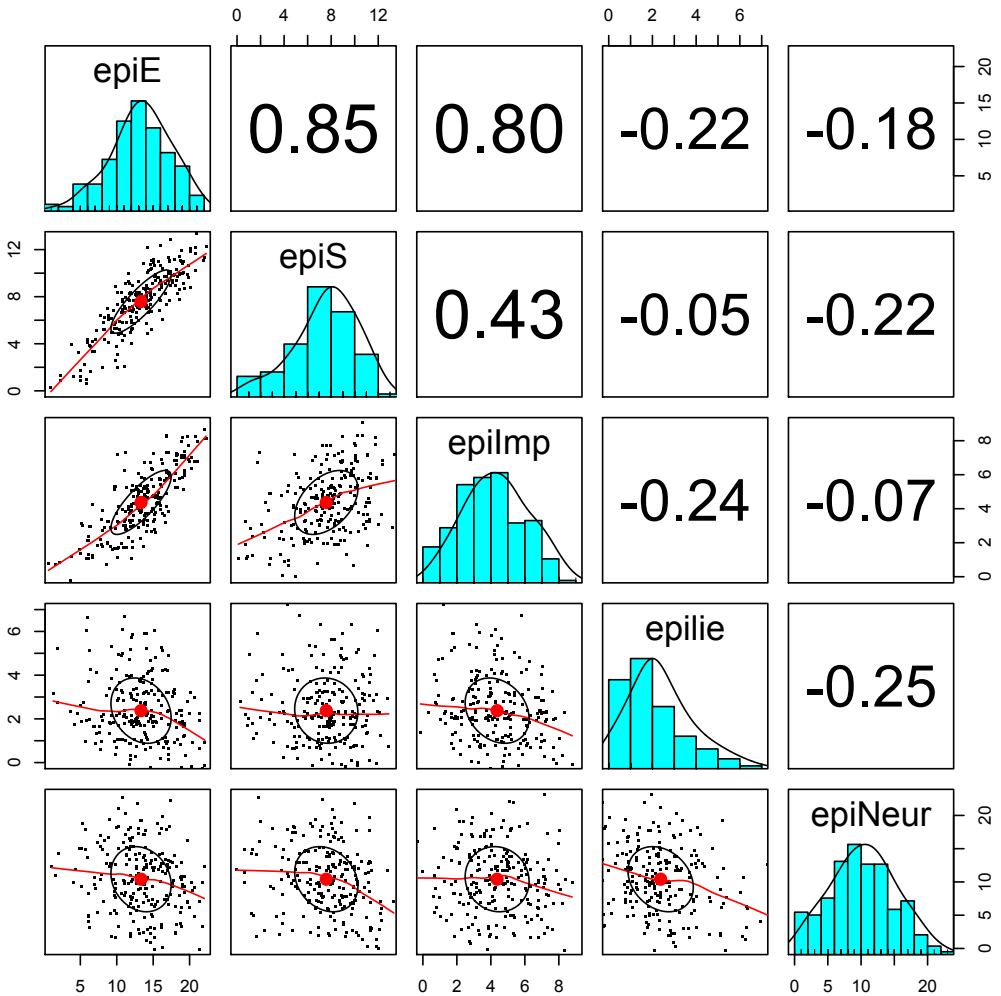
Plot the scatter plot matrix (SPLOM) of the first 5 variables using the `pairs.panels` function



Use the `pairs.panels` function from *psych*

```
pairs.panels(my.data[1:5])
```

Plot the scatter plot matrix (SPLOM) of the first 5 variables using the `pairs.panels` function but with smaller pch and jittering the points.



Use the `pairs.panels` function from *psych*

```
pairs.panels(my.data[1:5],pch='.',
      jiggle=TRUE)
```

Find the correlations for this data set, round off to 2 decimal places

```
> round(cor(my.data, use = "pairwise"), 2)
```

	epiE	epiS	epiImp	epilie	epiNeur	bfagree	bfcon	bfext	bfneur	bfopen	bdi	traitanx	stateanx
epiE	1.00	0.85	0.80	-0.22	-0.18	0.18	-0.11	0.54	-0.09	0.14	-0.16	-0.23	-0.13
epiS	0.85	1.00	0.43	-0.05	-0.22	0.20	0.05	0.58	-0.07	0.15	-0.13	-0.26	-0.12
epiImp	0.80	0.43	1.00	-0.24	-0.07	0.08	-0.24	0.35	-0.09	0.07	-0.11	-0.12	-0.09
epilie	-0.22	-0.05	-0.24	1.00	-0.25	0.17	0.23	-0.04	-0.22	-0.03	-0.20	-0.23	-0.15
epiNeur	-0.18	-0.22	-0.07	-0.25	1.00	-0.08	-0.13	-0.17	0.63	0.09	0.58	0.73	0.49
bfagree	0.18	0.20	0.08	0.17	-0.08	1.00	0.45	0.48	-0.04	0.39	-0.14	-0.31	-0.19
bfcon	-0.11	0.05	-0.24	0.23	-0.13	0.45	1.00	0.27	0.04	0.31	-0.18	-0.29	-0.14
bfext	0.54	0.58	0.35	-0.04	-0.17	0.48	0.27	1.00	0.04	0.46	-0.14	-0.39	-0.15
bfneur	-0.09	-0.07	-0.09	-0.22	0.63	-0.04	0.04	0.04	1.00	0.29	0.47	0.59	0.49
bfopen	0.14	0.15	0.07	-0.03	0.09	0.39	0.31	0.46	0.29	1.00	-0.08	-0.11	-0.04
bdi	-0.16	-0.13	-0.11	-0.20	0.58	-0.14	-0.18	-0.14	0.47	-0.08	1.00	0.65	0.61
traitanx	-0.23	-0.26	-0.12	-0.23	0.73	-0.31	-0.29	-0.39	0.59	-0.11	0.65	1.00	0.57
stateanx	-0.13	-0.12	-0.09	-0.15	0.49	-0.19	-0.14	-0.15	0.49	-0.04	0.61	0.57	1.00

Find the correlations for this data set, round off to 2 decimal places using `lowerCor`

```
> lowerCor(my.data)

         epiE  epiS  epImp epili epiNr bfagr bfcon bfext bfner bfopn bdi   trtnx sttnx
epiE      1.00
epiS      0.85  1.00
epiImp    0.80  0.43  1.00
epilie   -0.22 -0.05 -0.24  1.00
epiNeur  -0.18 -0.22 -0.07 -0.25  1.00
bfagree   0.18  0.20  0.08  0.17 -0.08  1.00
bfcon    -0.11  0.05 -0.24  0.23 -0.13  0.45  1.00
bfext     0.54  0.58  0.35 -0.04 -0.17  0.48  0.27  1.00
bfneur   -0.09 -0.07 -0.09 -0.22  0.63 -0.04  0.04  0.04  1.00
bfopen    0.14  0.15  0.07 -0.03  0.09  0.39  0.31  0.46  0.29  1.00
bdi      -0.16 -0.13 -0.11 -0.20  0.58 -0.14 -0.18 -0.14  0.47 -0.08  1.00
traitanx -0.23 -0.26 -0.12 -0.23  0.73 -0.31 -0.29 -0.39  0.59 -0.11  0.65  1.00
stateanx -0.13 -0.12 -0.09 -0.15  0.49 -0.19 -0.14 -0.15  0.49 -0.04  0.61  0.57  1.00
```

Test the significance and use Holm correction for multiple tests

```
> corr.test(my.data)
Call:corr.test(x = my.data)
Correlation matrix
          epiE  epiS epiImp epilie epiNeur bfagree bfcon bfext bfneur bfopen   bdi traitanx stateanx
epiE      1.00  0.85   0.80  -0.22   -0.18    0.18 -0.11  0.54  -0.09   0.14 -0.16    -0.23    -0.13
epiS      0.85  1.00   0.43  -0.05   -0.22    0.20  0.05  0.58  -0.07   0.15 -0.13    -0.26    -0.12
epiImp    0.80  0.43   1.00  -0.24   -0.07    0.08 -0.24  0.35  -0.09   0.07 -0.11    -0.12    -0.09
..
stateanx -0.13 -0.12  -0.09  -0.15    0.49   -0.19 -0.14 -0.15   0.49  -0.04  0.61     0.57     1.00
Sample Size
          epiE epiS epiImp epilie epiNeur bfagree bfcon bfext bfneur bfopen bdi traitanx stateanx
epiE       231  231    231    231     231     231   231   231    231    231 231      231      231
..
stateanx   231  231    231    231     231     231   231   231    231    231 231      231      231
Probability values (Entries above the diagonal are adjusted for multiple tests.)
          epiE epiS epiImp epilie epiNeur bfagree bfcon bfext bfneur bfopen  bdi traitanx stateanx
epiE      0.00 0.00   0.00   0.03    0.27    0.27  1.00  0.00   1.00   1.00 0.59    0.02     1.00
epiS      0.00 0.00   0.00   1.00    0.04    0.08  1.00  0.00   1.00   0.62 1.00    0.00     1.00
epiImp    0.00 0.00   0.00   0.01    1.00    1.00  0.01  0.00   1.00   1.00 1.00    1.00     1.00
epilie    0.00 0.43   0.00   0.00    0.01    0.32  0.03  1.00   0.03   1.00 0.08    0.02     0.61
epiNeur   0.01 0.00   0.26   0.00    0.00    1.00  1.00  0.33   0.00   1.00 0.00    0.00     0.00
bfagree   0.01 0.00   0.23   0.01    0.21    0.00  0.00  0.00   1.00   0.00 0.95    0.00     0.12
bfcon     0.08 0.48   0.00   0.00    0.04    0.00  0.00  0.00   1.00   0.00 0.25    0.00     1.00
bfext     0.00 0.00   0.00   0.50    0.01    0.00  0.00  0.00   1.00   0.00 0.99    0.00     0.76
bfneur    0.15 0.30   0.18   0.00    0.00    0.50  0.50  0.57   0.00   0.00 0.00    0.00     0.00
bfopen    0.04 0.02   0.30   0.70    0.19    0.00  0.00  0.00   0.00   0.00 1.00    1.00     1.00
bdi       0.02 0.04   0.11   0.00    0.00    0.03  0.01  0.03   0.00   0.25 0.00    0.00     0.00
traitanx  0.00 0.00   0.07   0.00    0.00    0.00  0.00  0.00   0.00   0.11 0.00    0.00     0.00
stateanx  0.05 0.07   0.18   0.02    0.00    0.00  0.04  0.02   0.00   0.52 0.00    0.00     0.00
>
```

t.test demonstration with Student's data (from the sleep dataset)

sleep

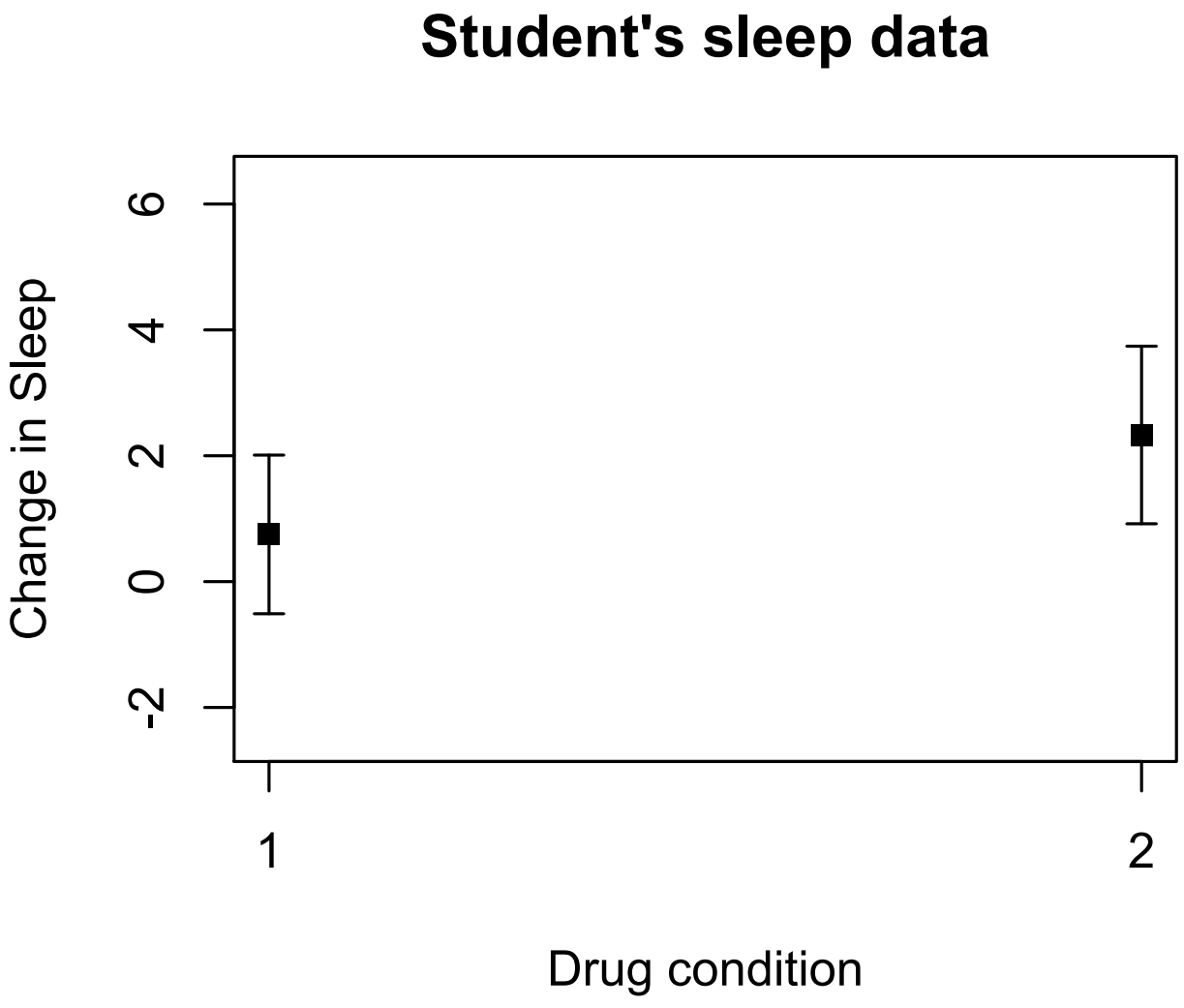
```
> sleep
   extra group ID
1    0.7     1  1
2   -1.6     1  2
3   -0.2     1  3
4   -1.2     1  4
5   -0.1     1  5
6    3.4     1  6
7    3.7     1  7
...
13   1.1     2  3
14   0.1     2  4
15  -0.1     2  5
16   4.4     2  6
17   5.5     2  7
18   1.6     2  8
19   4.6     2  9
20   3.4     2 10
```

```
> with(sleep,t.test(extra~group))

Welch Two Sample t-test
data:  extra by group
t = -1.8608, df = 17.776, p-value = 0.07939
alternative hypothesis: true difference in means is not equal t
95 percent confidence interval:
 -3.3654832  0.2054832
sample estimates:
mean in group 1 mean in group 2
          0.75              2.33
```

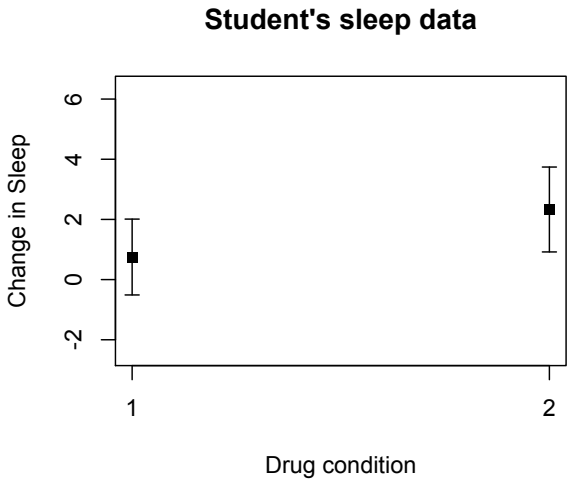
But the data were actually paired. Do it for a paired t-test

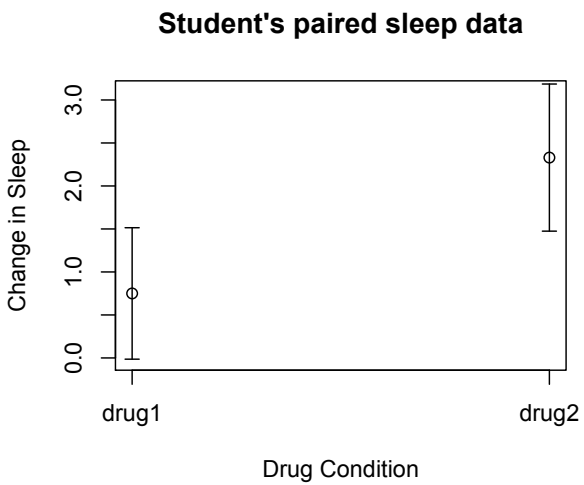
```
> with(sleep,t.test(extra~group,paired=TRUE))

Paired t-test
data:  extra by group
t = -4.0621, df = 9, p-value = 0.002833
alternative hypothesis: true difference in means is not equal t
95 percent confidence interval:
 -2.4598858 -0.7001142
sample estimates:
mean of the differences
                  -1.58
```

Two ways of showing Student's t test data



Two ways of showing Student's t test data





Use the `error.bars.by` and `error.bars` functions. Note that we need to change the data structure a little bit to get the within subject error bars.

```
> error.bars.by(sleep$extra,sleep$group,
    by.var=TRUE,  lines=FALSE,
    ylab="Change in Sleep", xlab="Drug
    condition",main="Student's sleep data")
```

```
> error.bars(data.frame(drug1=sleep[1:10,1],
      drug2=sleep[11:20,1]), within=TRUE,
       ylab="Change in Sleep"
       ,xlab="Drug Condition",
        main="Student's paired sleep data")
```

Analysis of Variance

1. aov is designed for balanced designs, and the results can be hard to interpret without balance: beware that missing values in the response(s) will likely lose the balance.
2. If there are two or more error strata, the methods used are statistically inefficient without balance, and it may be better to use `lme` in package *nlme*.

```
datafilename="http://personality-project.org/R/datasets/R.appendix2.data"
data.ex2=read.table(datafilename,header=T)   #read the data into a table
data.ex2                                      #show the data
```

```
 data.ex2                                       #show the data
   Observation Gender Dosage Alertness
1            1      m      a         8
2            2      m      a        12
3            3      m      a        13
4            4      m      a        12
...
14          14      f      b        12
15          15      f      b        18
16          16      f      b        22
```

Analysis of Variance

1. Do the analysis of variances and the show the table of results.

```
aov.ex2 = aov(Alertness~Gender*Dosage,data=data.ex2)  #do the analysis of varian
summary(aov.ex2)                                      #show the summary table
```

```
 > aov.ex2 = aov(Alertness~Gender*Dosage,data=data.ex2)  #do the analysis of va
> summary(aov.ex2)                                       #show the summary table
              Df  Sum Sq Mean Sq F value Pr(>F)
Gender         1  76.562  76.562  2.9518 0.1115
Dosage         1   5.062   5.062  0.1952 0.6665
Gender:Dosage  1   0.063   0.063  0.0024 0.9617
```

Show the results table

```
> print(model.tables(aov.ex2,"means"),digits=3)
Residuals     12 311.250  25.938

Tables of means
Grand mean

14.0625

 Gender
Gender
    f     m
16.25 11.88

 Dosage
Dosage
    a     b
13.50 14.62

 Gender:Dosage
      Dosage
Gender a     b
     f 15.75 16.75
     m 11.25 12.50
```

Analysis of Variance: Within subjects

1. Somewhat more complicated because we need to convert "wide" data.frames to "long" or "narrow" data.frame.
2. This can be done by using the `stack` function. Some data sets are already in the long format.
3. A detailed discussion of how to work with repeated measures designs is at http://personality-project.org/r/r.anova.html and at http://personality-project.org/r

Analysis of variance within subjects

```
> datafilename="http://personality-project.org/r/datasets/R.appendix5.data"
> data.ex5=read.table(datafilename,header=T)   #read the data into a table
> #data.ex5                                     #show the data
> aov.ex5 =
+ aov(Recall~(Task*Valence*Gender*Dosage)+Error(Subject/(Task*Valence))+
+ (Gender*Dosage),data.ex5)
> summary(aov.ex5)

Error: Subject
              Df  Sum Sq Mean Sq F value  Pr(>F)
Gender         1  542.26  542.26  5.6853 0.03449 *
Dosage         2  694.91  347.45  3.6429 0.05803 .
Gender:Dosage  2   70.80   35.40  0.3711 0.69760
Residuals     12 1144.56   95.38
Signif. codes:  0 Ô***Õ 0.001 Ô**Õ 0.01 Ô*Õ 0.05 Ô.Õ 0.1 Ô Õ 1

Error: Subject:Task
                   Df Sum Sq Mean Sq F value    Pr(>F)
Task                1 96.333  96.333 39.8621 3.868e-05 ***
Task:Gender         1  1.333   1.333  0.5517    0.4719
Task:Dosage         2  8.167   4.083  1.6897    0.2257
Task:Gender:Dosage  2  3.167   1.583  0.6552    0.5370
Residuals          12 29.000   2.417
... (lots more)
```

Multiple regression

1. Use the `sat.act` data set from *psych*
2. Do the linear model
3. Summarize the results

```
 mod1 <- lm(SATV ~ education + gender + SATQ,data=sat.act)
> summary(mod1,digits=2)

Call:
lm(formula = SATV ~ education + gender + SATQ, data = sat.act)
Residuals:
    Min      1Q  Median      3Q     Max
-372.91  -49.08    2.30   53.68  251.93
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 180.87348   23.41019   7.726 3.96e-14 ***
education     1.24043    2.32361   0.534  0.59363
gender       20.69271    6.99651   2.958  0.00321 **
SATQ          0.64489    0.02891  22.309  < 2e-16 ***
Signif. codes:  0 Ô***Õ 0.001 Ô**Õ 0.01 Ô*Õ 0.05 Ô.Õ 0.1 Ô Õ 1
Residual standard error: 86.24 on 683 degrees of freedom
  (13 observations deleted due to missingness)
Multiple R-squared: 0.4231, Adjusted R-squared: 0.4205
F-statistic:   167 on 3 and 683 DF,  p-value: < 2.2e-16
```

Zero center the data before examining interactions

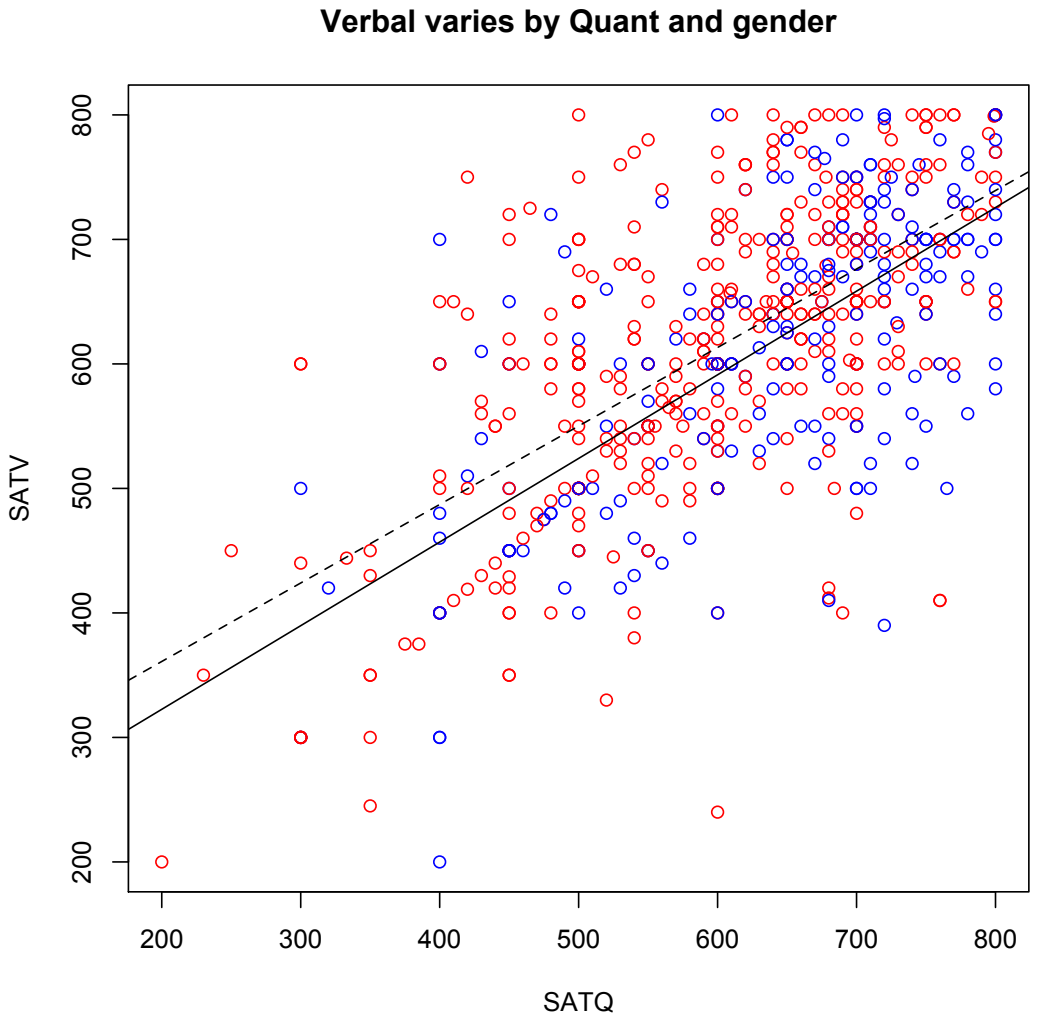
```
> zsat <- data.frame(scale(sat.act,scale=FALSE))
> mod2 <-  lm(SATV  ~ education * gender * SATQ,data=zsat)
> summary(mod2)

Call:
lm(formula = SATV ~ education * gender * SATQ, data = zsat)

Residuals:
    Min      1Q  Median      3Q     Max
-372.53  -48.76    3.33   51.24  238.50

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)            0.773576   3.304938   0.234  0.81500
education              2.517314   2.337889   1.077  0.28198
gender                18.485906   6.964694   2.654  0.00814 **
SATQ                   0.620527   0.028925  21.453  < 2e-16 ***
education:gender       1.249926   4.759374   0.263  0.79292
education:SATQ        -0.101444   0.020100  -5.047 5.77e-07 ***
gender:SATQ            0.007339   0.060850   0.121  0.90404
education:gender:SATQ  0.035822   0.041192   0.870  0.38481
---
Signif. codes:  0 Ô***Õ 0.001 Ô**Õ 0.01 Ô*Õ 0.05 Ô.Õ 0.1 Ô Õ 1
```

Compare model 1 and model 2

Test the difference between the two linear models

```
> anova(mod1,mod2)

Analysis of Variance Table

Model 1: SATV ~ education + gender + SATQ
Model 2: SATV ~ education * gender * SATQ
  Res.Df     RSS Df Sum of Sq      F    Pr(>F)
1    683 5079984
2    679 4870243  4    209742 7.3104 9.115e-06 ***
---
Signif. codes:  0 Ô***Õ 0.001 Ô**Õ 0.01 Ô*Õ 0.05 Ô.Õ 0.1 Ô
```

Show the regression lines by gender




```
> with(sat.act,plot(SATV~SATQ,
    col=c("blue","red")[gender]))
> by(sat.act,sat.act$gender,
    function(x) abline
        (lm(SATV~SATQ,data=x),
        lty=c("solid","dashed")))
> title("Verbal varies by Quant
        and gender")
```

Psychometrics

1. Classical test theory measures of reliability
   - Scoring tests
   - Reliability (alpha, beta, omega)
2. Multivariate Analysis
   - Factor Analysis
   - Components analysis
   - Multidimensional scaling
   - Structural Equation Modeling
3. Item Response Theory
   - One parameter (Rasch) models
   - 2PL and 2PN models

Classic theory estimates of reliabllity

1. Scoring tests

   `score.items` Score 1-n scales using a set of keys and finding the simple sum or average of items. Reversed items are indicated by -1

   `score.multipe.choice` : Score multiple choice items by first converting to 0 or 1 and then proceeding to score the items.

2. Alternative estimates of reliability

   `alpha` α reliability of a single scale finds the average split half reliability. (some items may be reversed keyed).

   `omega` ω_h reliability of a single scale estimates the general factor saturation of the test.

   `guttman` Find the 6 Guttman reliability estimates

Using `score.items` to score 25 Big 5 items (taken from the bfi example

```
> keys.list <- list(Agree=c(-1,2:5),Conscientious=c(6:8,-9,-10),Extraversion=c(-11,-12,13:15),
                                Neuroticism=c(16:20),Openness = c(21,-22,23,24,-25))
> keys <- make.keys(28,keys.list,item.labels=colnames(bfi))
> score.items(keys,bfi)

Call: score.items(keys = keys, items = bfi)

(Unstandardized) Alpha:
      Agree Conscientious Extraversion Neuroticism Openness
alpha   0.7          0.72         0.76        0.81      0.6

Average item correlation:
          Agree Conscientious Extraversion Neuroticism Openness
average.r  0.32          0.34         0.39        0.46     0.23

 Guttman 6* reliability:
         Agree Conscientious Extraversion Neuroticism Openness
Lambda.6   0.7          0.72         0.76        0.81      0.6

Scale intercorrelations corrected for attenuation
 raw correlations below the diagonal, alpha on the diagonal
 corrected correlations above the diagonal:
             Agree Conscientious Extraversion Neuroticism Openness
Agree         0.70          0.36         0.63      -0.245     0.23
Conscientious 0.26          0.72         0.35      -0.305     0.30
Extraversion  0.46          0.26         0.76      -0.284     0.32
Neuroticism  -0.18         -0.23        -0.22       0.812    -0.12
Openness      0.15          0.19         0.22      -0.086     0.60
...
```

score.items output, continued

```
Item by scale correlations:
 corrected for item overlap and scale reliability
          Agree Conscientious Extraversion Neuroticism Openness
A1        -0.40         -0.06        -0.11        0.14    -0.14
A2         0.67          0.23         0.40       -0.07     0.17
A3         0.70          0.22         0.48       -0.11     0.17
A4         0.49          0.29         0.30       -0.14     0.01
A5         0.62          0.23         0.55       -0.23     0.18
C1         0.13          0.53         0.19       -0.08     0.28
C2         0.21          0.61         0.17        0.00     0.20
C3         0.21          0.54         0.14       -0.09     0.08
C4        -0.24         -0.66        -0.23        0.31    -0.23
C5        -0.26         -0.59        -0.29        0.36    -0.10
E1        -0.30         -0.06        -0.59        0.11    -0.16
E2        -0.39         -0.25        -0.70        0.34    -0.15
E3         0.44          0.20         0.60       -0.10     0.37
E4         0.51          0.23         0.68       -0.22     0.04
E5         0.34          0.40         0.55       -0.10     0.31
N1        -0.22         -0.21        -0.11        0.76    -0.12
N2        -0.22         -0.19        -0.12        0.74    -0.06
N3        -0.14         -0.20        -0.14        0.74    -0.03
N4        -0.22         -0.30        -0.39        0.62    -0.02
N5        -0.04         -0.14        -0.19        0.55    -0.18
O1         0.16          0.20         0.31       -0.09     0.52
O2        -0.01         -0.18        -0.07        0.19    -0.45
O3         0.26          0.20         0.42       -0.07     0.61
O4         0.06         -0.02        -0.10        0.21     0.32
O5        -0.09         -0.14        -0.11        0.11    -0.53
gender     0.25          0.11         0.12        0.14    -0.07
education  0.06          0.03         0.01       -0.06     0.13
age        0.22          0.14         0.07       -0.13     0.10
```

Factor analysis of Thurstone 9 variable problem

```
> f3 <- fa(Thurstone,3) #use this built in dataset
> f3

Factor Analysis using method =  minres
Call: fac(r = r, nfactors = nfactors, n.obs = n.obs, rotate = rotate,
    scores = scores, residuals = residuals, SMC = SMC, missing = FALSE,
    impute = impute, min.err = min.err, max.iter = max.iter,
    symmetric = symmetric, warnings = warnings, fm = fm, alpha = alpha)
Standardized loadings based upon correlation matrix
                   MR1   MR2   MR3   h2   u2
Sentences         0.91 -0.04  0.04 0.82 0.18
Vocabulary        0.89  0.06 -0.03 0.84 0.16
Sent.Completion   0.83  0.04  0.00 0.73 0.27
First.Letters     0.00  0.86  0.00 0.73 0.27
4.Letter.Words   -0.01  0.74  0.10 0.63 0.37
Suffixes          0.18  0.63 -0.08 0.50 0.50
Letter.Series     0.03 -0.01  0.84 0.72 0.28
Pedigrees         0.37 -0.05  0.47 0.50 0.50
Letter.Group     -0.06  0.21  0.64 0.53 0.47

                 MR1  MR2  MR3
SS loadings     2.64 1.86 1.50
Proportion Var 0.29 0.21 0.17
Cumulative Var 0.29 0.50 0.67

 With factor correlations of
     MR1  MR2  MR3
MR1 1.00 0.59 0.54
MR2 0.59 1.00 0.52
MR3 0.54 0.52 1.00
...
```

Factor analysis output, continued

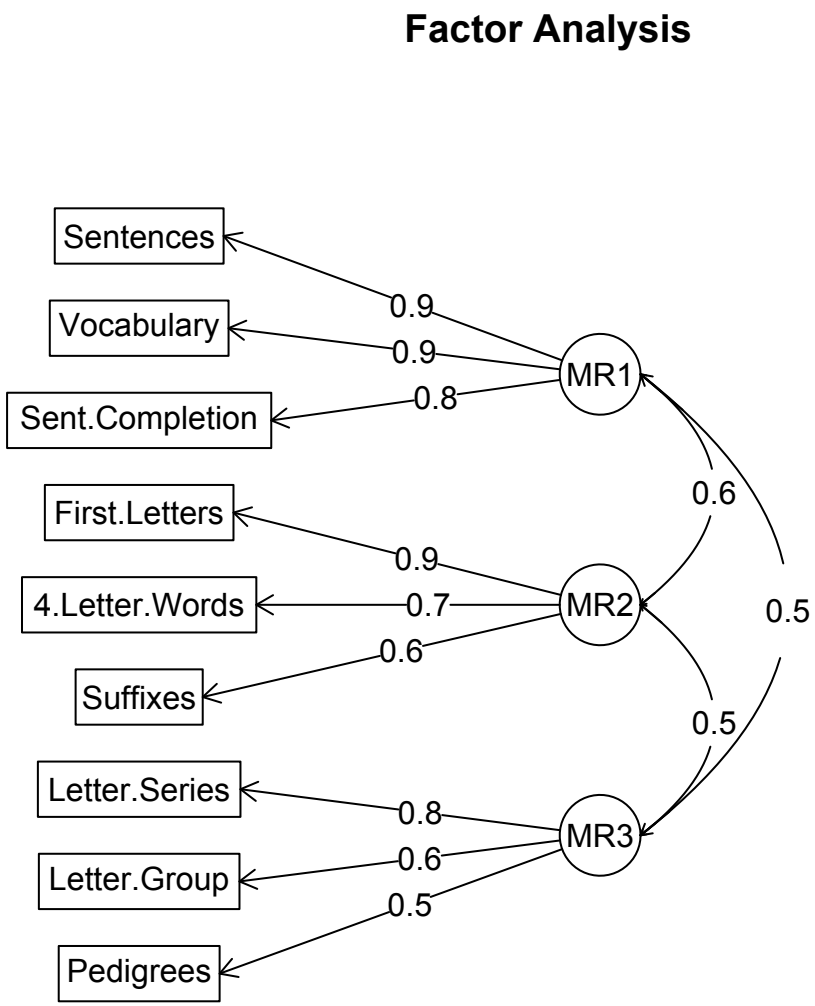
```
Test of the hypothesis that 3 factors are sufficient.

The degrees of freedom for the null model are  36  and the objective function was  5.2 with Chi Square of
The degrees of freedom for the model are 12  and the objective function was  0.01

The root mean square of the residuals is  0
The df corrected root mean square of the residuals is  0.01
The number of observations was  213  with Chi Square =  2.82  with prob <  1

Tucker Lewis Index of factoring reliability =  1.027
RMSEA index =  0  and the 90 % confidence intervals are  0 0.023
BIC =  -61.51
Fit based upon off diagonal values = 1
Measures of factor score adequacy
                                                MR1  MR2  MR3
Correlation of scores with factors             0.96 0.92 0.90
Multiple R square of scores with factors       0.93 0.85 0.81
Minimum correlation of possible factor scores  0.86 0.71 0.63
```

Bootstrapped confidence intervals

```
> f3 <- fa(Thurstone,3,n.obs=213,n.iter=20)   #to do bootstrapping

Coefficients and bootstrapped confidence intervals
                  low   MR1 upper   low   MR2 upper   low   MR3 upper
Sentences        0.77  0.91  0.96 -0.12 -0.04  0.07 -0.03  0.04  0.14
Vocabulary       0.85  0.89  0.95 -0.01  0.06  0.10 -0.12 -0.03  0.04
Sent.Completion  0.73  0.83  0.87 -0.04  0.04  0.13 -0.08  0.00  0.12
First.Letters   -0.06  0.00  0.10  0.68  0.86  0.93 -0.13  0.00  0.13
4.Letter.Words  -0.14 -0.01  0.07  0.58  0.74  0.86  0.01  0.10  0.25
Suffixes         0.07  0.18  0.27  0.46  0.63  0.76 -0.20 -0.08  0.06
Letter.Series   -0.04  0.03  0.13 -0.10 -0.01  0.10  0.56  0.84  0.93
Pedigrees        0.25  0.37  0.46 -0.16 -0.05  0.08  0.27  0.47  0.66
Letter.Group    -0.16 -0.06  0.06  0.09  0.21  0.31  0.44  0.64  0.79

 Interfactor correlations and bootstrapped confidence intervals
  lower estimate upper
1  0.40     0.59  0.64
2  0.29     0.54  0.63
3  0.29     0.52  0.61
```

The simple factor structure

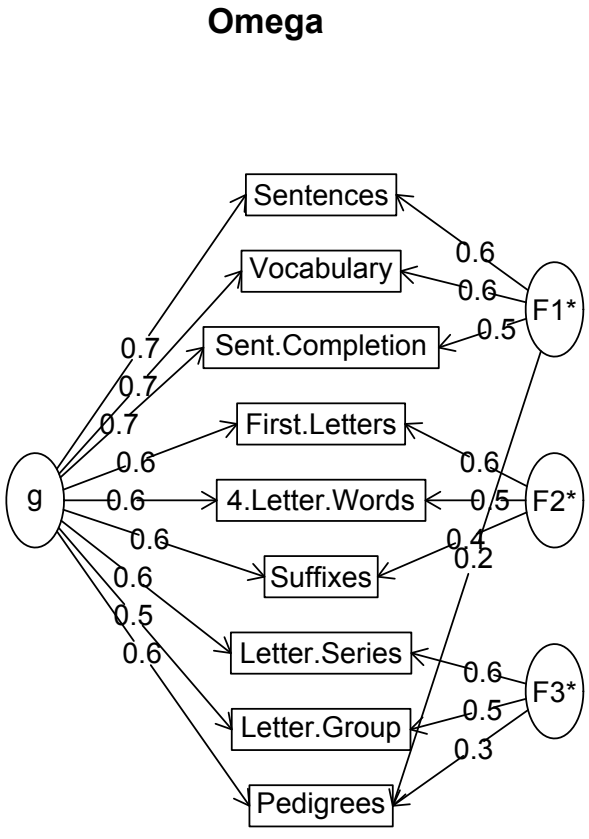
```
factor.diagram(f3) # show the diagram
```

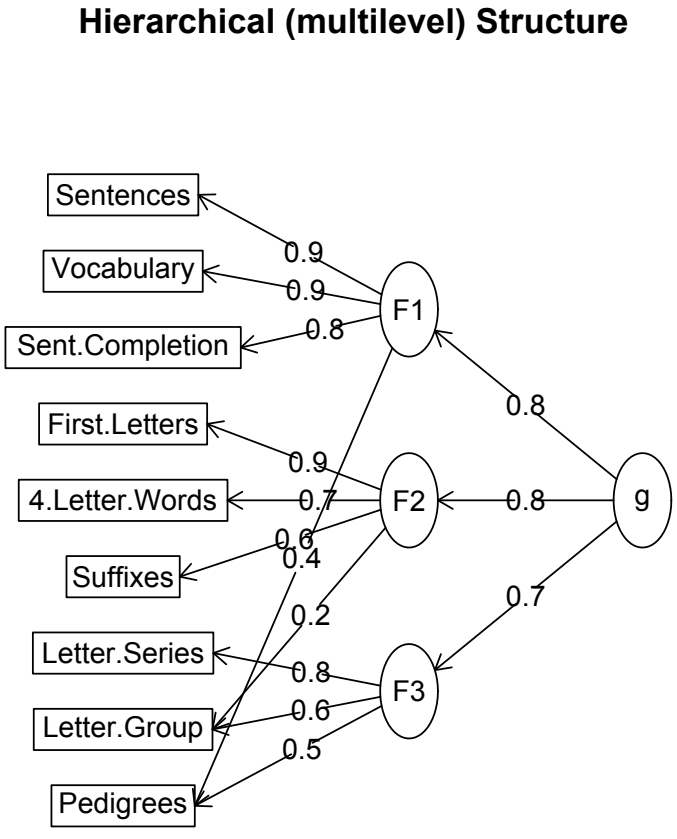


Two ways of viewing the higher order structure

om <- omega(Thurstone)

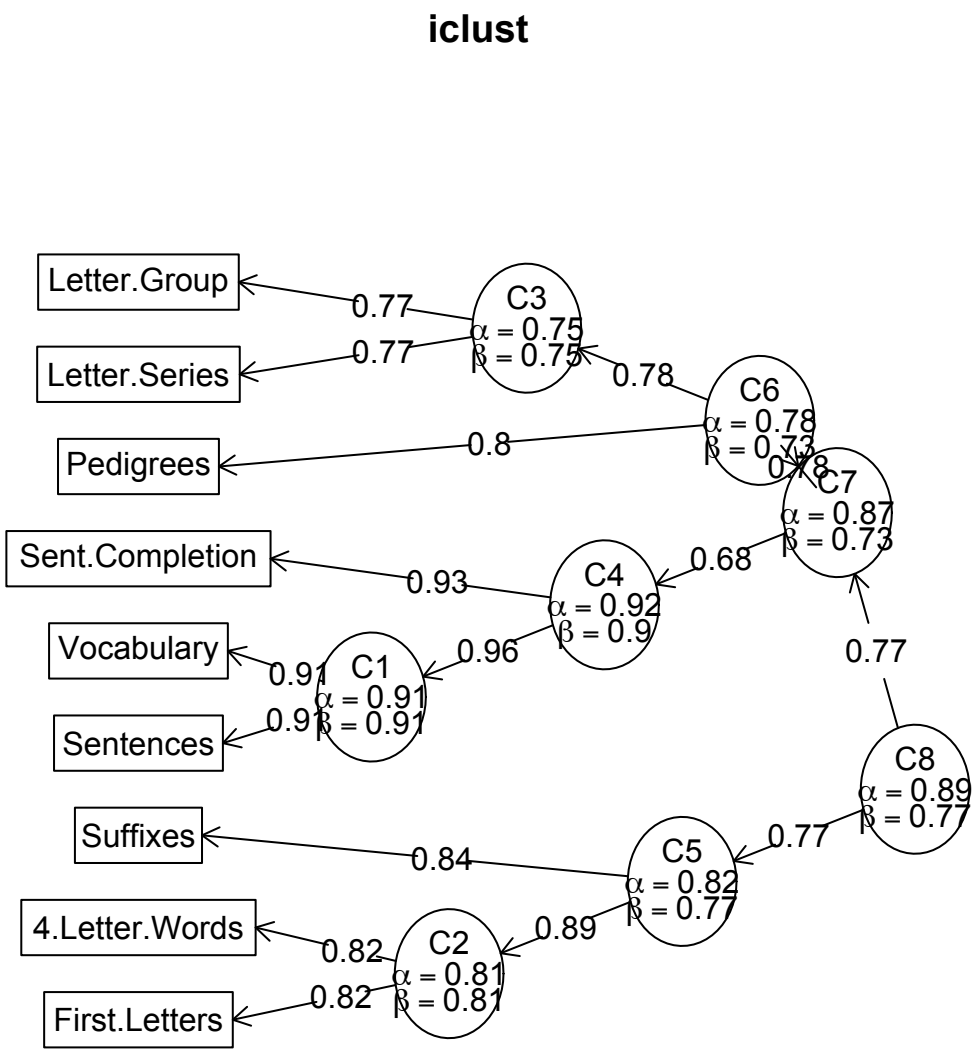
omega.diagram(om,sl=FALSE)





A hierarchical cluster structure found by `iclust`

iclust(Thurstone)



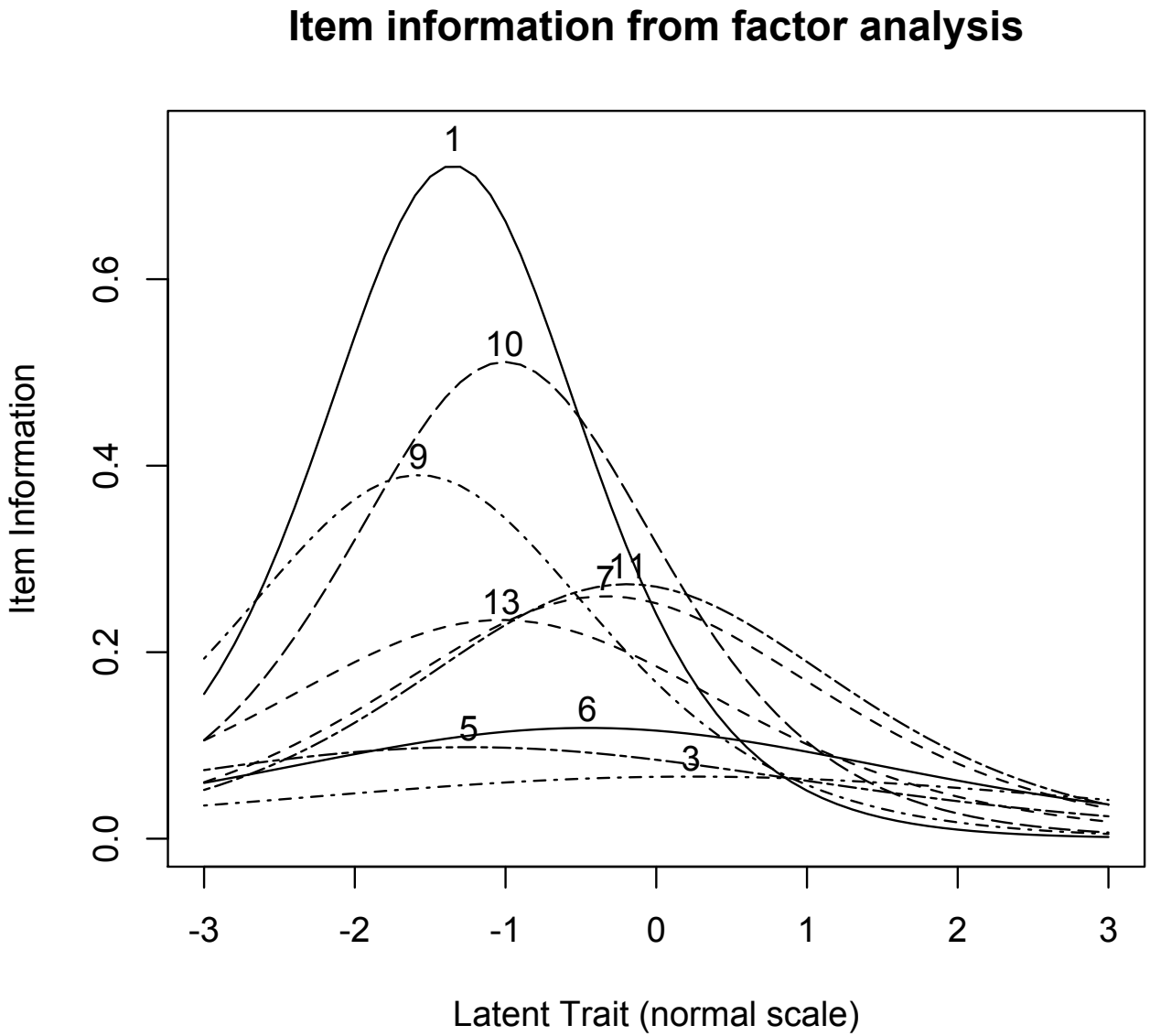
Structural Equation modeling packages

1. sem (by John Fox and others)
   - uses RAM notation
2. lavaan (by Yves Rosseel and others)
   - Mimics as much as possible MPLUS output
   - Allows for multiple groups
   - Easy syntax
3. OpenMx
   - Open source and R version of Mx
   - Allows for multiple groups (and almost anything else)
   - Complicated syntax

Mutiple packages to do Item Response Theory analysis

1. *psych* uses a factor analytic procedure to estimate item discriminations and locations
   - `irt.fa` finds either tetrachoric or polychoric correlation matrices
     - converts factor loadings to discriminations
   - `plot.irt` plots item information and item characteristic functions
   - look at examples for irt.fa
   - two example data sets: iqitems and bfi
2. Other packages include *ltm*, *eRm*, *mirt*, + others

Item Response Information curves for 14 iq items



A brief technical interlude

1. Data structures
   - The basic: scalers, vectors, matrices
   - More advanced data frames and lists
   - Showing the data
2. Getting the length, dimensions and structure of a data structure
   - length(x), dim(x), str(x)
3. Objects and Functions
   - Functions act upon objects
   - Functions actually are objects themselves
   - Getting help for a function or a package

The basic types of data structures

1. Scalers (characters, integers, reals, complex)

```
> A <- 1
> B <- 2
```

2. Vectors (of scalers, all of one type) have `length`

```
> C <- month.name[1:5]
> D <- 12:24
> length(D)
```

```
[1] 13
```

3. Matrices (all of one type) have `dimensions`

```
> E <- matrix(1:20, ncol = 4)
> dim(E)
```

```
[1] 5 4
```

Show values by entering the variable name

```
> A
[1] 1
> B
[1] 2
> C
[1] "January"  "February" "March"    "April"    "May"
> D
 [1] 12 13 14 15 16 17 18 19 20 21 22 23 24
> E
     [,1] [,2] [,3] [,4]
[1,]    1    6   11   16
[2,]    2    7   12   17
[3,]    3    8   13   18
[4,]    4    9   14   19
[5,]    5   10   15   20
```

More complicated (and useful) types: Data frames and Lists

1. Data frames are collections of vectors and may be of different type. They have two dimensions.

```
> E.df <- data.frame(names = C, values = c(31, 28, 31, 30, 31))
> dim(E.df)
```

```
[1] 5 2
```

2. Lists are collections of what ever you want. They have length, but do not have dimensions.

```
> F <- list(first = A, a.vector = C, a.matrix = E)
> length(F)
```

```
[1] 3
```

Show values by entering the variable name

```
> E.df
     names values
1  January     31
2 February     28
3    March     31
4    April     30
5      May     31
> F
$first
[1] 1

$a.vector
[1] "January"  "February" "March"    "April"    "May"

$a.matrix
     [,1] [,2] [,3] [,4]
[1,]    1    6   11   16
[2,]    2    7   12   17
[3,]    3    8   13   18
[4,]    4    9   14   19
[5,]    5   10   15   20
```

1. To show the structure of a list, use `str`

```
> str(F)

List of 3
 $ first    : num 1
 $ a.vector: chr [1:5] "January" "February" "March" "April" ...
 $ a.matrix: int [1:5, 1:4] 1 2 3 4 5 6 7 8 9 10 ...
```

2. to address an element of a list, call it by name or number, to get a row or column of a matrix specify the row, column or both.

```
> F[[2]]

[1] "January"  "February" "March"    "April"    "May"

> F[["a.matrix"]][, 2]

[1]  6  7  8  9 10

> F[["a.matrix"]][2, ]

[1]  2  7 12 17
```

Addressing the elements of a data.frame or matrix

Setting row and column names using paste

```
> E <- matrix(1:20, ncol = 4)
> colnames(E) <- paste("C", 1:ncol(E), sep = "")
> rownames(E) <- paste("R", 1:nrow(E), sep = "")
> E
```

```
   C1 C2 C3 C4
R1  1  6 11 16
R2  2  7 12 17
R3  3  8 13 18
R4  4  9 14 19
R5  5 10 15 20
```

```
> E["R2", ]
```

```
C1 C2 C3 C4
 2  7 12 17
```

```
> E[, 3:4]
```

```
   C3 C4
R1 11 16
R2 12 17
R3 13 18
R4 14 19
R5 15 20
```

Objects and Functions

1. R is a collection of Functions that act upon and return Objects
2. Although most functions can act on an object and return an object (a =f(b)), some are binary operators
   - primitive arithmetic functions +, -, * , /, %*%,
   - logical functions <, > ,==, !=
3. Some functions do not return values
   - `print(x,digits=3)`
   - `summary(some object)`
4. But most useful functions act on an object and return a resulting object
   - this allows for extraordinary power because you can combine functions by making the output of one the input of the next.
   - The number of R functions is very large, for each package has introduced more functions, but for any one task, not many functions need to be learned.

Getting help

1. All functions have a help menu
   - `help(the function)`
   - ? the function
   - most function help pages have examples to show how to use the function
2. Most packages have "vignettes" that give overviews of all the functions in the package and are somewhat more readable than the help for a specific function.
   - The examples are longer, somewhat more readable. (e.g., the vignette for *psych* is available either from the menu (Mac) or from http://cran.r-project.org/web/packages/psych/vignettes/overview.pdf
3. To find a function in the entire R space, use `findFn` in the *sos* package.
4. Online tutorials (e.g.,http://Rpad.org for a list of important commands, http://personality-project.org/r) for a tutorial for psychologists.
5. Online and hard copy books

A few of the most useful data manipulations functions (adapted from Rpad-refcard). Use ? for details

file.choose	() find a file
file.choose	(new=TRUE) create a new file
read.table	(filename)
read.csv	(filename) reads a comma separated file
read.delim	(filename) reads a tab delimited file
c	(...) combine arguments
from:to	e.g., 4:8
seq	(from,to, by)
rep	(x,times) repeat x
gl	(n,k,...) generate factor levels
matrix	(x,nrow=,ncol=) create a matrix
data.frame	(...) create a data frame
dim	(x) dimensions of x
str	(x) Structure of an object
list	(...) create a list
colnames	(x) set or find column names
rownames	(x) set or find row names
ncol(x), nrow(z)	number of row, columns
rbind	(...) combine by rows
cbind	(...) combine by columns
is.na	(x) also is.null(x), is...
na.omit	(x) ignore missing data
table	(x)
merge	(x,y)
apply	(x,rc,FUNCTION)
ls	() show workspace
rm	() remove variables from workspace

More useful statistical functions, Use ? for details

mean	(x)
is.na	(x) also is.null(x), is...
na.omit	(x) ignore missing data
sum	(x)
rowSums	(x) see also colSums(x)
min	(x)
max	(x)
range	(x)
table	(x)
summary	(x) depends upon x
sd	(x) standard deviation
cor	(x) correlation
cov	(x) covariance
solve	(x) inverse of x
lm	`(y~x) linear model`
aov	`(y~x) ANOVA`

Selected functions from *psych* package

describe	(x) descriptive stats
describe.by	(x,y) descriptives by group
pairs.panels	(x) SPLOM
error.bars	(x) means + error bars
error.bars.by	(x) Error bars by groups
fa	(x,n) Factor analysis
principal	(x,n) Principal components
iclust	(x) Item cluster analysis
score.items	(x) score multiple scales
score.multiple.choice	(x) score multiple choice scales
alpha	(x) Cronbach's alpha
omega	(x) MacDonald's omega
irt.fa	(x) Item response theory through factor analysis

Questions?