Bayesian Statistics and Hierarchical Bayesian Modeling for Psychological Science

Lecture 02

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https://github.com/lei-zhang/BayesCog_Wien

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Logical Operators

Operator	Summary
$<$	Less than
$>$	Greater than
$<=$	Less than or equal to
$>=$	Greater than or equal to
$==$	Equal to
$!=$	Not equal to
$!x$	NOT x
$x \mid y$	x OR y
$x \& y$	x AND y

Control Flow

cognitive model
statistics
computing

- if-else

```
if (cond) {
    ..statement..
}
```

```
if (cond) {
    ..statement..
} else {
    ..statement..
}
```

```
if (cond) {
    ..statement..
} else if (cond) {
    ..statement..
} else {
    ..statement..
}
```

- for-loop

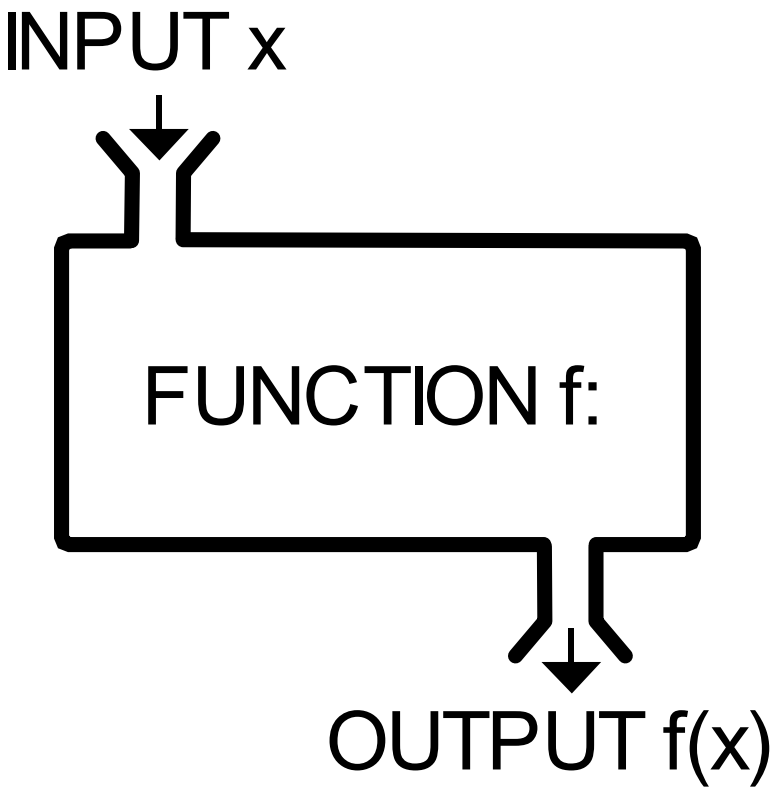
```
for ( j in 1:J) {
    ..statement..
}
```

```
for ( j in 1:J ) {
    for ( k in 1:K ) {
        ..statement..
    }
}
```

Functions

The operation(s) to obtain some quantity, based on another quantity.

- built-in functions
- external functions (packages)
- user-defined functions



User-defined Function

cognitive model
statistics
computing

```
funname <- function (input_arges) {
    .. function body ..
    .. function body ..
    return(output_arges)
}
```

$$sem = \sqrt{\frac{s^2}{n-1}}$$

```
sem <- function(x) {
    sqrt( var(x,na.rm=TRUE) / (length(na.omit(x))-1) )
}
```

Exercise II

cognitive model
statistics
computing

```
…/01.R_basics/_scripts/R_basics.R
```

TASK: practise control flow and user-defined function

Exercise II

cognitive model
statistics
computing

- Generate a random number between 0 and 1
- Compare it against 1/3 and 2/3
- Print the random number and its position relative to 1/3 and 2/3.

```r
# if-else
t <- runif(1) # random number between 0 and 1
if (t <= 1/3) {
    cat("t =", , ", t <= 1/3. \n")
} else if () {
    cat("t =", t, ", t > 2/3. \n")
} else {
    cat("t =", t, ", 1/3 < t <= 2/3. \n")
}
```

Example outcome:

```
t = 0.895 , t > 2/3.
```

- Get the name of each month
- Print it one by one

```r
# for-loop
month_name <- format(ISOdate(2018,1:12,1),"%B")
for (j in 1:length(month_name) ) {
    cat()
}
```

```
The month is January
The month is February
The month is March
The month is April
The month is May
The month is June
The month is July
The month is August
The month is September
The month is October
The month is November
The month is December
```

Packages in R

R packages are collections of functions and data sets developed by the community, to make your life a lot easier!

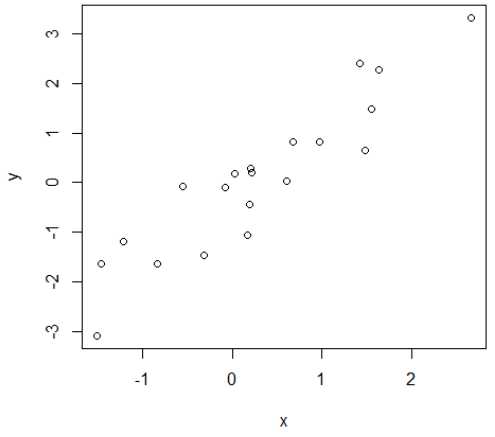
```
install.packages('ggplot2')
library(ggplot2)
detach('package:ggplot2')
```

Visualization

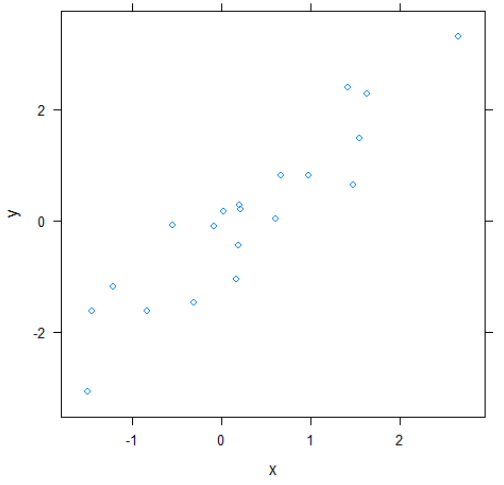
cognitive model
statistics
computing

- built-in plotting functions – first attempt / quick look / exploratory
- {lattice} – making nicer, similar to basic plotting functions (takes lm formulae)
- {ggplot2} – making nicer, a layering philosophy

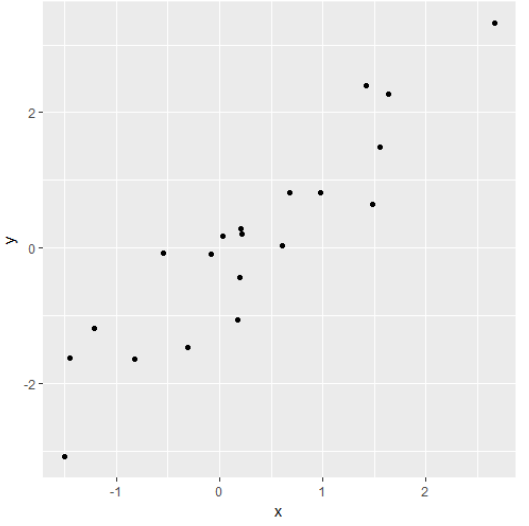
`plot(x,y)`



`lattice::xyplot(y~x)`



`ggplot2::qplot(x,y)`



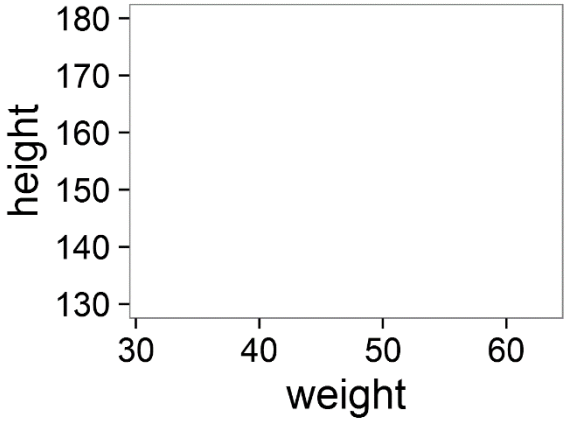
Brief Intro to ggplot2

cognitive model
statistics
computing

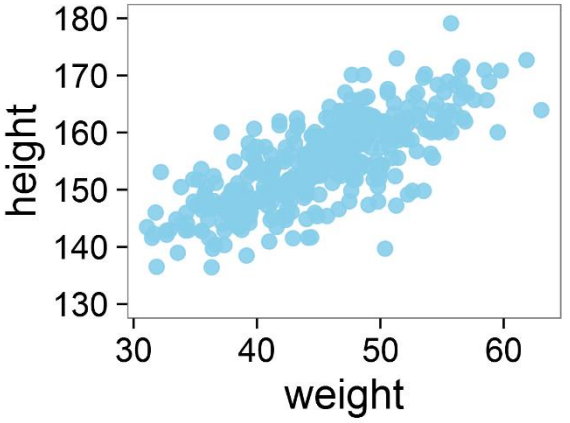
```
plot = geometric (points, lines, bars) + aesthetic (color, shape, size)
```

game of adding layers!

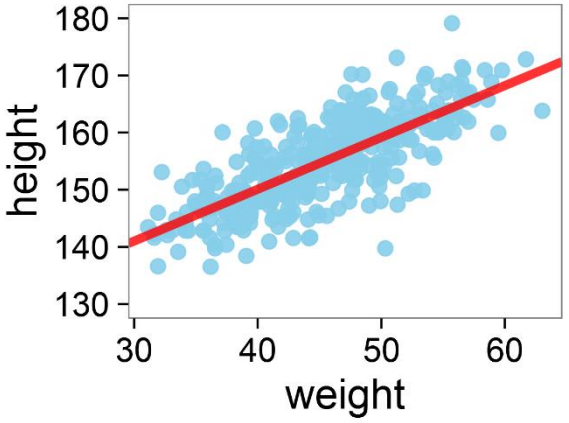
background



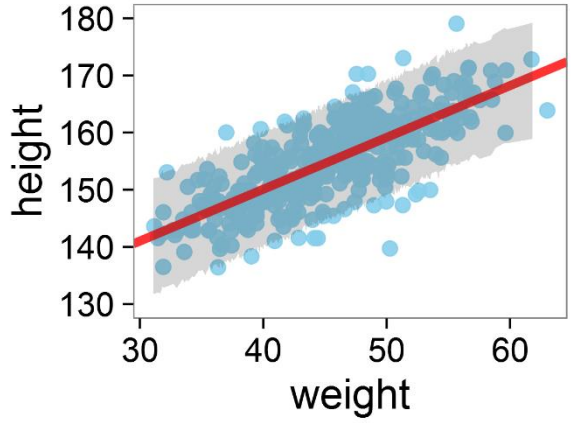
add scatters



add regression line

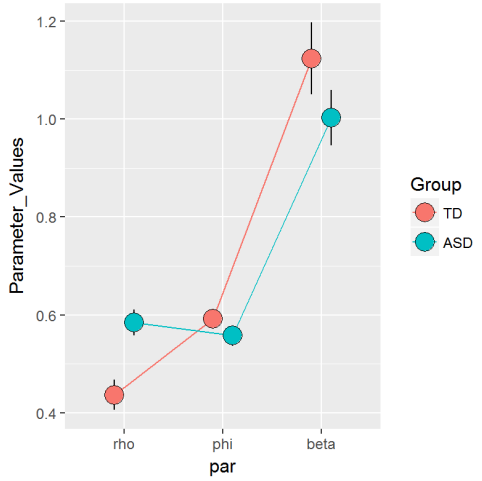


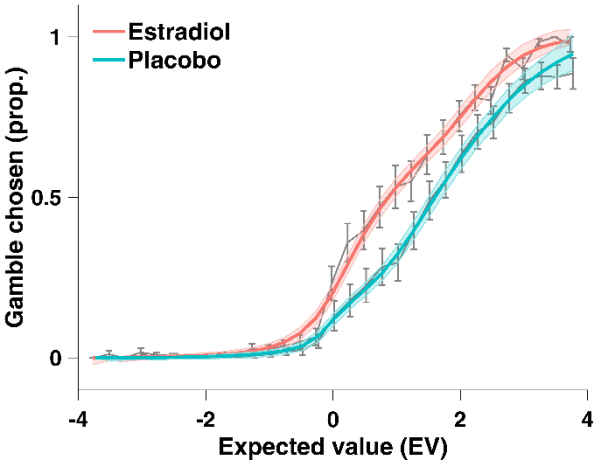
add uncertainty

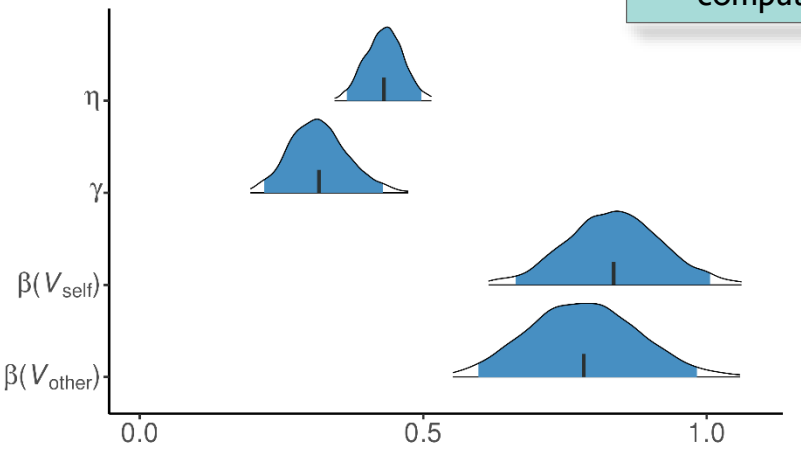


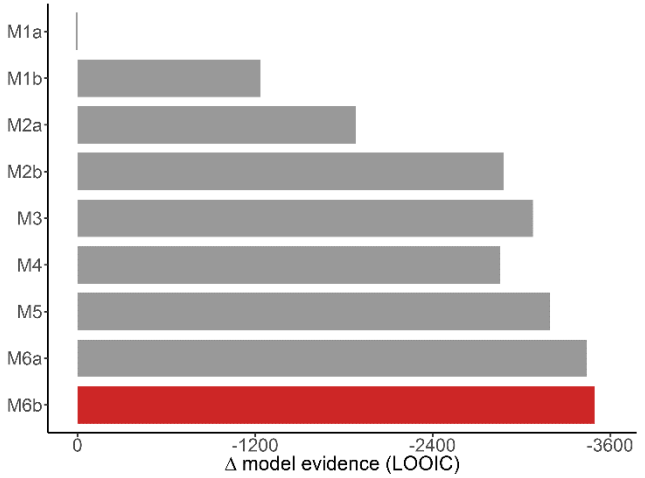
A taste of ggplot2

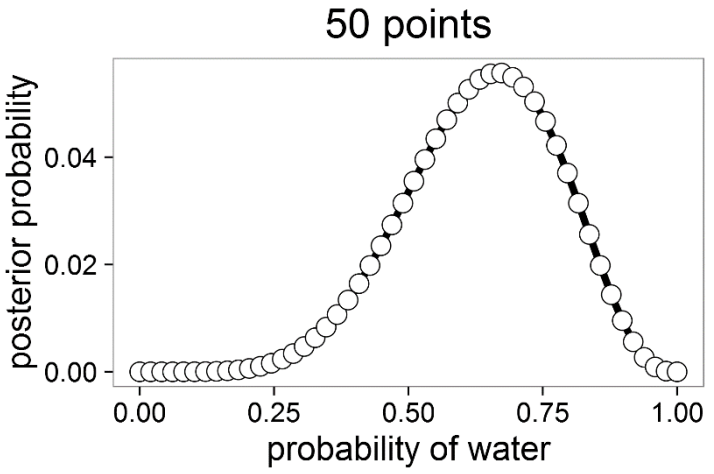
cognitive model
statistics
computing

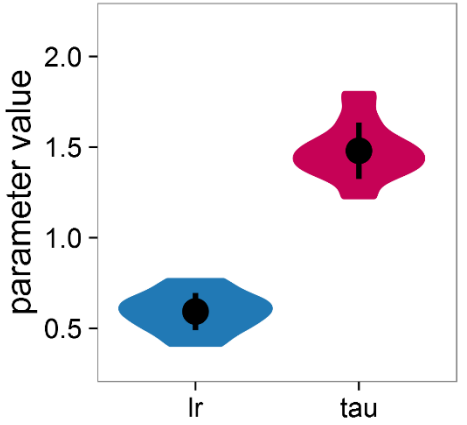






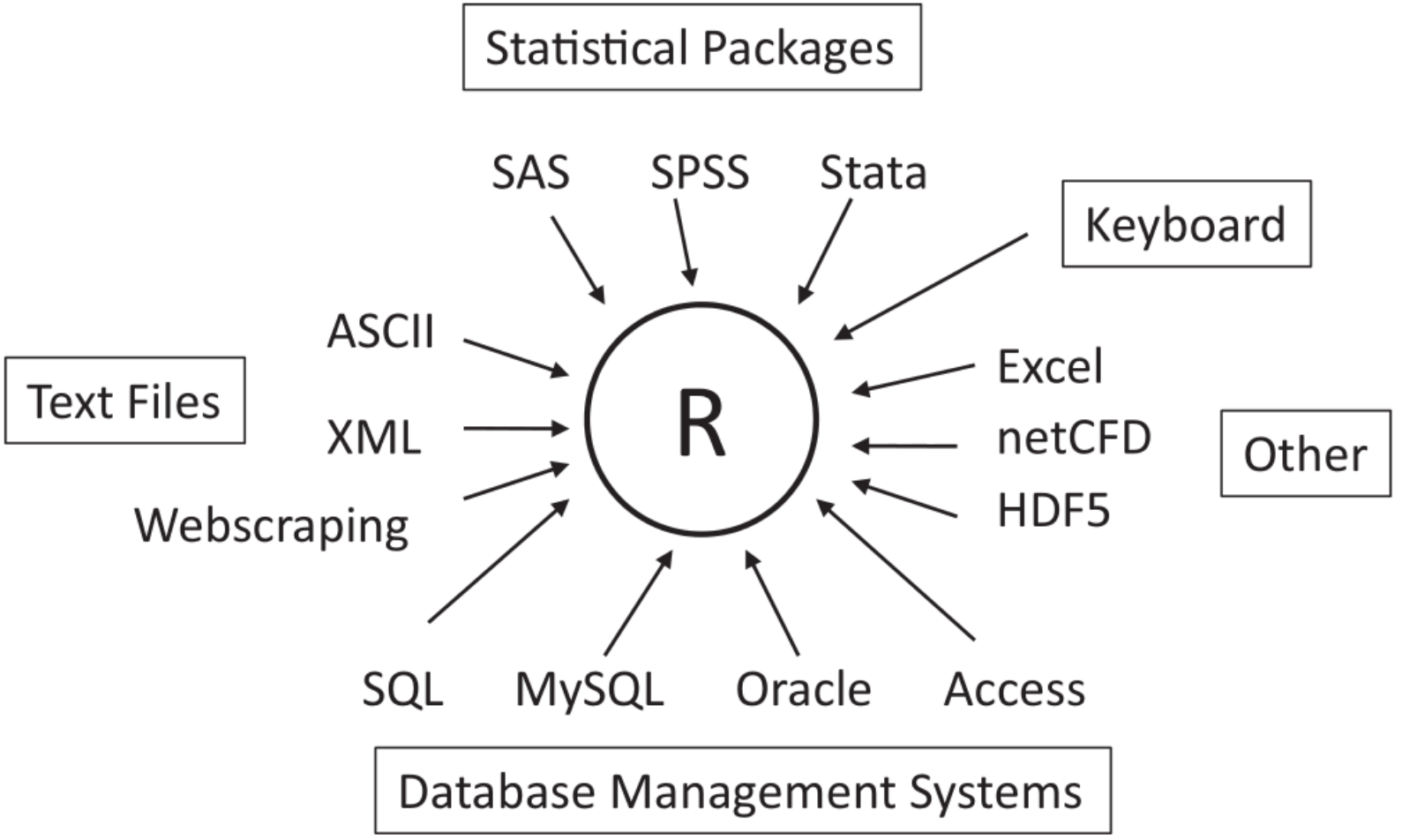






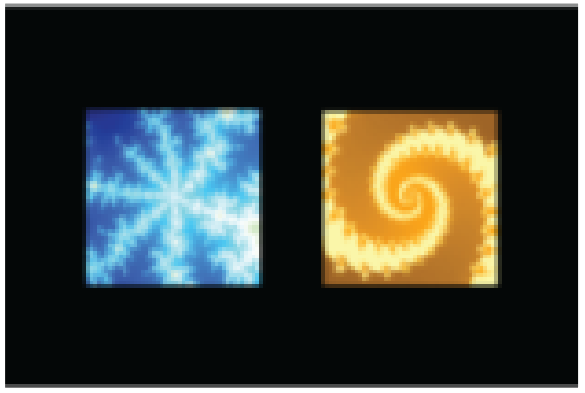
https://www.r-graph-gallery.com/

Data management

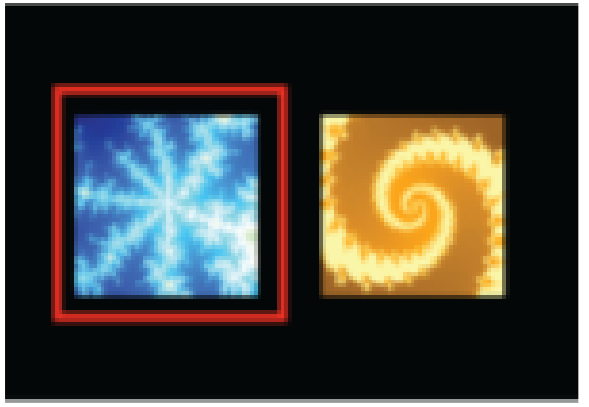


Kabacoff (2015)

One simple experiment



choice
presentation



action
selection

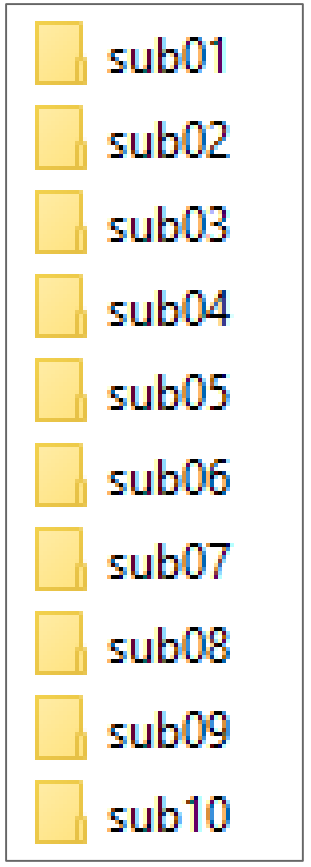
outcome

reward contingency – 80:20

The data

- nSub = 10
- nTrial = 80

./_data/_raw_data/sub01/raw_data_sub01.txt




```
subjID, trialID, choice, outcome, correct
1,1,2,-1,1
1,2,1,1,1
1,3,1,1,1
1,4,1,1,1
1,5,2,-1,1
1,6,1,1,1
1,7,1,1,1
1,8,1,1,1
1,9,1,-1,1
1,10,2,-1,1
1,11,1,1,1
1,12,1,1,1
1,13,1,-1,2
```

Import some data!

```
data_dir = ('_data/RL_raw_data/sub01/raw_data_sub01.txt')
data = read.table(data_dir, header = T, sep = ",")
head(data)

  subjID trialID choice outcome correct
1      1       1      1       1       1
2      1       2      1       1       1
3      1       3      1       1       1
4      1       4     NA       1       1
5      1       5      1      -1       1
6      1       6      2      -1       1

sum(complete.cases(data))   # number of valid trials
data = data[complete.cases(data),]
dim(data[complete.cases(data),])
```

Indexing

```
data[1,1]
data[1,]
data[,1]
data[1:10,]
data[,1:2]
data[1:10, 1:2]
data[c(1,3,5,6), c(2,4)]

data$choice
```

```
> data
   subjID trialID choice outcome correct
1       1       1      1       1       1
2       1       2      1       1       1
3       1       3      1       1       1
5       1       5      1      -1       1
6       1       6      2      -1       1
7       1       7      1       1       1
8       1       8      1       1       1
9       1       9      1       1       1
10      1      10      1       1       1
11      1      11      1       1       1
```

Exercise III

```
…/01.R_basics/_scripts/R_basics.R
```

TASK:

write a for loop

… which reads in each participant's raw data

… and reshape it in the "long format" by subj

TIP: complete line 173

```
for ( j in 1:n ) {
   read.table(file, header = T, sep = ",")
}
```

subID	Choice
sub01	1
sub01	2
…	
sub02	2
sub02	2
…	
sub10	2
sub10	1

Read all the data!

```
ns = 10
data_dir = '_data/RL_raw_data'

rawdata = c();
for (s in 1:ns) {
    sub_file = file.path(data_dir, sprintf('sub%02i/raw_data_sub%02i.txt',s,s))
    sub_data = read.table(sub_file, header = T, sep = ",")
    rawdata = rbind(rawdata, sub_data)
}
rawdata = rawdata[complete.cases(rawdata),]
rawdata$accuracy = (rawdata$choice == rawdata$correct) * 1.0

acc_mean = aggregate(rawdata$accuracy, by = list(rawdata$subjID), mean)[,2]
```

mean choice accuracy across trials, per participant.

Basic stats

```
mean(acc_mean)
sd(acc_mean)
sem(acc_mean)

t.test(acc_mean, mu = 0.5) # one sample t-test

        One Sample t-test

data:  acc_mean
t = 13.788, df = 9, p-value = 2.34e-07
alternative hypothesis: true mean is not equal to 0.5
95 percent confidence interval:
 0.6962988 0.7733565
sample estimates:
mean of x
0.7348277
```

Basic correlation

```
load('_data/RL_descriptive.RData')
descriptive$acc = acc_mean
df = descriptive

cor.test(df$IQ, df$acc)

        Pearson's product-moment correlation

data:  df$IQ and df$acc
t = 4.8347, df = 8, p-value = 0.001297
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.5114810 0.9671586
sample estimates:
      cor
0.8631401
```

```
> descriptive
   subjID        IQ      Age    acc
1       1 123.98691 31.07218 0.8125
2       2  87.63187 30.13800 0.7125
3       3  89.39930 23.44219 0.6875
4       4  84.34607 27.44848 0.6500
5       5 134.72208 23.30624 0.7750
6       6  84.60797 25.67858 0.7250
7       7 111.10238 24.36375 0.7750
8       8 117.89599 32.74026 0.8000
9       9  96.88233 22.80211 0.7500
10     10  76.01652 30.44258 0.6750
```

Exercise IV

```
…/01.R_basics/_scripts/R_basics.R
```

TASK:

Read in the descriptive data: _data/descriptive.RData

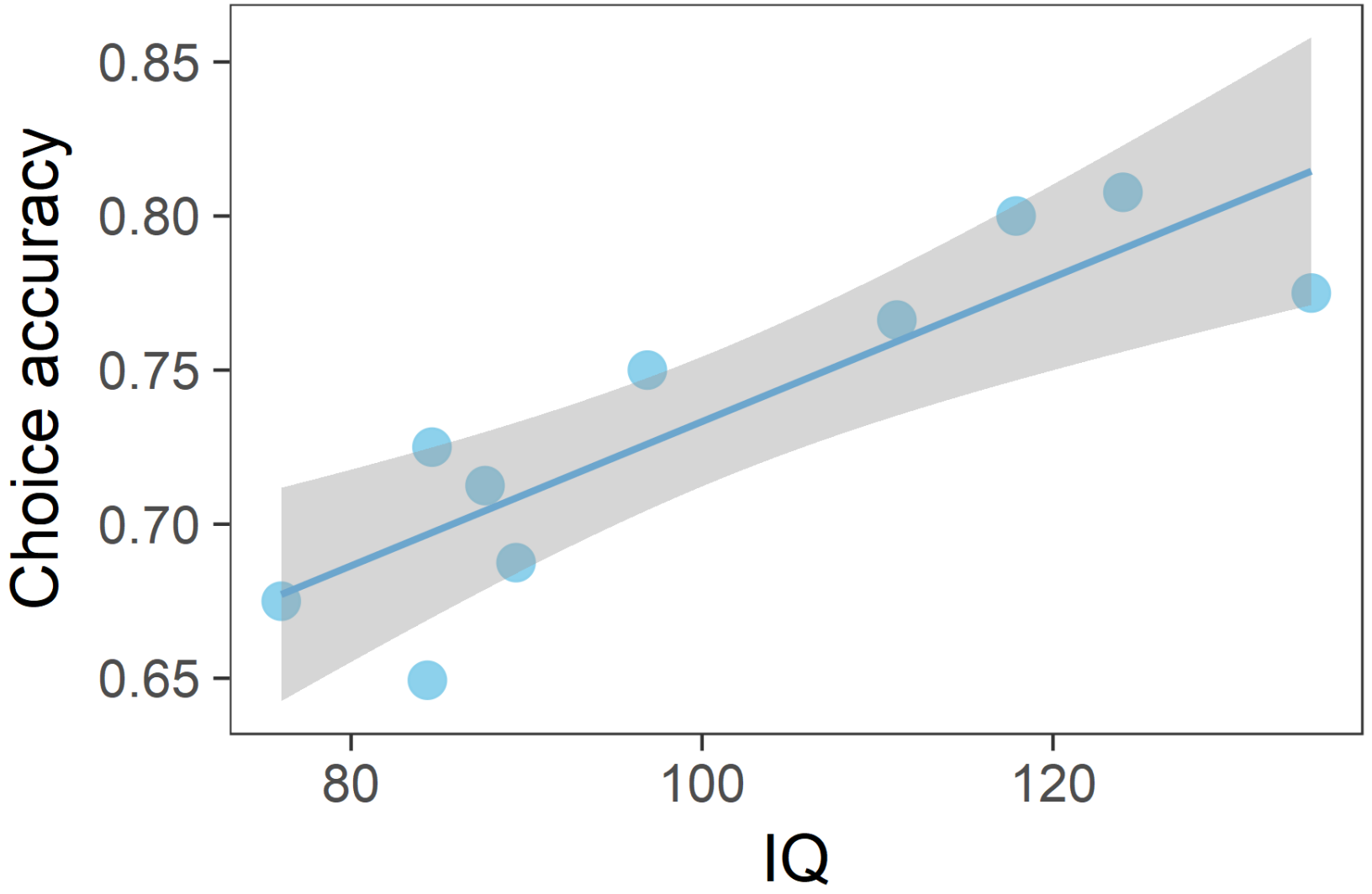
…include ‘acc_mean’ as a new column, and

…rename ‘descriptive’ as df.

Practice all the basic stats.

```
df$new_Col = new_Col
```

A simple linear regression



What is exactly the regression line in R?

$$\mu_i = \alpha + \beta x_i$$

$$y_i = \mu_i + \varepsilon$$

```
fit1 = lm(acc ~ IQ, data = df)
summary(fit1)

Call:
lm(formula = acc ~ IQ, data = df)

Residuals:
      Min        1Q    Median        3Q       Max
-0.047305 -0.016277  0.007562  0.022577  0.027731

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.499292   0.049565  10.073 8.04e-06 ***
IQ          0.002340   0.000484   4.835   0.0013 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.02885 on 8 degrees of freedom
Multiple R-squared:  0.745,  Adjusted R-squared:  0.7131
F-statistic: 23.37 on 1 and 8 DF,  p-value: 0.001297
```

Exercise V

```
…/01.R_basics/_scripts/R_basics.R
```

TASK:

Read and make sense of the ggplot functions,

… experiment make some adjustments (color marker size etc.), and

… run the `lm(acc ~ IQ)`