Hitchhikers' guide to **mixed effects regression models**

INTRO

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26.10.21

Statistics with R

This tutorial will take you to a journey around

- R studio,
- regression,
- and how to analyse "response times data" with mixed effects regression in R

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Statistics with R

What is R?

[Home]

Download

CRAN

R Project

Introduction to R

R is a language and environment for statistical computing and graphics. It is a GNU project which is similar to the S language and environment which was developed at Bell Laboratories (formerly AT&T, now Lucent Technologies) by John Chambers and colleagues. R can be considered as a different implementation of S. There are some important differences, but much code written for S runs unaltered under R.

ics and

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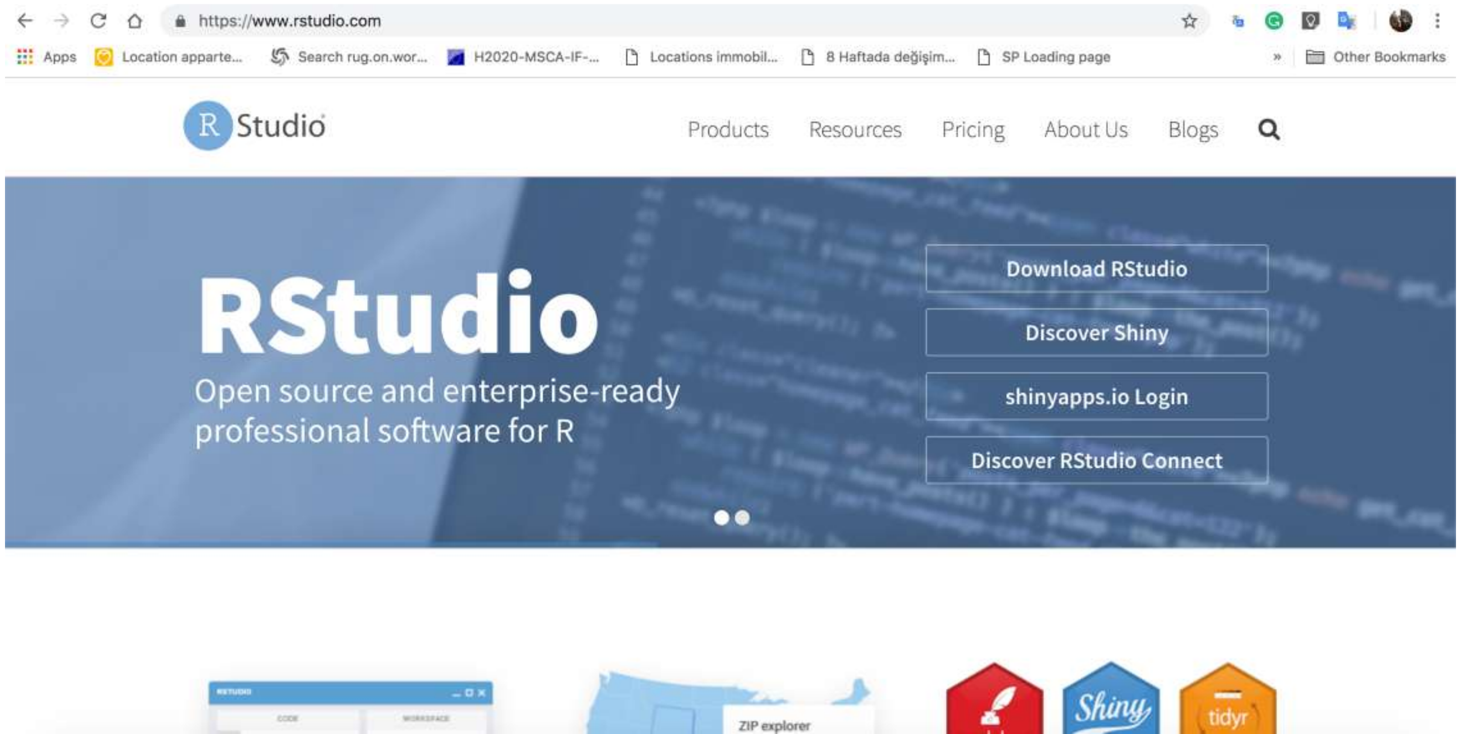
- **R and RStudio (download here)**

https://www.rstudio.com/products/rstudio/download/#download



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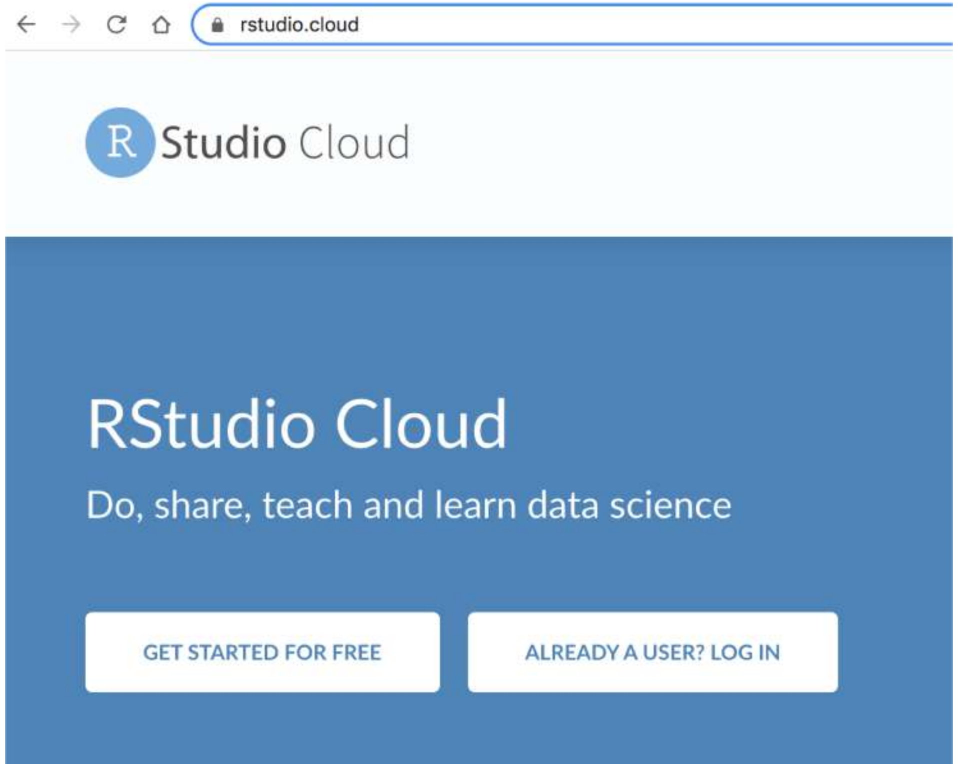
- **Follow from Rstudio Cloud (Recommended)**

https://rstudio.cloud/



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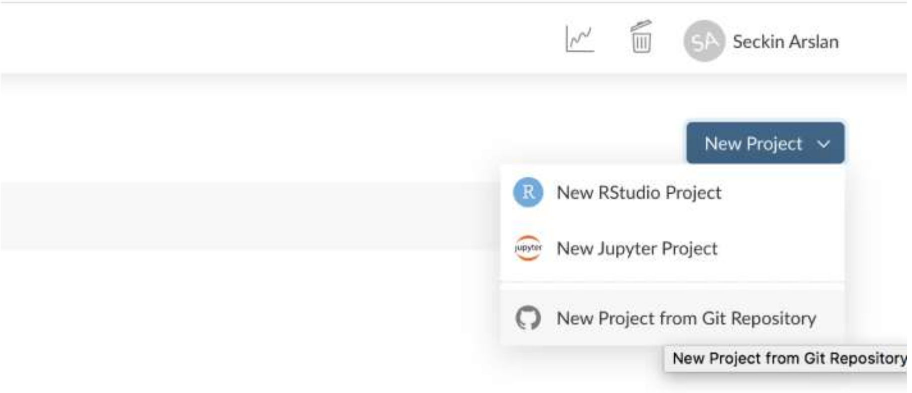
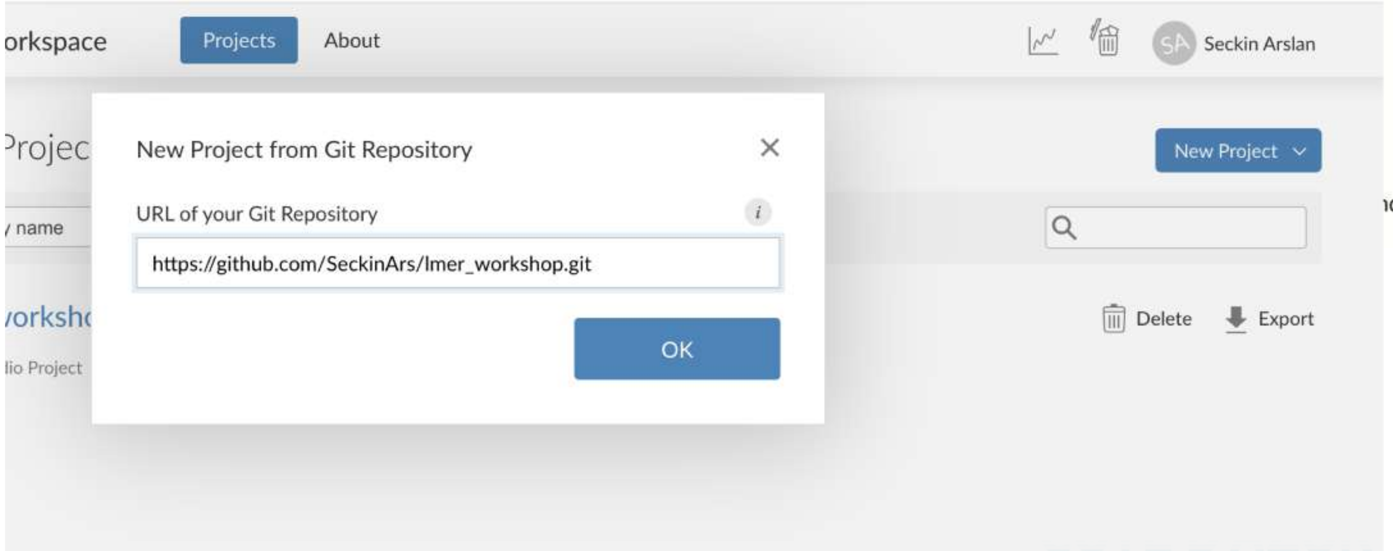
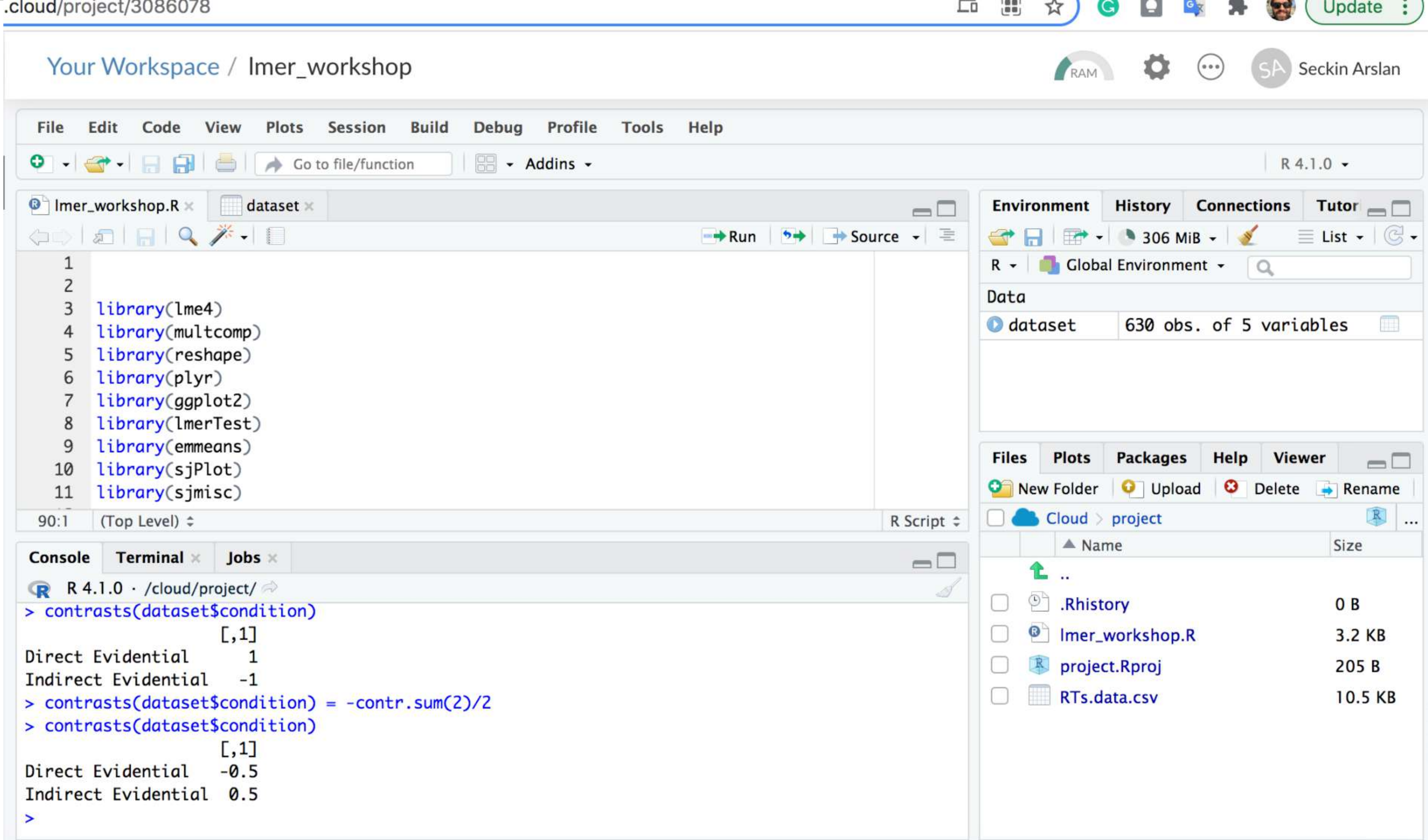
- **Follow from Rstudio Cloud (Recommended)**

https://rstudio.cloud/
https://github.com/SeckinArs/lmer_workshop.git






.cloud/project/3086078
Your Workspace / lmer_workshop
RAM
Seckin Arslan
File Edit Code View Plots Session Build Debug Profile Tools Help
Go to file/function
Addins
R 4.1.0
lmer_workshop.R
dataset
Run
Source
1
2
3 library(lme4)
4 library(multcomp)
5 library(reshape)
6 library(plyr)
7 library(ggplot2)
8 library(lmerTest)
9 library(emmeans)
10 library(sjPlot)
11 library(sjmisc)
90:1
(Top Level)
R Script
Console
Terminal
Jobs
R 4.1.0 · /cloud/project/
> contrasts(dataset$condition)
[,1]
Direct Evidential 1
Indirect Evidential -1
> contrasts(dataset$condition) = -contr.sum(2)/2
> contrasts(dataset$condition)
[,1]
Direct Evidential -0.5
Indirect Evidential 0.5
>
Environment
History
Connections
Tutor
306 MiB
List
R
Global Environment
Data
dataset
630 obs. of 5 variables
Files
Plots
Packages
Help
Viewer
New Folder
Upload
Delete
Rename
Cloud
project
Name
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.Rhistory
0 B
lmer_workshop.R
3.2 KB
project.Rproj
205 B
RTs.data.csv
10.5 KB

and

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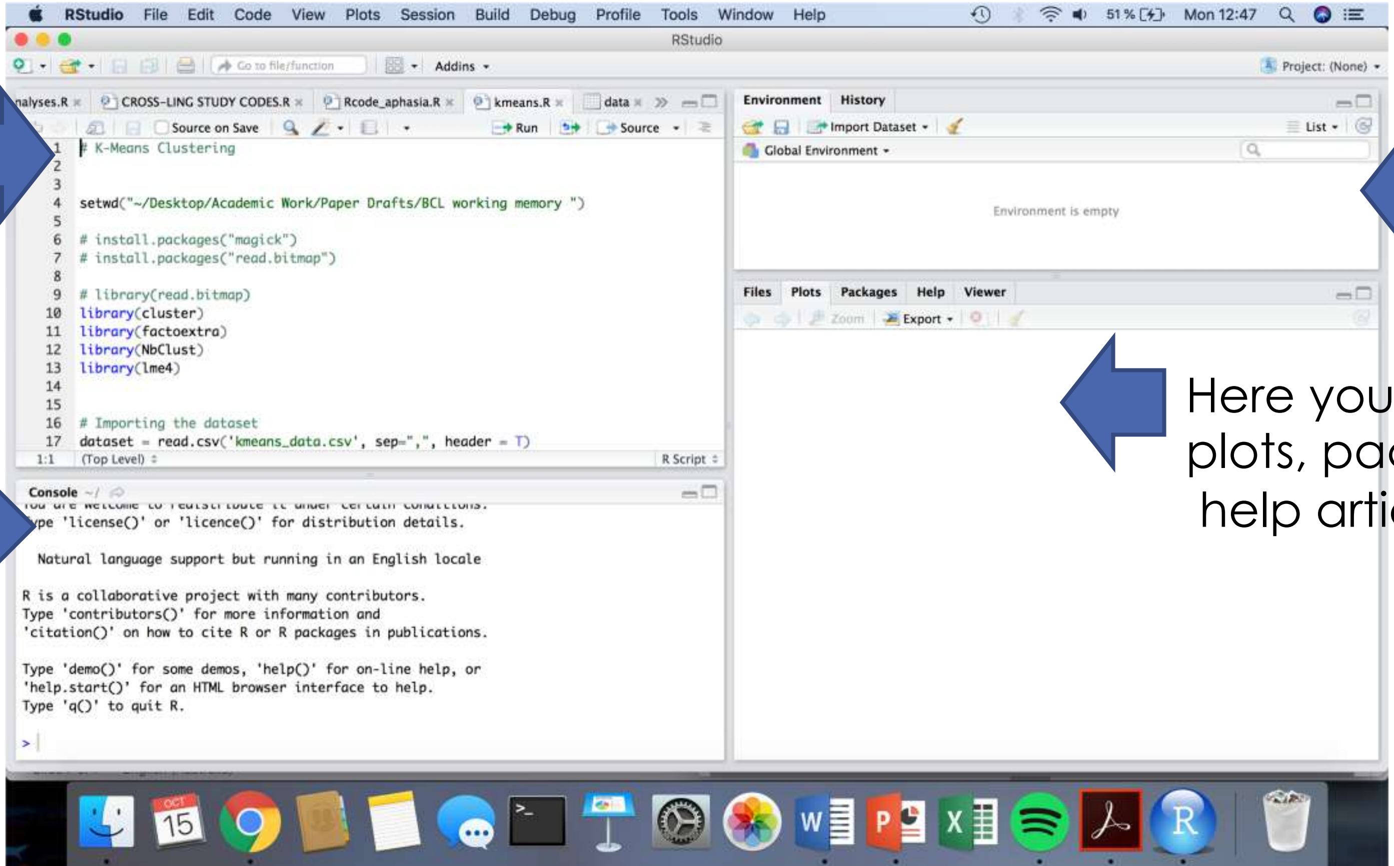
- **Introduction to R and RStudio**

The editor: where you write / manipulate code



Console: this is where you see outputs from statistical models

Environment: you can see variables, datasets, items created

Here you will see plots, packages, help articles

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```
# mixed-effects regression pckg

install.packages("lme4")

#call from library

library(lme4)
```

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DATA PREPROCESSING

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Pre-processing: power

Before you begin analysing, consider doing power analysis (PA)

- PA with cross-random effects (https://jakewestfall.shinyapps.io/crossedpower/)

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Westfall, J., Kenny, D. A., & Judd, C. M. (2014). *Journal of Experimental Psychology: General, 143* (5), 2020-2045.

See recommendations from Figner etal.:
http://decision-lab.org/wp-content/uploads/2020/07/SOP_Mixed_Models_D2P2_v1_0_0.pdf

Pre-processing: power

What is p-value?

“p < .05” null-hypothesis is true less than 5% of chance, so we reject null-hypothesis with more than 95% confidence.

What is p-value hacking?

Misreporting or selective reporting of your results especially because when tests did not yield significant p-values.

AVOID THIS!!

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Head, M. L., Holman, L., Lanfear, R., Kahn, A. T., & Jennions, M. D. (2015). The extent and consequences of p-hacking in science. *PLoS Biol*, *13*(3), e1002106.

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PREPARING VARIABLES & CONTRAST CODING

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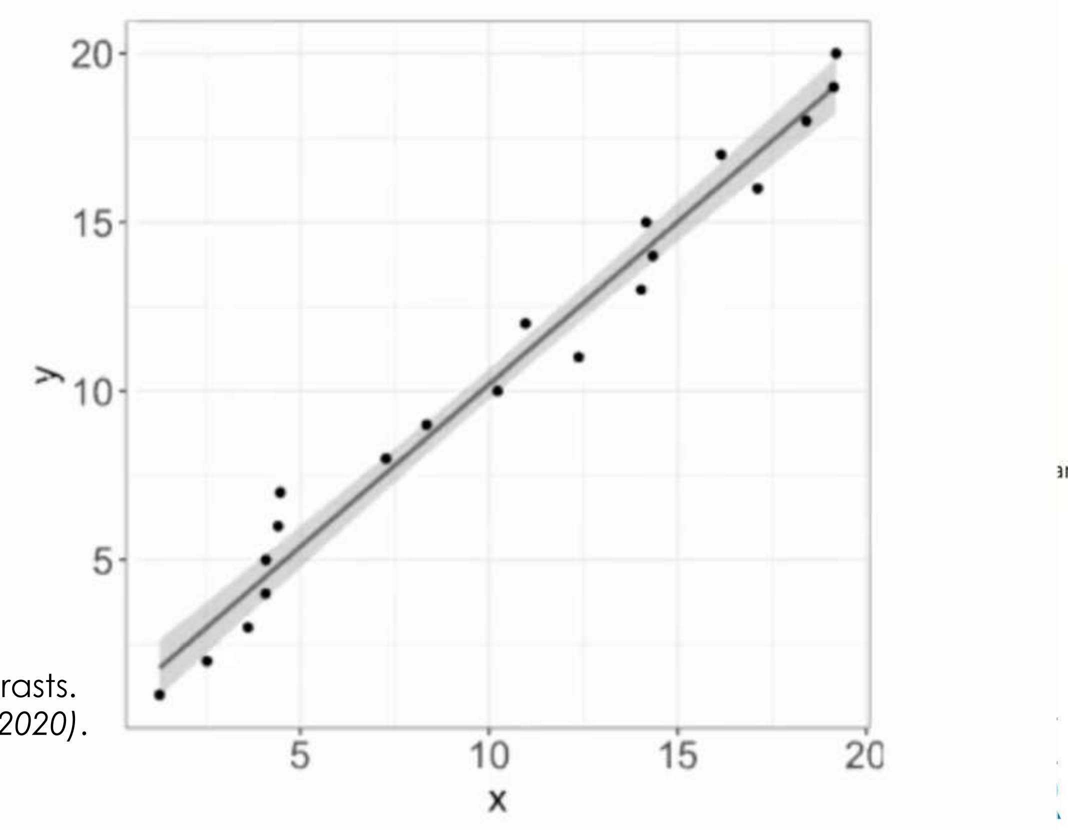
Pre-processing: contrast coding

What is a contrast?

In regression, we predict a dependent variable (y) by an predicting variable (x)



and

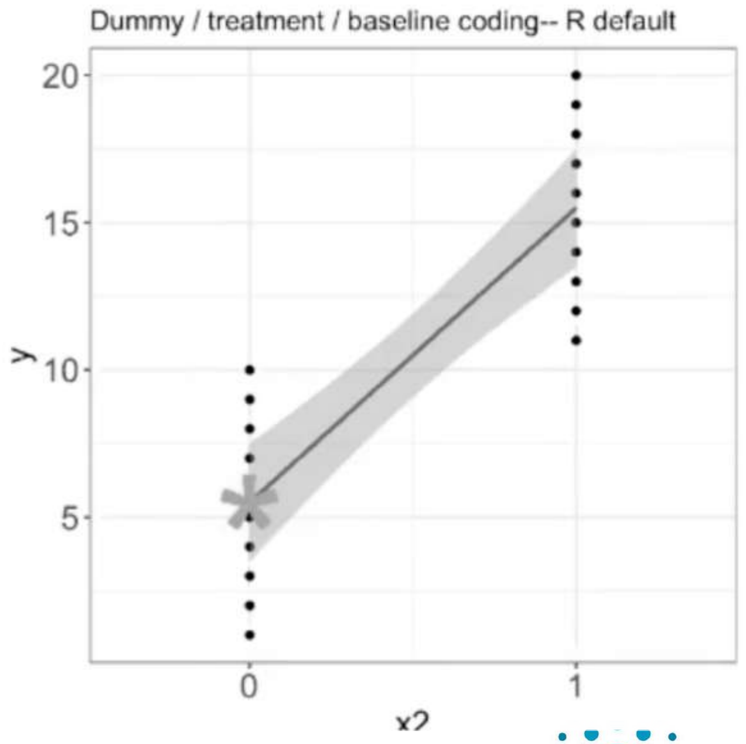
Brehm, L., & Alday, P. M. (2020). A decade of mixed models: It's past time to set your contrasts. In *the 26th Architectures and Mechanisms for Language Processing Conference (AMLap 2020)*.

A very good talk at AMLAP 2020 :
https://mediaup.uni-potsdam.de/Play/Chapter/223
Blog post by Dale Barr: https://talklab.psy.gla.ac.uk/tvw/catpred/

Pre-processing: contrast coding

What is a contrast?

In categorical variables, levels in (x) are contrasts, which allow you to effects of different treatments



Brehm, L., & Alday, P. M. (2020). A decade of mixed models: It's past time to set your contrasts. In *the 26th Architectures and Mechanisms for Language Processing Conference (AMLap 2020)*.

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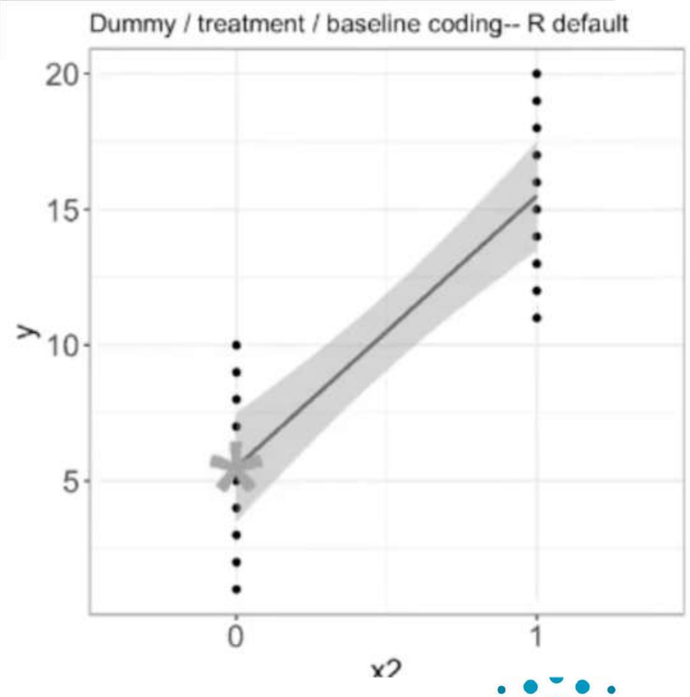
Blog post by Dale Barr: https://talklab.psy.gla.ac.uk/tvw/catpred/

Pre-processing: contrast coding

What is a contrast?

1) dummy (treatment) coding -->



Categorical vars are taken as dummy by default in R

- model intercept when x = 0.

Brehm, L., & Alday, P. M. (2020). A decade of mixed models: It's past time to set your contrasts. In *the 26th Architectures and Mechanisms for Language Processing Conference (AMLap 2020)*.

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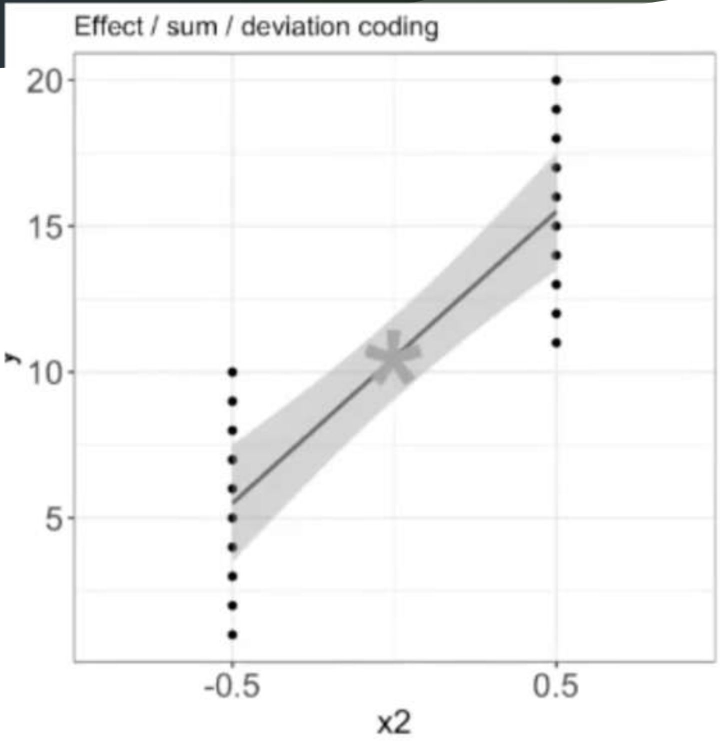
Pre-processing: contrast coding

What is a contrast?

2) sum (to zero) coding -->



When values of contrasts change, estimates change

- model intercept is **x = 0** (which is now mean)

Brehm, L., & Alday, P. M. (2020). A decade of mixed models: It's past time to set your contrasts. In *the 26th Architectures and Mechanisms for Language Processing Conference (AMLap 2020)*.

A very good talk at AMLAP 2020 :
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Blog post by Dale Barr: https://talklab.psy.gla.ac.uk/tvw/catpred/

Pre-processing: contrast coding

How to do sum-coding?

R-code:

```
contrasts(DataFrame$Variable) = contr.sum(2)

#If you have 2 levels to this variable
# this will change 1/0 coding to -0.5/0.5 coding.
```

Pre-processing: contrast coding

Pre-processing: scaling or standardizing

Continuous independent variables
- if you have multiple continuous variables on different scales, consider scaling…

- Multicollinearity can be a problem
- Numeric values on different scales

Participant	age	Group	Gender	score.MMSE	digit.span.FWD
1	21	young	M	29	8
2	20	young	F	30	6
3	23	young	M	29	6
4	21	young	F	30	7
5	25	young	M	29	5
6	21	young	F	30	7
7	20	young	F	30	7
8	23	young	F	29	8
9	20	young	M	29	7
10	21	young	F	27	6
11	20	young	F	29	6
12	21	young	F	29	6

columns

Pre-processing: scaling or standardizing

Continuous independent variables
how to scale in R

DF$Var <- scale(DF$Var)

#This rescales the variable
#by subtracting mean from each
#observation

Participant	age	Group	Gender	score.MMSE	digit.span.FWD
1	21	young	M	29	1.8516402
2	20	young	F	30	0.0000000
3	23	young	M	29	0.0000000
4	21	young	F	30	0.9258201
5	25	young	M	29	-0.9258201
6	21	young	F	30	0.9258201
7	20	young	F	30	0.9258201
8	23	young	F	29	1.8516402
9	20	young	M	29	0.9258201
10	21	young	F	27	0.0000000
11	20	young	F	29	0.0000000
12	21	young	F	29	0.0000000

Pre-processing: scaling or standardizing

Continuous independent variables
how to scale in R

DF$Var <- scale(DF$Var)

Participant	age	Group	Gender	score.MMSE	digit.span.FWD
1	21	young	M	0.09046821	1.8516402
2	20	young	F	0.75993295	0.0000000
3	23	young	M	0.09046821	0.0000000
4	21	young	F	0.75993295	0.9258201
5	25	young	M	0.09046821	-0.9258201
6	21	young	F	0.75993295	0.9258201
7	20	young	F	0.75993295	0.9258201
8	23	young	F	0.09046821	1.8516402
9	20	young	M	0.09046821	0.9258201
10	21	young	F	-1.24846128	0.0000000
11	20	young	F	0.09046821	0.0000000
12	21	young	F	0.09046821	0.0000000

Both continuous independent vars are now on the same scale

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LINEAR (MIXED EFFECTS) REGRESSION

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Regression

- Relationship between dependent variable and one or more predicting variable
- In regression, you can measure how an independent variable predicts dependent variable

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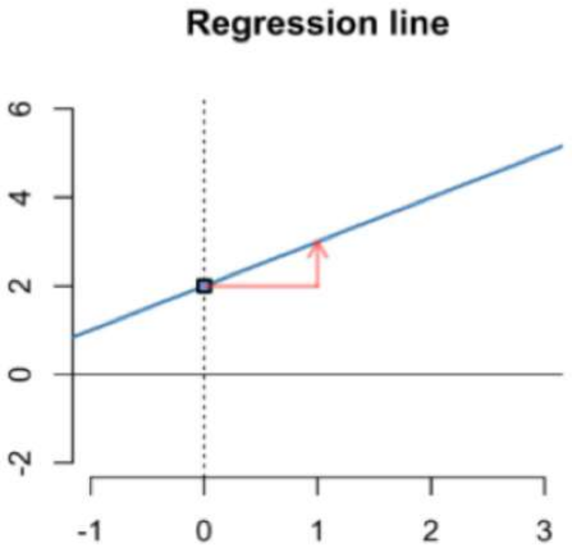
Regression

Linear regression

- Examines linear relationship between a dependent variable and independent variable(s)



$y_i = \beta_1 x_i + \beta_0 + \varepsilon_i$

Which means… the dependent variable (y) independent variable (x), Intercept (β_0), Coefficient (β_1) and error (ε_i)

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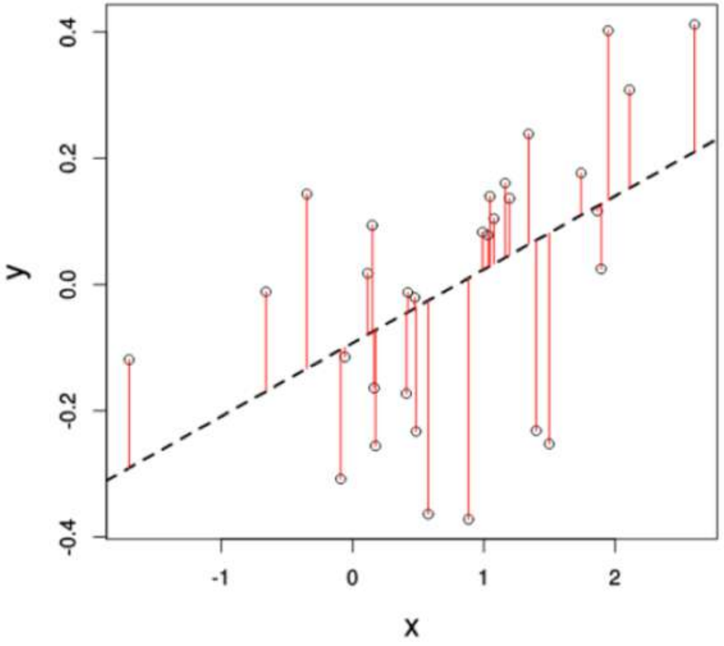
Regression

Residuals show distance / differences between the data points predicted by the regression model and the actual data points



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Hitchhikers' guide to **mixed effects regression models**

- **Language-as-fixed-effect ?**

- **Fixed-effect factor**: has *repeatable* few levels

- **Random-effect factor**: has many possible levels

- Are experimental subjects fixed or random?
- Are linguistic stimulus materials fixed or random?

JOURNAL OF VERBAL LEARNING AND VERBAL BEHAVIOR 12, 335–359 (1973)

The Language-as-Fixed-Effect Fallacy: A Critique of Language Statistics in Psychological Research

HERBERT H. CLARK[1]
Stanford University

Current investigators of words, sentences, and other language materials almost never provide statistical evidence that their findings generalize beyond the specific sample of language materials they have chosen. Nevertheless, these same investigators do not hesitate to conclude that their findings are true for language in general. In so doing, it is argued, they are committing the language-as-fixed-effect fallacy, which can lead to serious error. The problem is illustrated for one well-known series of studies in semantic memory. With the appropriate statistics these studies are shown to provide no reliable evidence for most of the main conclusions drawn from them. A review of other experiments in semantic memory shows that many of them are likewise suspect. It is demonstrated how this fallacy can be avoided by doing the right statistics, selecting the appropriate design, and sampling by systematic procedures, or, alternatively, by proceeding according to the so-called method of single cases.

In 1964, Edmund B. Coleman published an important methodological paper called "Generalizing to a Language Population" in which he criticized some of the procedures replicated if a different sample of language materials were used (p. 219)." Coleman then described available statistical procedures that would assure generality across language

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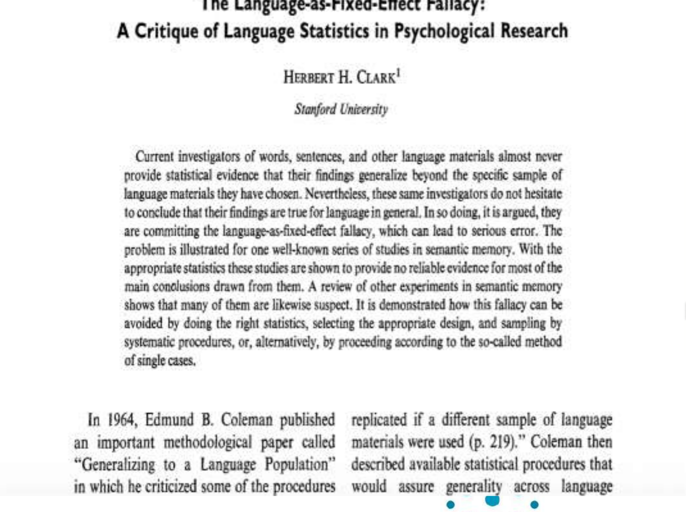
- **Language-as-fixed-effect ?**

• Clark (1973) suggested to use by-subject (F_1) and by-item (F_2) analysis, so that the analysis can account for variability across subject and items.

• So apparently your subjects and also your items are random factors!



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- **What do I mean by F1 vs. F2 ANOVA ?**

By-subject analysis (average over items)

1	2	3	4	5	6
Subjects	Item1	Item2	Item3	Item4	Item5
1					
2					
3					
4					
5					
6					

By-item analysis (average over subjects)

1	2	3	4	5	6	7
Items	Subject1	Subject2	Subject3	Subject4	Subject5	Subject6
1						
2						
3						
4						
5						

But what if you get sig. by subjects and not by-items?

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Hitchhikers' guide to
mixed effects regression models

- **Why should you use mixed-effects regression?**

[HTML] Mixed-effects modeling with crossed random effects for subjects and items

RH Baayen, DJ Davidson, DM Bates - Journal of memory and language, 2008 - Elsevier

This paper provides an introduction to mixed-effects models for the analysis of repeated measurement data with subjects and items as crossed random effects. A worked-out example of how to use recent software for mixed-effects modeling is provided. Simulation studies illustrate the advantages offered by mixed-effects analyses compared to traditional analyses based on quasi-F tests, by-subjects analyses, combined by-subjects and by-items analyses, and random regression. Applications and possibilities across a range of domains …

Cited by 6908 Related articles All 26 versions

[HTML] sciencedirect.com

Hitchhikers' guide to **mixed effects regression models**

- **Why should you use mixed-effects regression?**
  - Doing regression is much easier than doing F_1/F_2 tests.
  - Robust to missing data (no interpolation required)
  - There is no balancing needed.
  - You do not (always) need many post-hoc tests (multiple testing corrections were problematic)
  - Mixed-effects models allow for including random <u>**intercepts**</u> and <u>**slopes**</u>.

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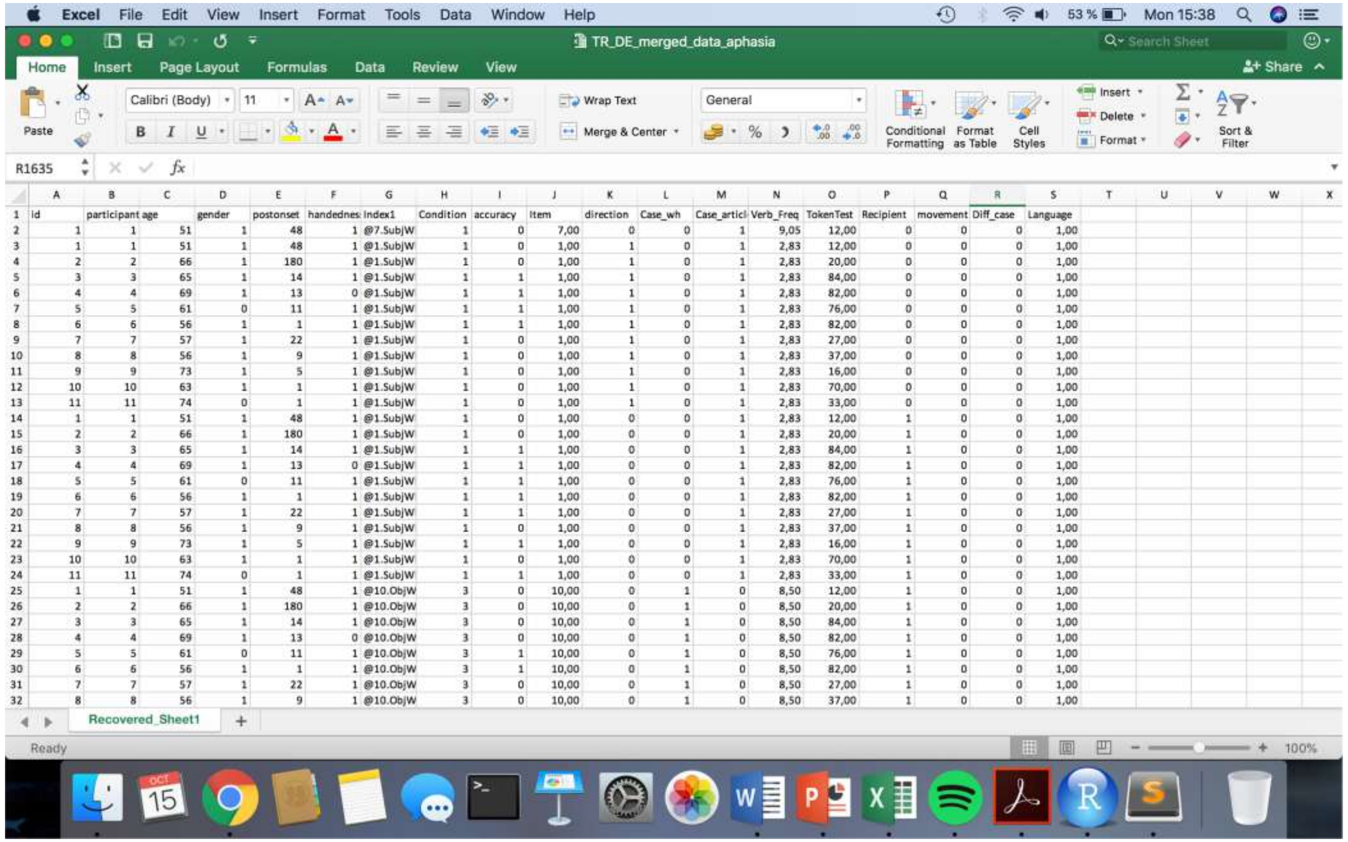
▶ How to import your data into R



Oftentimes, we have data in excel files, you can easily go

File > save as

And then choose .csv as the file extension (comma separated values)

p.s. I prefer .csv but you are at liberty to use other formats

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This lecture

Linear mixed-effects regression model (lmer)

We will learn how to use linear regression to analyse Reaction times (RTs) data

The most essential part of this model is **random factors**

This lecture

What are random-effect factors

- Random-effects are the potential sources of variability (subject & items here), because RTs can vary across subjects and items
- Some subjects react slower (or faster) than others, and some items may be reacted to slower/faster than others

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Random intercepts and slopes

- **What are random-effect factors**
- ***Random intercept*** for subject = *model's estimated RTs (ß) varies per subject*
- ***Random intercept*** for items = *model's estimated RTs varies per item*
- ***Random slope*** for age per item = effect of subjects' age may be different on some item than others

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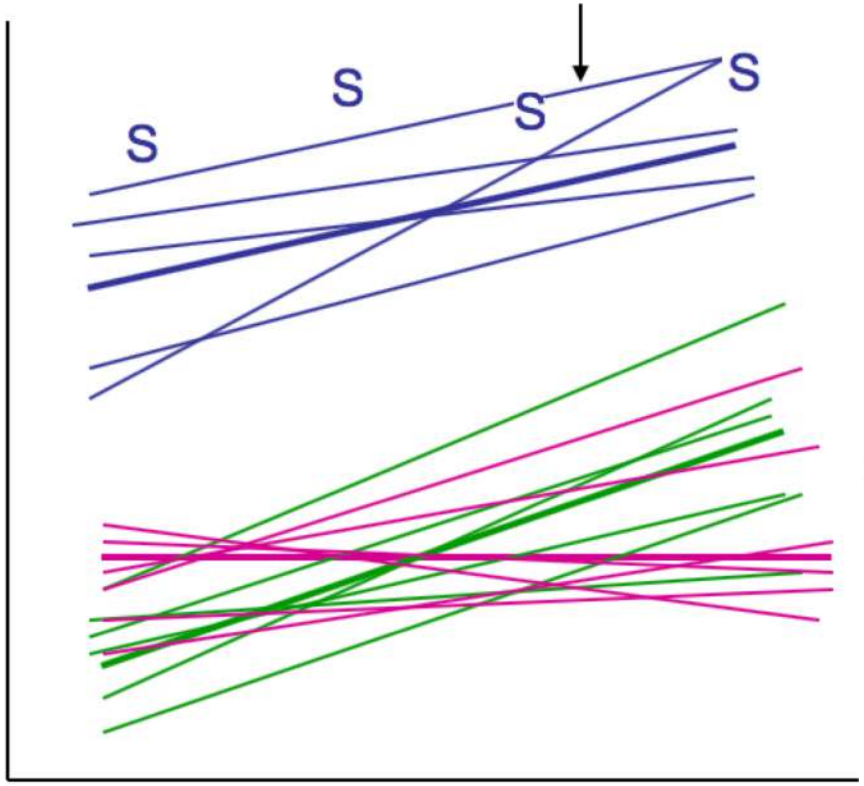
Random intercepts and slopes

- **Random intercepts**

Your model will make estimates per subject and per item when these are included as random intercepts (i.e. random baselines)



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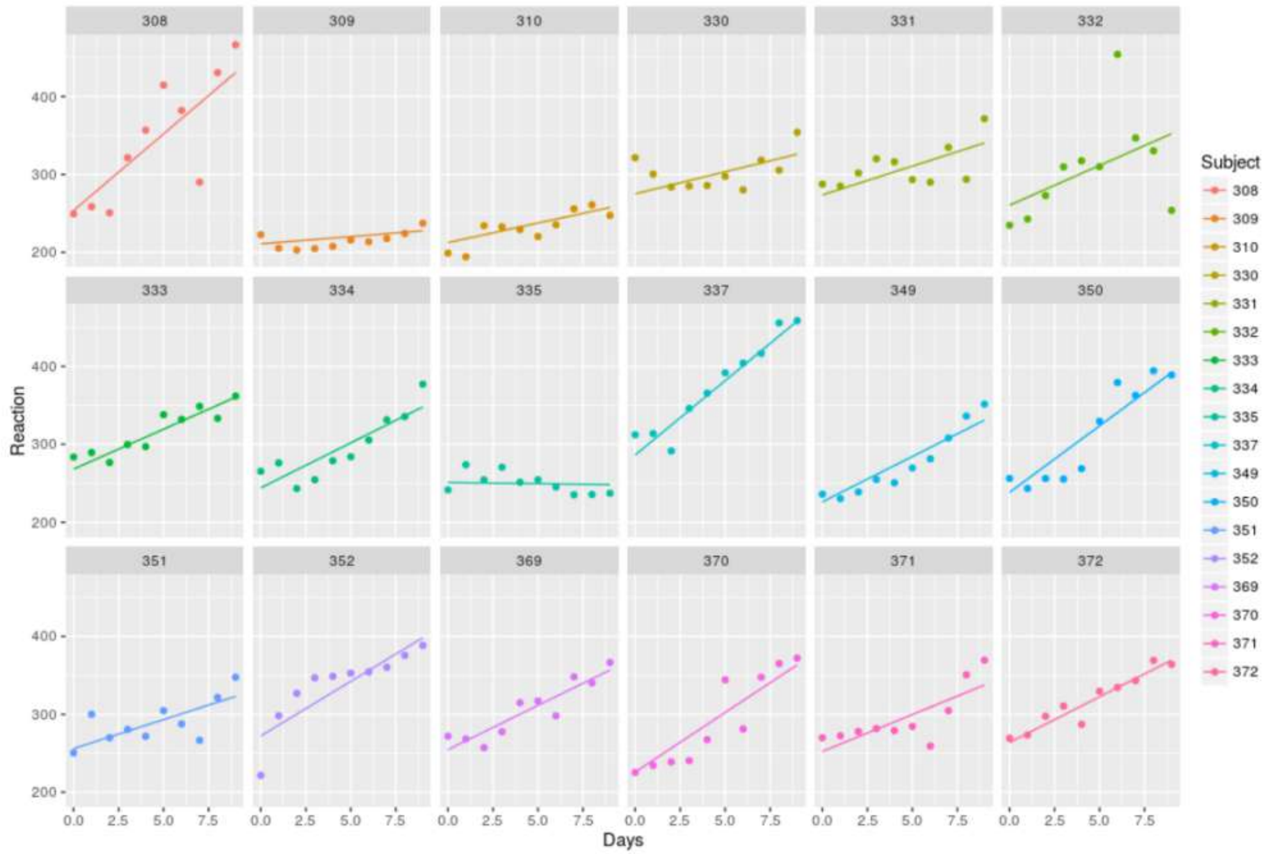
Random slope

Linear regression assumes all individuals come from a sample with a same slope (ß).

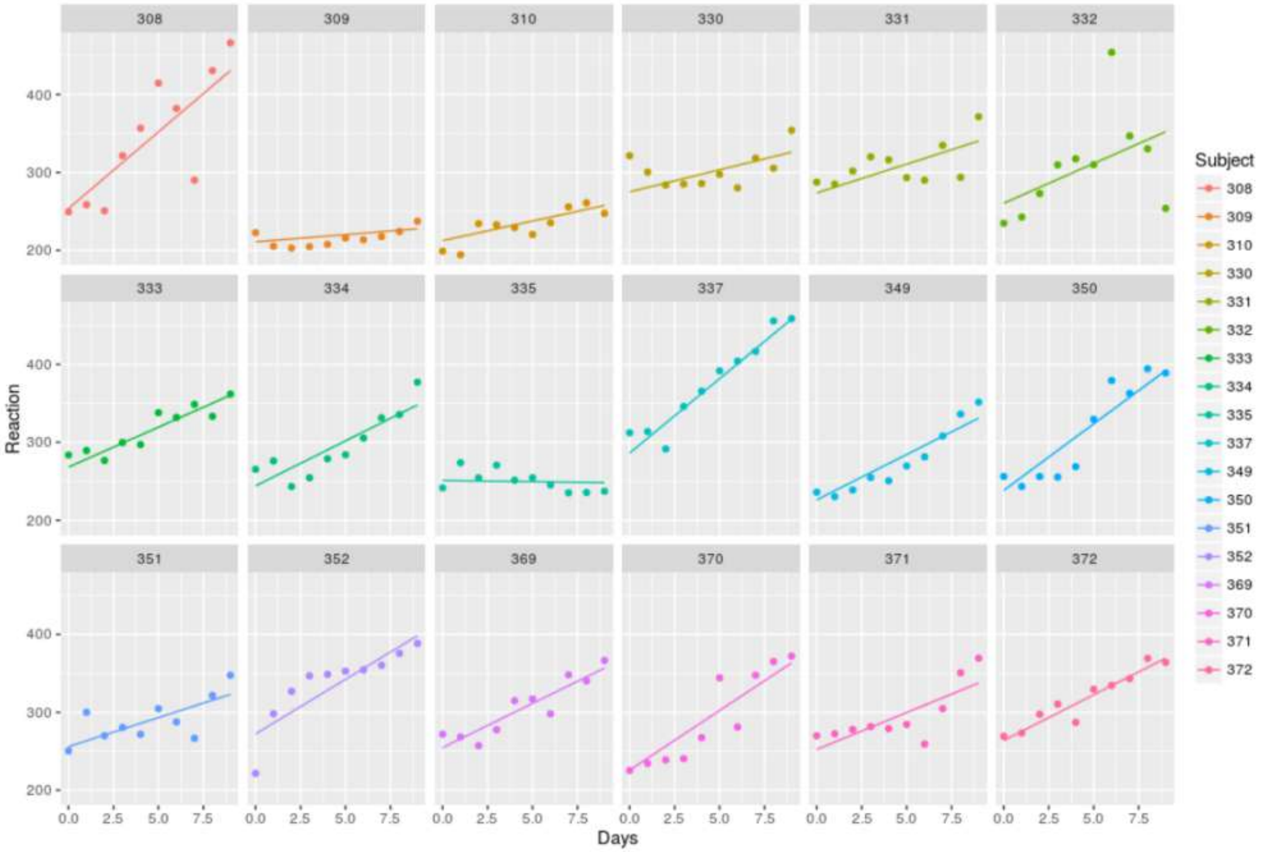
We can let slopes vary depending on a **covariate** factor.



- **Random slope**

For instance, days without sleep can impact different individuals to different levels in their reaction

So, “days” variable affects responses per subject (and to different levels)



Mixed-effect regression

- **Lmer assumes:**
- Relationship between dependent and independent variable is linear
- No strong multicollinearity
- Variance in residuals is homoscedastic (homogeneous)
- Residuals are normally distributed

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Mixed-effect regression

- Check distribution of residuals with a simple hist() histogram or a similar tool.

- If they are very abnormal, transform the data or use generalized linear mixed effects regression GLMER (w will see in next sessions)

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2.5. STEPS FOR LMER USING R (APPLIED)

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Hitchhikers' guide to **mixed effects regression models**

- <u>**Case study for today**</u>

Dataset is in the shared folder (session 1)

This is a sentence processing experiment that I did in my PhD

It is about "evidentiality" and involved a simple reaction times experiment

Press a button when there is a violation in the sentence (similar to ***go/no-go task***)

Bilingualism: Language and Cognition: page 1 of 16 © Cambridge University Press 2015 doi:10.1017/S136672891500084X

Processing grammatical evidentiality and time reference in Turkish heritage and monolingual speakers*

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University of Newcastle, UK;
University of Trento, Italy;
Macquarie University, Sydney, Australia;
Center for Language and Cognition (CLCG), Department of Linguistics, University of Groningen, The Netherlands
DÖRTE DE KOK
Department of Linguistics, University of Tübingen, Germany
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Center for Language and Cognition (CLCG), Department of Linguistics, University of Groningen, The Netherlands.

(Received: July 29, 2014; final revision received: November 9, 2015; accepted: November 9, 2015)

In the current study, we examined how adult heritage and monolingual speakers of Turkish process evidentiality (the linguistic expression of information source) through finite verb inflections and time reference, expressed on non-finite participles. A sentence-verification task was used to measure participants' sensitivity to evidentiality and time-reference violations in Turkish. Our findings showed that the heritage speakers were less accurate and slower than the monolinguals in responding to both evidentiality and time-reference violations. Also, the heritage speakers made more errors and had longer RTs when responding to evidentiality violations as compared to time-reference violations. The monolinguals had longer RTs (and more accurate responses) to time reference than to evidentiality violations. This study shows that evidentiality is susceptible to incomplete acquisition in Turkish heritage speakers. It is suggested that the requirement for simultaneous processing at different linguistic levels makes the evidentiality markers vulnerable.

Keywords: evidentiality, time reference, heritage language speaker, Turkish–Dutch bilingualism

Hitchhikers' guide to **mixed effects regression models**

Ready?

Now, then, we will follow these 11 steps

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1) Set working directory & Load data

```
setwd("~/Desktop/Academic Work/UCA teaching/Course week 4")

dataset = read.csv('RTs.data.csv', sep=",", header = T)
```

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Be sure to adapt the directory according to where you saved the data files.

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2) View the data

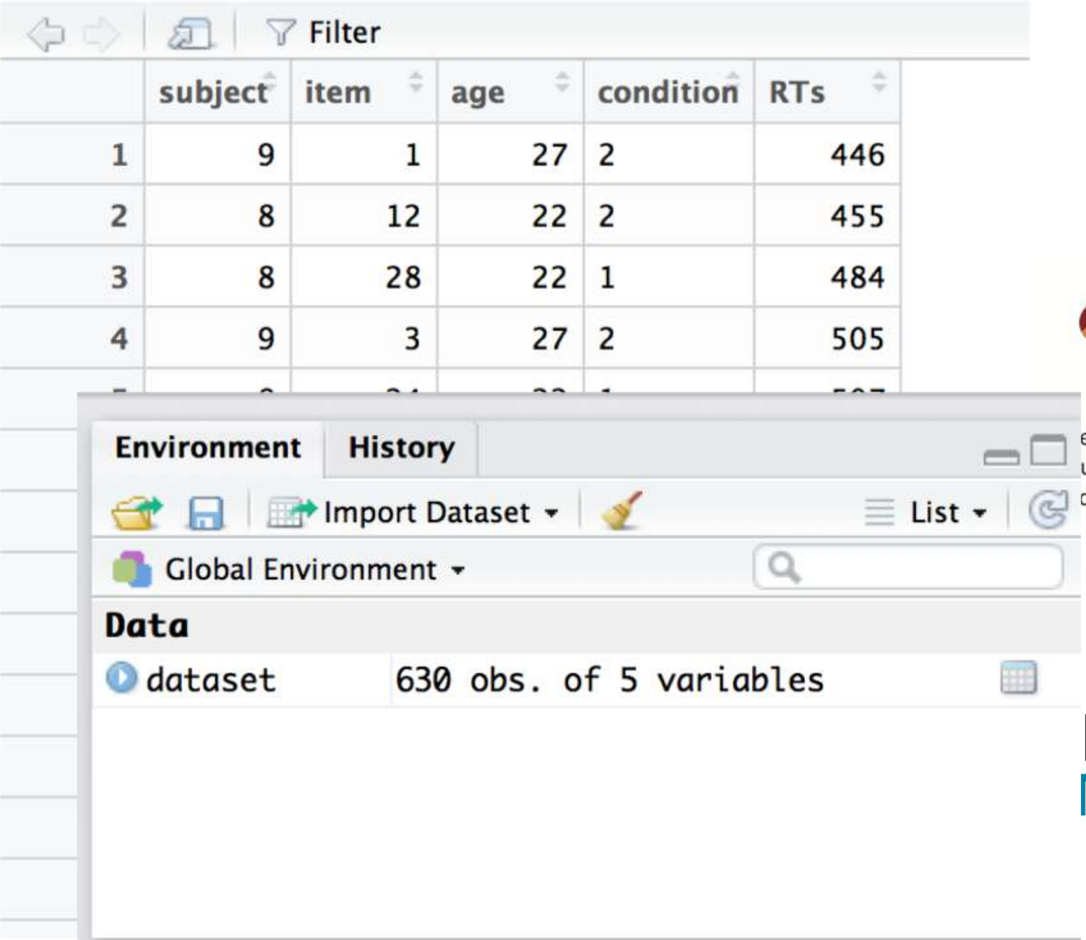
subject: number of participants

item: number of items

age: age of participants

condition: experimental manipulation

RTs: reaction times (in milliseconds)



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3) Inspect data

head(dataset)

summary(dataset)

```
Console ~/Desktop/Academic Work/UCA teaching/Course week 4/
> head(dataset)
  subject item age condition RTs
1       9    1  27         2 446
2       8   12  22         2 455
3       8   28  22         1 484
4       9    3  27         2 505
5       8   24  22         1 507
6       9   29  27         1 509
> summary(dataset)
    subject           item            age          condition          RTs
 Min.   : 1.00   Min.   : 1.00   Min.   :18.00   Min.   :1.000   Min.   : 446.0
 1st Qu.: 7.00   1st Qu.: 9.00   1st Qu.:24.00   1st Qu.:1.000   1st Qu.: 877.2
 Median :12.00   Median :16.00   Median :27.00   Median :1.000   Median :1268.0
 Mean   :13.12   Mean   :15.83   Mean   :27.97   Mean   :1.495   Mean   :1667.8
 3rd Qu.:20.00   3rd Qu.:23.00   3rd Qu.:28.00   3rd Qu.:2.000   3rd Qu.:2183.8
 Max.   :26.00   Max.   :30.00   Max.   :48.00   Max.   :2.000   Max.   :5516.0
> 
```

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4) Conditions

Conditions are currently coded as numeric values

(1) = Direct evidential

(2) = Indirect evidential

It is better if we convert them into **factors**

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4) Conditions -- This code will convert numeric values into levels of a factor

```
dataset$condition <- factor(dataset$condition,
                            levels = c(1,2),
                            labels = c("Direct Evidential", "Indirect Evidential"))
```

	subject	item	age	condition	RTs
1	9	1	27	Indirect Evidential	446
2	8	12	22	Indirect Evidential	455
3	8	28	22	Direct Evidential	484
4	9	3	27	Indirect Evidential	505
5	8	24	22	Direct Evidential	507
6	9	29	27	Direct Evidential	509
7	8	14	22	Direct Evidential	519
8	9	15	27	Indirect Evidential	553

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4) Conditions -- This code will convert numeric values into levels of a factor

```
dataset$condition <- factor(dataset$condition,
                            levels = c(1,2),
                            labels = c("Direct Evidential", "Indirect Evidential"))
```

Filter

	subject	item	age	condition	RTs
1	9	1	27	Indirect Evidential	446
2	8	12	22	Indirect Evidential	455
3	8	28	22	Direct Evidential	484
4	9	3	27	Indirect Evidential	505
5	8	24	22	Direct Evidential	507
6	9	29	27	Direct Evidential	509
7	8	14	22	Direct Evidential	519
8	9	15	27	Indirect Evidential	553

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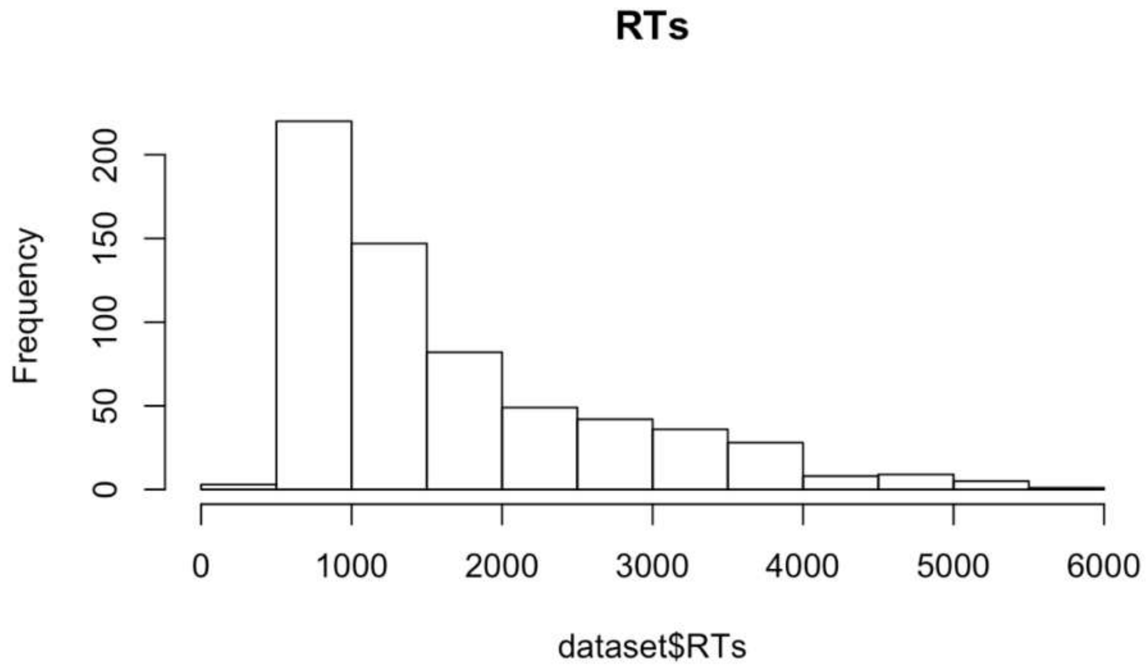
5) Visualise your data

```
# a quick visualisation

hist(dataset$RTs, main="RTs")
```

It is almost always the case that human RTs data are never normally distributed;
We will come to this later!



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6) Fit your first linear mixed-effects regression model (***lmer***)

lmer (*dep.var* ~ *indep.var* + (1 | random intercept) + (1 | random intercept), data = dataset))

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6) Fit your first **lmer**

```
# fit your first lmer
model1 <- lmer(RTs ~ condition + (1 |subject) + (1|item), data=dataset)
summary(model1)
```

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7) Interpreting fixed and random effects

Intercept **or baseline** = 1684.7 ms estimated RTs based on default (= Direct evidential)

Fixed effect of condition: the estimated RTs for the indirect evidential are 160.4 ms longer on average

```
Fixed effects:
                              Estimate Std. Error      df t value Pr(>|t|)
(Intercept)                    1684.79     172.87   26.60   9.746 2.92e-10 ***
conditionIndirect Evidential    160.43      58.71  576.10   2.732  0.00648 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr)
cndtnIndrcE -0.169
```

p<0.05 or t> ~+/- 2 indicate significance.

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mixed effects regression models

7) Interpreting fixed and random effects

the intercept is the estimated value of the DV, if IV is default (or 0).

Our IV (condition) is a categorical variable (direct vs indirect)

Default = Direct evidential

```
Fixed effects:
                             Estimate Std. Error      df t value Pr(>|t|)    
(Intercept)                   1684.79     172.87   26.60   9.746 2.92e-10 ***
conditionIndirect Evidential   160.43      58.71  576.10   2.732  0.00648 ** 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            (Intr)
cndtnIndrcE -0.169
```

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7) Interpreting random and fixed effects

Random effects provide sources of
variability as random factors in your model

RTs can vary across subjects and items randomly!!

```
> model1 <- lmer(RTs ~ condition + (1 |subject) + (1|item), data=dataset)
> summary(model1)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: RTs ~ condition + (1 | subject) + (1 | item)
   Data: dataset

Random effects:
 Groups   Name        Variance Std.Dev.
 item     (Intercept)  28120   167.7
 subject  (Intercept) 678408   823.7
 Residual             539836   734.7
```

Random effects are interpreted in similar way as fixed effects

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7) Interpreting random and fixed effects

ranef(model1)

Will tell you how much each random effect deviates from the average estimated RTs

Subject 10 has an estimated RTs of 588 ms **shorter** than the model1's average estimation, but Subject 2 is 1482 ms **longer!**

```
$subject
   (Intercept)
1  1654.422406
2  1482.595330
3     7.606509
4  -563.414393
5  -854.564550
6   -23.056498
7  -228.146745
8  -836.146449
9  -935.458037
10 -588.180945
11 -471.087435
12 -348.936568
13  126.735388
14 -665.048671
15 -151.024033
```

```
$item
   (Intercept)
1    3.8902098
2  354.5189523
3    7.1983734
4  168.3919481
5   75.3544240
6   75.4667053
7   38.3696174
8   67.3735019
9  108.8551542
10  76.4075424
11  30.3745443
12 173.2201174
13  26.3369920
14 -120.5982693
15  77.3813912
```

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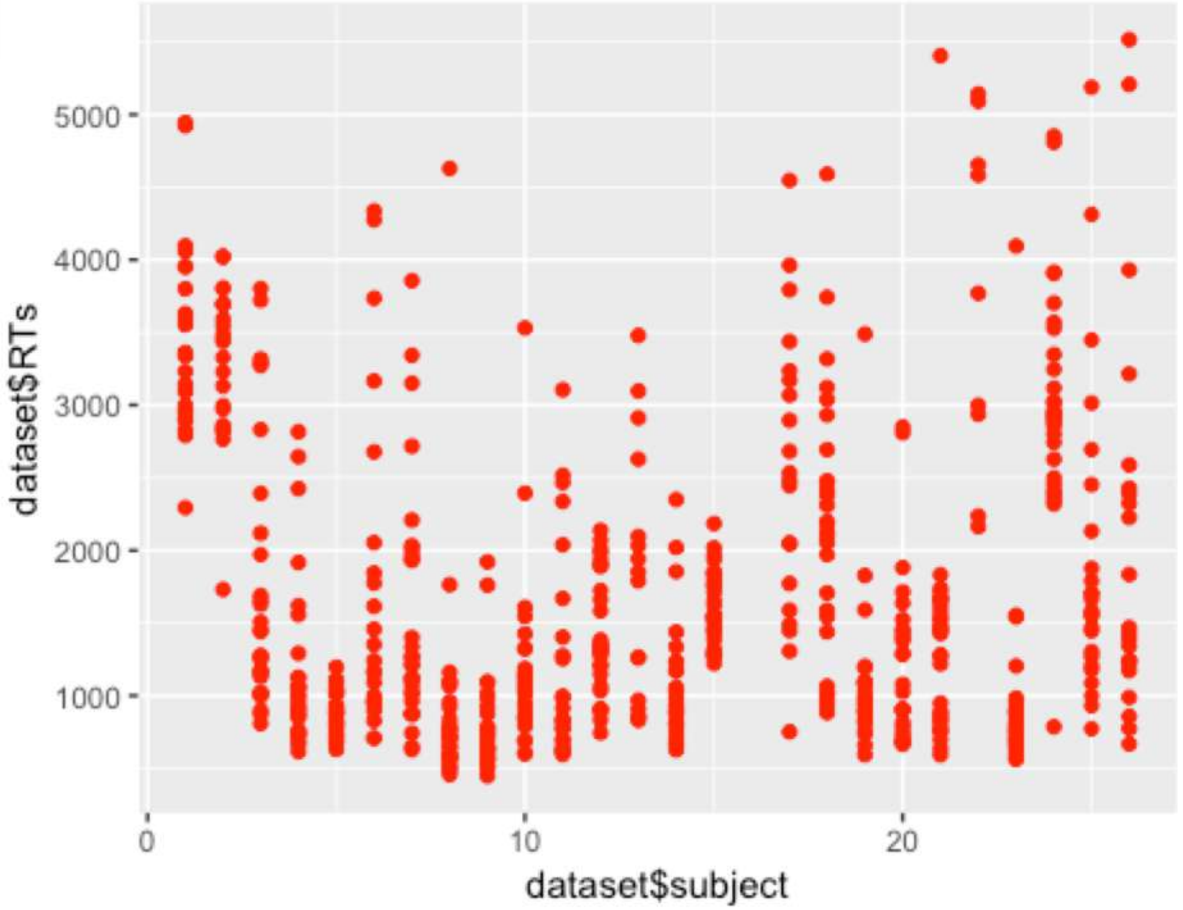
8) Visualize actual data vs. estimated data

```
ggplot() +
  geom_point(aes(x = dataset$subject, y = dataset$RTs),
             colour = 'red')
```

This is our actual data == >



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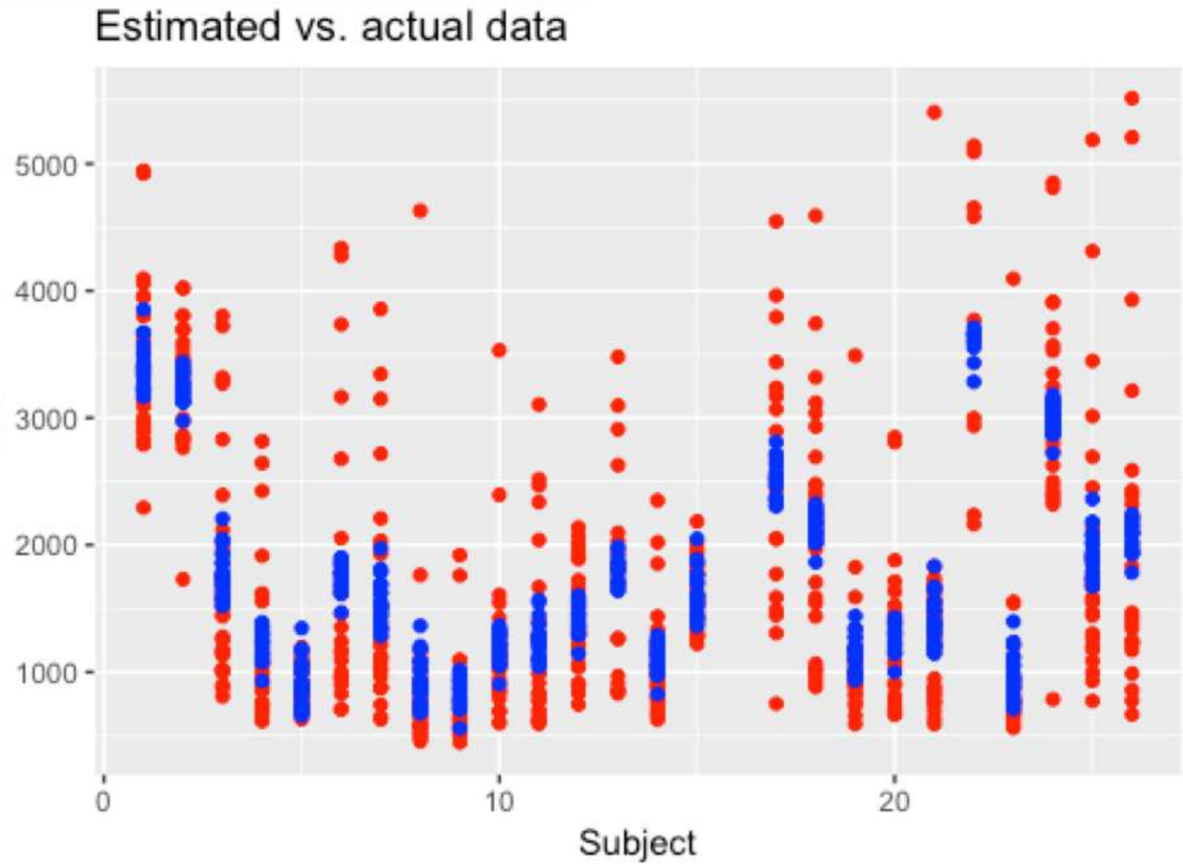
8) Visualize actual data vs. estimated data

```
ggplot() +
  geom_point(aes(x = dataset$subject, y = dataset$RTs),
             colour = 'red')+
  geom_point(aes(x = dataset$subject, y = predict(model1)),
            colour = 'blue') +
  ggtitle('Estimated vs. actual data') +
  xlab('Subject') +
  ylab('RTs')
```



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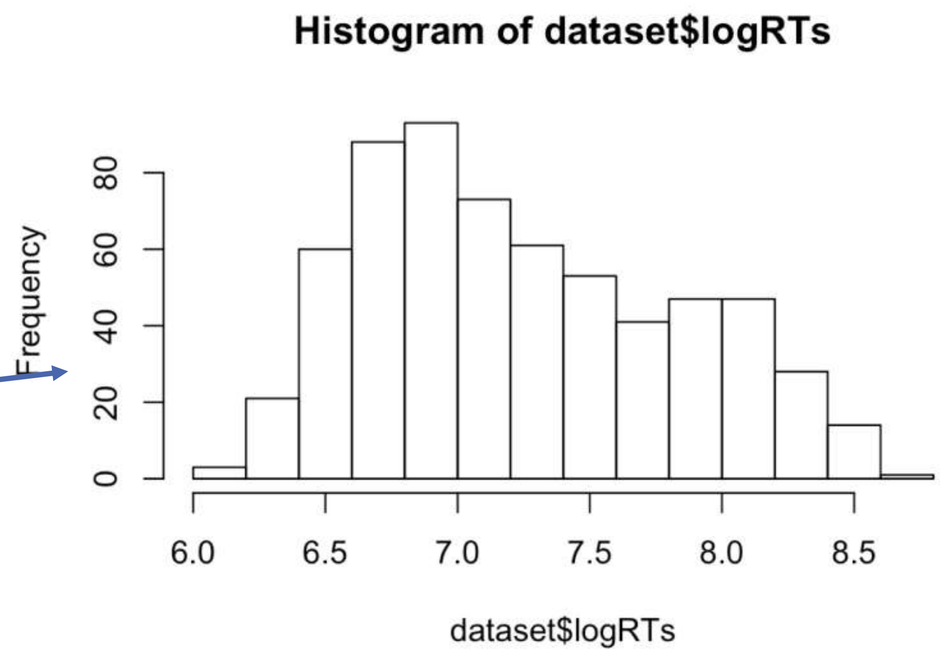
9) Normalize RTs data while running lmer

```
# normalizing RTs data while running lmer

dataset$logRTs = log(dataset$RTs)
hist(dataset$logRTs)
```



Log transformed values have a distribution that is closer to normal distribution.

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9) Normalize RTs data while running lmer

```
model2 <- lmer(log(RTs) ~ condition + (1 |subject) + (1|item), data=dataset)
summary(model2)
```

Log transform your data when you need a normal-like distribution

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10) Add random slopes in addition to random intercepts!

```
# adding random slopes

model3 <- lmer (RTs ~ condition + (1 + condition|subject) + (1|item), data=dataset)
summary(model3)
```

Adding "condition" as a random slope per subject = each subject may respond differently to each condition

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10) Add random slopes in addition to random intercepts!

```
# adding random slopes

model3 <- lmer (RTs ~ condition + (1 + condition|subject) + (1|item), data=da

summary(model4)


model4 <- lmer (RTs ~ condition + (1 + condition |subject) + (1 + age |item), data=dataset)

summary(model4)
```

Age as random slope per item = Participants' age can affect responses to some items differently than others

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11) Compare your models to determine the best model

```
# anova(model1, model2)
```

To see if your model is better than the others!

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12) Interpreting interaction and post-hoc tests

emmeans with single predicting variables

```
model3 <- lmer (RTs ~ condition + (1 |subject) + (1 + age|item), data=dataset)

emmeans(model3, "condition")

pairs(emmeans(model3, "condition"))
```

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12) Interpreting interaction and post-hoc tests

emmeans with crossed factors / multiple predicting variabls

```
model4 <- lmer (log(RTs) ~ age * condition  + (1 |subject) + (1  |item), data=dataset)
```

```
emmeans(model4, "condition", by = "age")
pairs(emmeans(model4, "condition", by = "age"))
```

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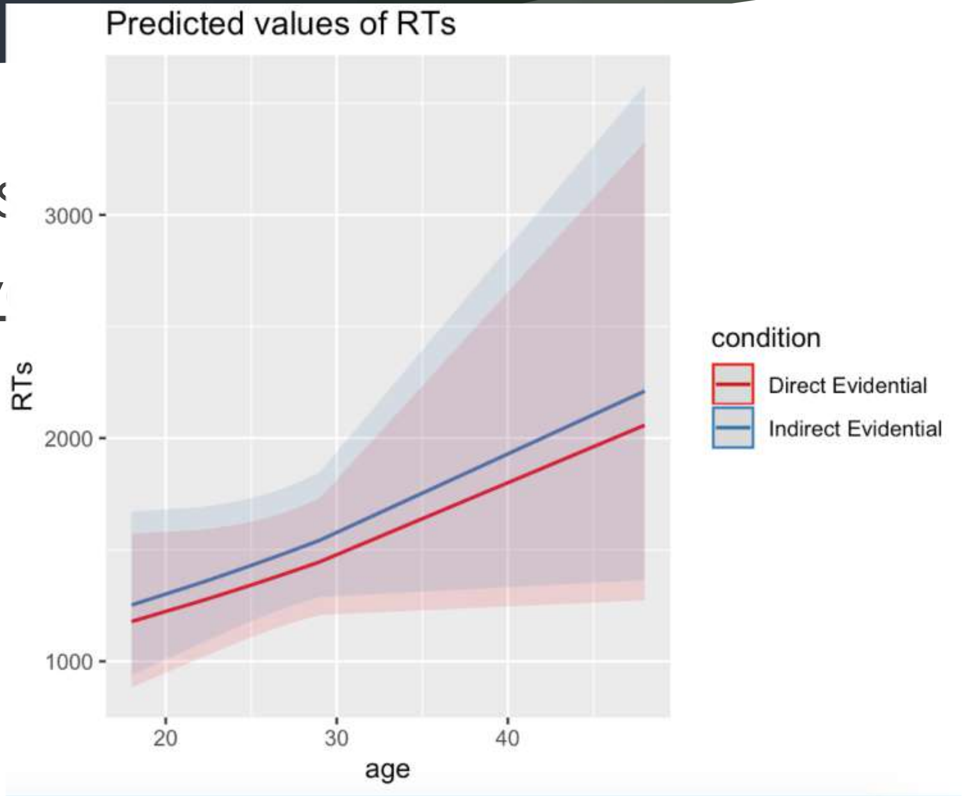
12) Interpreting interaction and post-hoc tes

emmeans with crossed factors / multiple predicting v

Plot interaction:

plot_model(model4, type = "pred",

terms = c("age", "condition"))



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Final notes # 1

If you are having non-convergence issues (probably due to including random slopes), try **optimization by quadratic approximation (bobyqa)**:

```
model5 <- lmer (log(RTs) ~  age * condition + (1 |subject) + (1 |item),
        control = lmerControl(optimizer='bobyqa'),
        data=dataset)
```

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Final notes # 2

By default "lmer" fits with REML (= **Re**stricted **M**aximum **L**ikelihood)

You can choose to fit your model with "Maximum Likelihood" by setting # **REML = FALSE** # in your code

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Final notes # 3

Use contrast coding when this is possible

```
contrasts(dataset$condition) = contr.sum(2)
contrasts(dataset$condition)
[,1]
Direct Evidential      1
Indirect Evidential   -1
```

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Fernanda Ferreira
@fernandaedi

Replying to @fernandaedi

We spend an extraordinary amount of time setting up models, simplifying models, and hoping for each one to converge. And waiting for days for a model to finish running. Like many labs, we now use dedicated machines for running statistical analyses.

5:18 PM · Dec 20, 2020 · Twitter Web App

1 Quote Tweet **35** Likes

Fernanda Ferreira
@fernandaedi

Replying to @fernandaedi

Our papers are held up for weeks due to that one model that won't converge as we try, simplify, run, wait, repeat, over and over. Many are experiments with a 2x2 within-S design that you used to be able to analyze with an HP calculator. Students' work is delayed getting out.

5:18 PM · Dec 20, 2020 · Twitter Web App

28 Likes

Fernanda Ferreira
@fernandaedi

Replying to @fernandaedi

We're now running 2x2 experiments with 100s of subjects because our complex models require that large an N to test for possible effects we're not the slightest bit interested in. These Ss have to be paid for or recruited as "volunteers".

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